

**MAY 24**

**AB  
GRAD  
CON  
23**



1  
00:00:06,859 --> 00:00:11,920  
thank you

2  
00:00:37,870 --> 00:00:30,700  
[Music]

3  
00:01:05,770 --> 00:00:39,240  
thank you

4  
00:01:22,810 --> 00:01:05,780  
[Music]

5  
00:01:22,820 --> 00:01:28,970  
thank you

6  
00:02:05,710 --> 00:01:55,730  
[Music]

7  
00:02:21,650 --> 00:02:05,720  
thank you

8  
00:02:21,660 --> 00:02:40,449  
[Music]

9  
00:02:40,459 --> 00:02:47,620  
thank you

10  
00:03:20,110 --> 00:03:05,620  
[Music]

11  
00:03:20,120 --> 00:03:23,550  
thank you

12  
00:03:58,750 --> 00:03:32,310  
[Music]

13  
00:03:58,760 --> 00:04:05,430

thank you

14

00:04:05,440 --> 00:04:28,370

[Music]

15

00:04:28,380 --> 00:04:31,390

foreign

16

00:05:42,189 --> 00:04:50,150

[Music]

17

00:05:42,199 --> 00:05:49,230

thank you

18

00:06:21,370 --> 00:06:14,350

[Music]

19

00:06:21,380 --> 00:06:25,160

thank you

20

00:07:17,050 --> 00:06:33,870

[Music]

21

00:07:32,990 --> 00:07:17,060

thank you

22

00:07:33,000 --> 00:07:39,490

[Music]

23

00:07:39,500 --> 00:07:46,670

thank you

24

00:08:18,490 --> 00:07:58,150

[Music]

25

00:08:18,500 --> 00:08:21,720

thank you

26  
00:09:00,840 --> 00:08:44,769  
[Music]

27  
00:09:16,770 --> 00:09:00,850  
thank you

28  
00:09:36,250 --> 00:09:30,460  
[Music]

29  
00:09:36,260 --> 00:09:42,720  
thank you

30  
00:10:15,250 --> 00:10:01,490  
[Music]

31  
00:10:34,620 --> 00:10:18,120  
thank you

32  
00:10:34,630 --> 00:10:54,370  
[Music]

33  
00:10:54,380 --> 00:11:00,560  
thank you

34  
00:11:56,030 --> 00:11:14,240  
[Music]

35  
00:12:18,410 --> 00:11:57,840  
foreign

36  
00:12:18,420 --> 00:12:28,430  
[Music]

37  
00:12:28,440 --> 00:12:32,070  
foreign

38  
00:13:32,840 --> 00:12:40,560

[Music]

39

00:14:58,850 --> 00:13:32,850

foreign

40

00:14:58,860 --> 00:15:08,689

thank you

41

00:15:08,699 --> 00:15:16,960

foreign

42

00:16:56,990 --> 00:15:33,100

[Music]

43

00:16:57,000 --> 00:17:08,470

thank you

44

00:17:29,930 --> 00:17:17,880

[Music]

45

00:17:29,940 --> 00:17:32,790

foreign

46

00:18:35,270 --> 00:17:56,950

[Music]

47

00:18:53,430 --> 00:18:45,230

foreign

48

00:19:38,990 --> 00:19:24,840

[Music]

49

00:19:39,000 --> 00:19:43,850

foreign

50

00:20:00,670 --> 00:19:55,730

[Music]

51  
00:20:21,430 --> 00:20:00,680  
foreign

52  
00:21:00,470 --> 00:20:32,270  
[Music]

53  
00:21:00,480 --> 00:21:05,550  
foreign

54  
00:21:56,450 --> 00:21:08,870  
[Music]

55  
00:22:06,440 --> 00:21:56,950  
thank you

56  
00:22:06,450 --> 00:22:18,770  
[Music]

57  
00:22:18,780 --> 00:22:29,940  
foreign

58  
00:23:04,930 --> 00:22:35,130  
[Music]

59  
00:23:04,940 --> 00:23:11,400  
thank you

60  
00:23:11,410 --> 00:23:22,730  
[Music]

61  
00:23:28,070 --> 00:23:25,730  
we hope you enjoyed Sharia last night

62  
00:23:30,950 --> 00:23:28,080  
and we pick up this morning with tremors

63  
00:23:33,409 --> 00:23:30,960

chemical fingerprints and climates and

64

00:23:36,649 --> 00:23:33,419

our first speaker is Andrea Bryant from

65

00:23:49,270 --> 00:23:38,110

foreign

66

00:23:54,049 --> 00:23:51,950

PhD student at University of Chicago and

67

00:23:55,850 --> 00:23:54,059

today I will talk about investigating

68

00:23:59,149 --> 00:23:55,860

the use of long periods seismology to

69

00:24:00,649 --> 00:23:59,159

explore Titan's interior I'm aware that

70

00:24:02,270 --> 00:24:00,659

um I'm actually quite new to seismology

71

00:24:03,409 --> 00:24:02,280

myself when we began a couple years ago

72

00:24:05,210 --> 00:24:03,419

so

73

00:24:06,890 --> 00:24:05,220

um I will try to do a little bit of

74

00:24:10,730 --> 00:24:06,900

background for everyone all right so

75

00:24:12,830 --> 00:24:10,740

starting with uh Cassini we learned a

76

00:24:15,409 --> 00:24:12,840

lot about the saturnian system but

77

00:24:18,350 --> 00:24:15,419

especially for this study we learned a

78

00:24:19,610 --> 00:24:18,360

lot about Titan and so

79

00:24:21,049 --> 00:24:19,620

um there was actually a probe the

80

00:24:22,850 --> 00:24:21,059

huggins probe that landed on the surface

81

00:24:25,669 --> 00:24:22,860

of Titan and you can if you go on

82

00:24:29,990 --> 00:24:25,679

YouTube you can Google it and or you can

83

00:24:31,370 --> 00:24:30,000

YouTube it and see the landing um there

84

00:24:33,110 --> 00:24:31,380

it's landing through the haze and you

85

00:24:36,470 --> 00:24:33,120

see some water ice Pebbles on the

86

00:24:37,730 --> 00:24:36,480

surface and there's so much I could say

87

00:24:39,230 --> 00:24:37,740

about Titan but for the sake of time

88

00:24:43,250 --> 00:24:39,240

I'll just say it's an amazing natural

89

00:24:44,210 --> 00:24:43,260

astrobiology laboratory and

90

00:24:47,210 --> 00:24:44,220

um

91

00:24:48,230 --> 00:24:47,220

I'm very excited to do some theory about

92

00:24:50,390 --> 00:24:48,240

it

93

00:24:53,630 --> 00:24:50,400

um okay so here is what we currently

94

00:24:56,090 --> 00:24:53,640

know about Titan

95

00:24:58,430 --> 00:24:56,100

um and so we know that there is a liquid

96

00:25:00,110 --> 00:24:58,440

water ocean underneath

97

00:25:03,529 --> 00:25:00,120

um a very thick shell of ice so it's

98

00:25:04,909 --> 00:25:03,539

between 50 and 150 kilometers deep we

99

00:25:07,669 --> 00:25:04,919

don't know the exact compositions of

100

00:25:10,909 --> 00:25:07,679

this ice shell or the ocean but we do

101

00:25:12,830 --> 00:25:10,919

know that there's water there

102

00:25:15,049 --> 00:25:12,840

um and also there could be some high

103

00:25:16,630 --> 00:25:15,059

pressure ice underneath the ocean and

104

00:25:19,730 --> 00:25:16,640

this actually has very big

105

00:25:20,930 --> 00:25:19,740

astrobiological implications because it

106

00:25:22,510 --> 00:25:20,940

could actually act if there is high

107

00:25:25,190 --> 00:25:22,520

pressurized it could act as a barrier

108

00:25:27,590 --> 00:25:25,200

from there's the enrichment of the ocean

109

00:25:30,110 --> 00:25:27,600

for potential life

110

00:25:32,210 --> 00:25:30,120

um if it's there and so

111

00:25:33,710 --> 00:25:32,220

um yeah so that's something that

112

00:25:35,630 --> 00:25:33,720

seismology can help us to constrain

113

00:25:38,330 --> 00:25:35,640

whether or not that's there

114

00:25:42,890 --> 00:25:38,340

um okay so this brings me to NASA

115

00:25:47,570 --> 00:25:42,900

dragonfly and so dragonfly is a rotor

116

00:25:48,950 --> 00:25:47,580

craft that will launch in 2027

117

00:25:52,130 --> 00:25:48,960

um and it'll take about six years or so

118

00:25:53,750 --> 00:25:52,140

to get to Titan but this instrument will

119

00:25:55,909 --> 00:25:53,760

be loaded with many many different

120

00:25:58,310 --> 00:25:55,919

instrument packages that are really

121

00:26:01,070 --> 00:25:58,320

there's a very large Focus for Astro bio

122

00:26:02,390 --> 00:26:01,080

and in particular the seismometer

123

00:26:04,190 --> 00:26:02,400

um which is going to be on the other

124

00:26:07,130 --> 00:26:04,200

Underside you can see here it's like

125

00:26:08,810 --> 00:26:07,140

dangling or it's up under the rotocraft

126

00:26:10,909 --> 00:26:08,820

but it's going to be tethered it's

127

00:26:12,769 --> 00:26:10,919

tethered and so it'll be lowered down at

128

00:26:15,649 --> 00:26:12,779

each location on Titan that's going to

129

00:26:17,750 --> 00:26:15,659

visit and then measure the seismic

130

00:26:19,490 --> 00:26:17,760

activity there and there also these

131

00:26:21,350 --> 00:26:19,500

geophones which are essentially less

132

00:26:23,269 --> 00:26:21,360

sensitive seismometers and they're a bit

133

00:26:26,149 --> 00:26:23,279

smaller that are going to be there's two

134

00:26:29,330 --> 00:26:26,159

under under the underside of the skids

135

00:26:31,130 --> 00:26:29,340

and so in particular the seismometer the

136

00:26:33,230 --> 00:26:31,140

geophones and other instruments within

137

00:26:35,870 --> 00:26:33,240

the this drag met package

138

00:26:38,450 --> 00:26:35,880

um are going to be looking to measure

139

00:26:39,529 --> 00:26:38,460

habitability

140

00:26:42,710 --> 00:26:39,539

okay

141

00:26:45,409 --> 00:26:42,720

so um dragonfly says melody seismology

142

00:26:47,510 --> 00:26:45,419

in a nutshell will help us to constrain

143

00:26:50,750 --> 00:26:47,520

the interior structure of Titan more

144

00:26:52,549 --> 00:26:50,760

precisely and so seismology

145

00:26:54,250 --> 00:26:52,559

um similarly like on Earth has helped us

146

00:26:58,010 --> 00:26:54,260

to understand more about the actual

147

00:26:59,990 --> 00:26:58,020

interior of Earth to like very great

148

00:27:01,490 --> 00:27:00,000

detail and so we hope to be able to do a

149

00:27:05,330 --> 00:27:01,500

bit of the same

150

00:27:07,549 --> 00:27:05,340

um on Titan and so some possible causes

151  
00:27:10,370 --> 00:27:07,559  
of Titan Quakes will be tidal flexing or

152  
00:27:12,649 --> 00:27:10,380  
Quail volcanoes and then also like ice

153  
00:27:13,730 --> 00:27:12,659  
cracking events of various kinds and

154  
00:27:17,029 --> 00:27:13,740  
then this is of course not a

155  
00:27:19,130 --> 00:27:17,039  
non-exhaustive list and so we'll be able

156  
00:27:22,010 --> 00:27:19,140  
to put like very precise

157  
00:27:24,470 --> 00:27:22,020  
um more precise hopefully measurements

158  
00:27:26,210 --> 00:27:24,480  
on what's actually going on there okay

159  
00:27:29,510 --> 00:27:26,220  
so now this brings me to the namesake of

160  
00:27:31,250 --> 00:27:29,520  
this talk long period seismology so

161  
00:27:32,810 --> 00:27:31,260  
um I'm talking about so if you're

162  
00:27:34,310 --> 00:27:32,820  
familiar with seismograms we have the

163  
00:27:35,990 --> 00:27:34,320

Body Waves or those are the p waves

164

00:27:38,090 --> 00:27:36,000

compressive waves and the shear waves S

165

00:27:40,070 --> 00:27:38,100

waves and then we have

166

00:27:42,230 --> 00:27:40,080

um later on we have these long these

167

00:27:43,669 --> 00:27:42,240

surface waves and so I'm looking as

168

00:27:45,049 --> 00:27:43,679

opposed to using Body Waves

169

00:27:47,210 --> 00:27:45,059

investigating

170

00:27:48,950 --> 00:27:47,220

um and particularly with these I'm

171

00:27:51,350 --> 00:27:48,960

looking at methane cloth rate models

172

00:27:53,510 --> 00:27:51,360

what if I were to use the surface wave

173

00:27:57,230 --> 00:27:53,520

information particularly dispersion

174

00:27:59,029 --> 00:27:57,240

information to be able to try to learn

175

00:28:01,130 --> 00:27:59,039

about Titan and maybe about the

176  
00:28:03,049 --> 00:28:01,140  
eyeshadow thickness so let's see what I

177  
00:28:04,250 --> 00:28:03,059  
found okay so starting with methane

178  
00:28:04,850 --> 00:28:04,260  
clathrates

179  
00:28:06,950 --> 00:28:04,860  
um

180  
00:28:07,970 --> 00:28:06,960  
I for those of you who don't know what

181  
00:28:09,710 --> 00:28:07,980  
that is

182  
00:28:12,289 --> 00:28:09,720  
um so a clothway is essentially I like

183  
00:28:14,269 --> 00:28:12,299  
to say a water cage and so you can see

184  
00:28:16,070 --> 00:28:14,279  
um I don't know if you can see those

185  
00:28:18,890 --> 00:28:16,080  
um it's essentially

186  
00:28:22,130 --> 00:28:18,900  
um a structure of water molecules around

187  
00:28:26,330 --> 00:28:22,140  
and they're entrapping a single molecule

188  
00:28:28,370 --> 00:28:26,340

and and the case of or in my the study

189

00:28:30,710 --> 00:28:28,380

the molecule we're looking at would be

190

00:28:32,990 --> 00:28:30,720

methane okay so imagine there's this

191

00:28:35,510 --> 00:28:33,000

molecule and now we have tens of

192

00:28:37,310 --> 00:28:35,520

kilometers of this these methane

193

00:28:40,130 --> 00:28:37,320

clathrides and we think that this could

194

00:28:43,070 --> 00:28:40,140

be very possible and very plausible for

195

00:28:45,289 --> 00:28:43,080

the Titan Photon conditions and I think

196

00:28:49,490 --> 00:28:45,299

I forgot to mention Titan surface is 94

197

00:28:51,350 --> 00:28:49,500

Kelvin so on the surface methane we have

198

00:28:53,450 --> 00:28:51,360

a hydrological cycle but it's a methane

199

00:28:55,430 --> 00:28:53,460

hydrological cycle

200

00:28:58,610 --> 00:28:55,440

um six percent or five or six percent of

201  
00:29:00,830 --> 00:28:58,620  
the atmosphere is methane and so we have

202  
00:29:02,210 --> 00:29:00,840  
instead of lakes of water lakes of

203  
00:29:04,250 --> 00:29:02,220  
hydrocarbons

204  
00:29:05,029 --> 00:29:04,260  
um and lakes of methane

205  
00:29:10,430 --> 00:29:05,039  
um

206  
00:29:12,529 --> 00:29:10,440  
and ice under Titan temperatures and

207  
00:29:13,970 --> 00:29:12,539  
pressures they will readily form these

208  
00:29:15,769 --> 00:29:13,980  
methane clathrates and this has been

209  
00:29:17,450 --> 00:29:15,779  
shown in the laboratory so it's thought

210  
00:29:20,330 --> 00:29:17,460  
that they're most likely will be lots of

211  
00:29:23,269 --> 00:29:20,340  
these methane clathrates on Titan

212  
00:29:25,370 --> 00:29:23,279  
um and so the models that we considered

213  
00:29:27,110 --> 00:29:25,380

um were essentially they were all the

214

00:29:30,710 --> 00:29:27,120

same so we were looking at 100 kilometer

215

00:29:33,350 --> 00:29:30,720

thick ice shell and just varying the um

216

00:29:35,149 --> 00:29:33,360

the clathrated lid thickness so um the

217

00:29:37,370 --> 00:29:35,159

cloth rates were just at the surface so

218

00:29:39,769 --> 00:29:37,380

hence the cloth rate lid

219

00:29:41,149 --> 00:29:39,779

um and um yeah these are all spherically

220

00:29:42,529 --> 00:29:41,159

symmetric models they were generated

221

00:29:44,149 --> 00:29:42,539

with an open source code called Planet

222

00:29:46,669 --> 00:29:44,159

profile if you're interested in

223

00:29:48,110 --> 00:29:46,679

generating this it's on GitHub also you

224

00:29:50,149 --> 00:29:48,120

can I couldn't show you how to get it or

225

00:29:52,789 --> 00:29:50,159

you can just Google it

226

00:29:54,830 --> 00:29:52,799

um and there's a ton of other bodies you

227

00:29:56,690 --> 00:29:54,840

can look at there as well

228

00:29:59,510 --> 00:29:56,700

um and so we simulated a magnitude 3

229

00:30:01,610 --> 00:29:59,520

quick and then these were the data that

230

00:30:02,990 --> 00:30:01,620

we'll be looking at come from a three

231

00:30:06,889 --> 00:30:03,000

kilometer Source step so three

232

00:30:11,029 --> 00:30:08,330

so um

233

00:30:14,930 --> 00:30:11,039

the from the study

234

00:30:16,370 --> 00:30:14,940

um I this was led by Angela marusiak at

235

00:30:18,889 --> 00:30:16,380

um who is now professor at University of

236

00:30:20,570 --> 00:30:18,899

Arizona uh and so we actually saw some

237

00:30:22,250 --> 00:30:20,580

small differences in dispersion between

238

00:30:24,289 --> 00:30:22,260

two of the models in particular that

239

00:30:25,850 --> 00:30:24,299

we're looking at and in that paper so

240

00:30:27,409 --> 00:30:25,860

that was the 10 kilometer cloth rate lid

241

00:30:31,130 --> 00:30:27,419

and the

242

00:30:33,830 --> 00:30:31,140

um pure water is shell and so just for

243

00:30:35,269 --> 00:30:33,840

this is a primer about dispersion it's

244

00:30:37,130 --> 00:30:35,279

related to the material properties of

245

00:30:38,870 --> 00:30:37,140

the ice shell and particularly in the

246

00:30:41,510 --> 00:30:38,880

case of elastic waves that we're looking

247

00:30:42,830 --> 00:30:41,520

at here and so this wave speed depends

248

00:30:44,810 --> 00:30:42,840

on frequency and that's kind of like the

249

00:30:47,289 --> 00:30:44,820

meat of what dispersion is is seeing how

250

00:30:49,549 --> 00:30:47,299

the wave speed or the group velocities

251  
00:30:51,649 --> 00:30:49,559  
they change as a function of frequency

252  
00:30:53,510 --> 00:30:51,659  
and so we saw like about two percent

253  
00:30:55,730 --> 00:30:53,520  
difference a two percent difference

254  
00:30:57,950 --> 00:30:55,740  
between the dispersion so that's looking

255  
00:31:00,350 --> 00:30:57,960  
at this group velocity curve here it's

256  
00:31:01,610 --> 00:31:00,360  
very small differences but they're small

257  
00:31:03,350 --> 00:31:01,620  
enough that if you have a really high

258  
00:31:05,210 --> 00:31:03,360  
Precision seismometer you could actually

259  
00:31:06,830 --> 00:31:05,220  
detect that which is actually I found

260  
00:31:08,930 --> 00:31:06,840  
that quite intriguing so I was like well

261  
00:31:09,950 --> 00:31:08,940  
let's dig deeper and see what else we

262  
00:31:13,430 --> 00:31:09,960  
can find

263  
00:31:16,310 --> 00:31:13,440

um so this brings me to the setup of the

264

00:31:18,529 --> 00:31:16,320

um on the project of this long period

265

00:31:21,110 --> 00:31:18,539

study that I'm leading now so

266

00:31:22,789 --> 00:31:21,120

um I take theoretical dispersion curves

267

00:31:24,649 --> 00:31:22,799

so it's all theoretical but these are

268

00:31:26,330 --> 00:31:24,659

extra theoretical

269

00:31:27,350 --> 00:31:26,340

um and I can explain what that means

270

00:31:29,269 --> 00:31:27,360

later

271

00:31:30,950 --> 00:31:29,279

um or if you if you ask um so

272

00:31:33,470 --> 00:31:30,960

theoretical this version curve they're

273

00:31:35,990 --> 00:31:33,480

generated with a code called minios and

274

00:31:38,750 --> 00:31:36,000

elaborate on that and then take these

275

00:31:41,269 --> 00:31:38,760

other axi Simmons it says that's another

276

00:31:42,230 --> 00:31:41,279

code so the different methods of doing

277

00:31:44,630 --> 00:31:42,240

these things

278

00:31:46,430 --> 00:31:44,640

um the seismograms to create these mock

279

00:31:49,909 --> 00:31:46,440

observational data of which I would go

280

00:31:51,950 --> 00:31:49,919

and pick and calculate by hand and with

281

00:31:53,630 --> 00:31:51,960

a computer the group velocities for each

282

00:31:56,029 --> 00:31:53,640

Titan input model

283

00:31:58,669 --> 00:31:56,039

I'm not sure that I'm across a range of

284

00:32:00,710 --> 00:31:58,679

distances um and frequencies so

285

00:32:03,409 --> 00:32:00,720

um now just I'll talk about the

286

00:32:06,409 --> 00:32:03,419

theoretical group velocities

287

00:32:08,870 --> 00:32:06,419

um and so these are looking at group

288

00:32:10,970 --> 00:32:08,880

velocity as a functional frequency so

289

00:32:12,529 --> 00:32:10,980

group velocity on the y-axis and

290

00:32:14,090 --> 00:32:12,539

frequency on the X axes and I'm looking

291

00:32:15,409 --> 00:32:14,100

at different modes so I'll talk about

292

00:32:17,149 --> 00:32:15,419

what the screw velocities and phase

293

00:32:19,730 --> 00:32:17,159

velocities are and or group velocities

294

00:32:22,070 --> 00:32:19,740

are and then what the modes are

295

00:32:24,950 --> 00:32:22,080

um so group velocity if we were to look

296

00:32:27,769 --> 00:32:24,960

if you look on the right hand side it's

297

00:32:30,529 --> 00:32:27,779

um the the actual velocity of the like

298

00:32:32,450 --> 00:32:30,539

wave packet that's encapsulating the

299

00:32:34,730 --> 00:32:32,460

like more the bigger larger scale

300

00:32:36,590 --> 00:32:34,740

structure of our seismograms and the

301  
00:32:38,210 --> 00:32:36,600  
phase velocities that's another measure

302  
00:32:41,870 --> 00:32:38,220  
of dispersion

303  
00:32:43,970 --> 00:32:41,880  
um it is the actual velocity of the

304  
00:32:45,529 --> 00:32:43,980  
Peaks and so when you have the groove

305  
00:32:48,110 --> 00:32:45,539  
velocity not equal to the phase velocity

306  
00:32:49,730 --> 00:32:48,120  
you you know you have dispersive wave

307  
00:32:50,450 --> 00:32:49,740  
um and so

308  
00:32:54,049 --> 00:32:50,460  
um

309  
00:32:55,730 --> 00:32:54,059  
the terminal information so mode so if

310  
00:32:58,190 --> 00:32:55,740  
if you remember from physics the like

311  
00:33:00,830 --> 00:32:58,200  
wave on the string analogy

312  
00:33:02,630 --> 00:33:00,840  
um or it's not analogy but the wave on a

313  
00:33:04,430 --> 00:33:02,640

string representation of modes

314

00:33:06,889 --> 00:33:04,440

um the fundamental modes will be here

315

00:33:09,710 --> 00:33:06,899

there's no node first overturn one node

316

00:33:12,350 --> 00:33:09,720

second third second and two and three

317

00:33:13,909 --> 00:33:12,360

nodes uh accordingly or respectively and

318

00:33:16,970 --> 00:33:13,919

then you can go all the way up to I mean

319

00:33:18,529 --> 00:33:16,980

as many nodes and modes as you'd like to

320

00:33:21,529 --> 00:33:18,539

um so for this study we actually looked

321

00:33:24,710 --> 00:33:21,539

at up to three thousand uh overtones to

322

00:33:26,210 --> 00:33:24,720

create an entire seismogram but here

323

00:33:28,370 --> 00:33:26,220

um we know that most of the information

324

00:33:30,169 --> 00:33:28,380

of this surface wave that we're looking

325

00:33:31,610 --> 00:33:30,179

at and I forgot to mention that it's a

326

00:33:35,210 --> 00:33:31,620

Rayleigh wave

327

00:33:37,490 --> 00:33:35,220

um it was it would normally be in the

328

00:33:39,049 --> 00:33:37,500

fundamental mode but

329

00:33:40,850 --> 00:33:39,059

um there's a surprise that I'll show you

330

00:33:41,450 --> 00:33:40,860

in the next slide

331

00:33:44,210 --> 00:33:41,460

um

332

00:33:47,870 --> 00:33:44,220

and so essentially what we found was

333

00:33:49,669 --> 00:33:47,880

that when we're comparing

334

00:33:52,190 --> 00:33:49,679

um when we're looking at the data and I

335

00:33:53,389 --> 00:33:52,200

I went and used actually some this other

336

00:33:55,190 --> 00:33:53,399

data set

337

00:33:56,330 --> 00:33:55,200

um and took the seismograms themselves

338

00:33:57,710 --> 00:33:56,340

and

339

00:33:59,149 --> 00:33:57,720

um calculated the group velocities as

340

00:34:01,190 --> 00:33:59,159

opposed to just them being spit out from

341

00:34:03,649 --> 00:34:01,200

a code for me

342

00:34:05,930 --> 00:34:03,659

um consistently that

343

00:34:07,430 --> 00:34:05,940

um the dispersion profiles um they're

344

00:34:09,710 --> 00:34:07,440

when we look at the different interior

345

00:34:11,389 --> 00:34:09,720

structures they do like differ slightly

346

00:34:13,250 --> 00:34:11,399

but then when we lay them on top of each

347

00:34:15,169 --> 00:34:13,260

other essentially like there isn't

348

00:34:17,089 --> 00:34:15,179

various little differences and it's so

349

00:34:18,349 --> 00:34:17,099

small that you probably would not and

350

00:34:20,629 --> 00:34:18,359

not probably wouldn't they would be

351

00:34:23,089 --> 00:34:20,639

smaller than what we could observe

352

00:34:25,790 --> 00:34:23,099

um on Titan

353

00:34:27,409 --> 00:34:25,800

um so and then also the Israeli waves we

354

00:34:28,849 --> 00:34:27,419

thought that they would be the

355

00:34:30,530 --> 00:34:28,859

information would be in the fundamental

356

00:34:32,389 --> 00:34:30,540

mode but actually it was in the first

357

00:34:34,669 --> 00:34:32,399

overtone which is a little interesting

358

00:34:36,829 --> 00:34:34,679

and it's consistently so okay so there's

359

00:34:39,530 --> 00:34:36,839

this yellow line is the first overtone

360

00:34:42,290 --> 00:34:39,540

and so this blue little Cloud thing is

361

00:34:44,210 --> 00:34:42,300

the one Sigma standard deviation from

362

00:34:47,450 --> 00:34:44,220

these group velocity measurements which

363

00:34:49,250 --> 00:34:47,460

are taken over a range of this instances

364

00:34:51,770 --> 00:34:49,260

and frequencies

365

00:34:54,349 --> 00:34:51,780

um and so

366

00:34:56,690 --> 00:34:54,359

um yeah it's it's a pretty pretty strong

367

00:34:59,570 --> 00:34:56,700

uh thing that's happening or signal that

368

00:35:00,950 --> 00:34:59,580

we're seeing for it not being and the

369

00:35:03,349 --> 00:35:00,960

fundamental mode

370

00:35:04,310 --> 00:35:03,359

um and so then that just shows that this

371

00:35:07,250 --> 00:35:04,320

method

372

00:35:08,329 --> 00:35:07,260

um we wouldn't be able to use Body Waves

373

00:35:11,150 --> 00:35:08,339

to

374

00:35:13,190 --> 00:35:11,160

um this sorry the surface wave this

375

00:35:14,930 --> 00:35:13,200

particular surface wave as

376

00:35:18,650 --> 00:35:14,940

um to diagnose the thickness of Titan's

377

00:35:23,210 --> 00:35:18,660

eyeshadow so that's intriguing and so

378

00:35:25,609 --> 00:35:23,220

um I will dig deeper and and see

379

00:35:27,589 --> 00:35:25,619

um more about that in the future

380

00:35:29,690 --> 00:35:27,599

all right so a quick summary I use data

381

00:35:31,490 --> 00:35:29,700

driven models of Titan's Interiors or to

382

00:35:33,410 --> 00:35:31,500

compute Titan synthetic seismograms for

383

00:35:35,750 --> 00:35:33,420

comparison to real data that we'll get

384

00:35:37,849 --> 00:35:35,760

from dragonfly in the mid-2030s and in

385

00:35:38,930 --> 00:35:37,859

the study we investigate energy trapped

386

00:35:41,089 --> 00:35:38,940

in the eye shell to determine the

387

00:35:43,069 --> 00:35:41,099

structure of Titan and the presence of

388

00:35:45,589 --> 00:35:43,079

surface clathrates

389

00:35:47,990 --> 00:35:45,599

um and AKA long period seismology And

390

00:35:49,370 --> 00:35:48,000

while the surface waves observation that

391

00:35:50,990 --> 00:35:49,380

we saw in the study did not clearly

392

00:35:53,270 --> 00:35:51,000

determine eggshell thickness we can

393

00:35:54,890 --> 00:35:53,280

constrain it using body wave arrivals so

394

00:35:56,690 --> 00:35:54,900

pns waves and if you're interested in

395

00:35:58,550 --> 00:35:56,700

learning more about isolation seismology

396

00:36:01,130 --> 00:35:58,560

and then particularly about some of the

397

00:36:03,230 --> 00:36:01,140

methodology that we were implementing

398

00:36:06,710 --> 00:36:03,240

talk to me or also consult Simon

399

00:36:09,410 --> 00:36:06,720

staler's paper uh it's very looking also

400

00:36:11,390 --> 00:36:09,420

at other icy ocean worlds as well and

401  
00:36:13,190 --> 00:36:11,400  
then understanding the composition of

402  
00:36:14,630 --> 00:36:13,200  
Titan's interior especially the ice

403  
00:36:16,910 --> 00:36:14,640  
shell and ocean will have important

404  
00:36:19,010 --> 00:36:16,920  
implications for astrobiology and

405  
00:36:23,690 --> 00:36:19,020  
habitability studies so thank you so

406  
00:36:23,700 --> 00:36:39,230  
foreign

407  
00:36:39,240 --> 00:36:44,690  
yes good

408  
00:36:49,670 --> 00:36:46,849  
hi nice talk

409  
00:36:50,630 --> 00:36:49,680  
um so presumably like in the lab we

410  
00:36:52,970 --> 00:36:50,640  
don't have

411  
00:36:55,670 --> 00:36:52,980  
like kilometers of class rates so what

412  
00:36:58,790 --> 00:36:55,680  
does it take to extrapolate from just

413  
00:37:00,589 --> 00:36:58,800

this lab made amount to how it'll behave

414

00:37:03,290 --> 00:37:00,599

when it's this much

415

00:37:05,870 --> 00:37:03,300

as a medium yeah so we use this paper

416

00:37:07,970 --> 00:37:05,880

called by calassova and soton

417

00:37:09,950 --> 00:37:07,980

um I think it's in like 20

418

00:37:12,230 --> 00:37:09,960

20.

419

00:37:14,690 --> 00:37:12,240

um but that was their paper is where we

420

00:37:17,390 --> 00:37:14,700

got the actual thermal thermal models to

421

00:37:28,250 --> 00:37:17,400

model to model this for the cloth raids

422

00:37:31,730 --> 00:37:29,870

thank you for the talk

423

00:37:35,030 --> 00:37:31,740

um I I have a question that may be

424

00:37:37,010 --> 00:37:35,040

outside of the scope of what you do but

425

00:37:40,010 --> 00:37:37,020

um I know that the eye shelf thickness

426

00:37:42,710 --> 00:37:40,020

can be a proxy for for heat loss and

427

00:37:43,970 --> 00:37:42,720

that can also kind of um

428

00:37:46,370 --> 00:37:43,980

uh

429

00:37:48,349 --> 00:37:46,380

provide clues as to whether the ocean

430

00:37:50,510 --> 00:37:48,359

may be like a transient feature like or

431

00:37:52,609 --> 00:37:50,520

a more long-lived feature is that

432

00:37:54,730 --> 00:37:52,619

anything you can determine using the

433

00:37:57,410 --> 00:37:54,740

data that may be

434

00:37:59,329 --> 00:37:57,420

collected by dragonfly or anything like

435

00:38:02,030 --> 00:37:59,339

that or is that outside of the scope of

436

00:38:04,250 --> 00:38:02,040

because I mean the the longevity of the

437

00:38:05,870 --> 00:38:04,260

ocean like if there is like a like a

438

00:38:07,730 --> 00:38:05,880

liquid water ocean

439

00:38:09,109 --> 00:38:07,740

um beneath the ice layers that could

440

00:38:10,609 --> 00:38:09,119

have implications in the habitability

441

00:38:12,650 --> 00:38:10,619

whether it's like persisted over

442

00:38:17,329 --> 00:38:12,660

geologic time scales

443

00:38:18,589 --> 00:38:17,339

yeah I mean I mean we can constrain the

444

00:38:23,750 --> 00:38:18,599

the

445

00:38:25,130 --> 00:38:23,760

but regarding

446

00:38:27,530 --> 00:38:25,140

yeah it's a little bit outside of my

447

00:38:36,890 --> 00:38:27,540

preview uh okay I apologize no it's okay

448

00:38:39,650 --> 00:38:38,930

uh so I'm curious

449

00:38:41,569 --> 00:38:39,660

um

450

00:38:43,370 --> 00:38:41,579

what is the amount of confidence we have

451  
00:38:45,530 --> 00:38:43,380  
that there's a high pressure ice layer

452  
00:38:48,650 --> 00:38:45,540  
on the bottom instead of you know a

453  
00:38:51,109 --> 00:38:48,660  
direct contact with the ocean yeah

454  
00:38:52,510 --> 00:38:51,119  
we don't have like any confidence to say

455  
00:38:55,730 --> 00:38:52,520  
I mean

456  
00:38:56,569 --> 00:38:55,740  
we think that there could be I think

457  
00:38:58,849 --> 00:38:56,579  
there's

458  
00:39:00,829 --> 00:38:58,859  
definitely a big Camp thinking that

459  
00:39:02,810 --> 00:39:00,839  
there is

460  
00:39:05,510 --> 00:39:02,820  
um but it's highly debatable so if I

461  
00:39:07,550 --> 00:39:05,520  
were to like look at that diagram

462  
00:39:08,630 --> 00:39:07,560  
um I could put a big sorry going way

463  
00:39:11,150 --> 00:39:08,640

back

464

00:39:12,530 --> 00:39:11,160

um there

465

00:39:13,790 --> 00:39:12,540

um for the high pressure eyes you could

466

00:39:15,710 --> 00:39:13,800

put like a big question mark there

467

00:39:17,030 --> 00:39:15,720

because we don't know if it's there we

468

00:39:18,829 --> 00:39:17,040

don't know how thick it is it's like

469

00:39:22,069 --> 00:39:18,839

really deep down we know there's no

470

00:39:24,050 --> 00:39:22,079

molten core in Titan from some Casini

471

00:39:25,730 --> 00:39:24,060

measurements but high pressure rise we

472

00:39:28,370 --> 00:39:25,740

have a zero idea

473

00:39:30,170 --> 00:39:28,380

um but it could be there

474

00:39:31,670 --> 00:39:30,180

um and so especially because it's so

475

00:39:34,069 --> 00:39:31,680

cold but then

476

00:39:35,990 --> 00:39:34,079

yeah and if it is there there's

477

00:39:37,849 --> 00:39:36,000

different scenarios also that if we have

478

00:39:40,310 --> 00:39:37,859

porous high pressure eyes and it's

479

00:39:41,569 --> 00:39:40,320

really saline and then it could still we

480

00:39:43,310 --> 00:39:41,579

could still have some enrichment of the

481

00:39:45,470 --> 00:39:43,320

ocean so even if it is there depending

482

00:39:47,150 --> 00:39:45,480

on its composition they could still be

483

00:39:49,069 --> 00:39:47,160

in Richmond of the ocean

484

00:39:52,970 --> 00:39:49,079

um so it may not necessarily be a

485

00:40:06,349 --> 00:39:52,980

barrier to life also if it isn't thank

486

00:40:10,970 --> 00:40:09,050

hi nice store I would like to ask you if

487

00:40:13,130 --> 00:40:10,980

you have considered the influenza of the

488

00:40:15,530 --> 00:40:13,140

titleistic patient in your mothers

489

00:40:17,630 --> 00:40:15,540

always the title dissipation

490

00:40:19,550 --> 00:40:17,640

oh do I incorporate that if you have

491

00:40:21,890 --> 00:40:19,560

considered that influence in the

492

00:40:24,170 --> 00:40:21,900

generation of a Titanic earthquake Titan

493

00:40:26,750 --> 00:40:24,180

Quake sorry so have you considered the

494

00:40:28,370 --> 00:40:26,760

influences of the title dissipation

495

00:40:29,690 --> 00:40:28,380

um no we're not considering title

496

00:40:31,970 --> 00:40:29,700

dissipation

497

00:40:34,790 --> 00:40:31,980

um in the models or we're assuming

498

00:40:36,349 --> 00:40:34,800

there's a very perfect Titan but I also

499

00:40:38,089 --> 00:40:36,359

don't think

500

00:40:41,150 --> 00:40:38,099

um we're assuming we're considering

501  
00:40:44,270 --> 00:40:41,160  
attenuation within the ice shell but

502  
00:40:48,470 --> 00:40:46,790  
um we're not really thinking about I

503  
00:40:53,050 --> 00:40:48,480  
think and I don't think we need to yeah

504  
00:40:56,990 --> 00:40:55,310  
about earthquake

505  
00:40:59,810 --> 00:40:57,000  
if you

506  
00:41:00,890 --> 00:40:59,820  
um synthesize the sex meet analysis and

507  
00:41:04,730 --> 00:41:00,900  
the influencing of the technology

508  
00:41:07,730 --> 00:41:04,740  
patients I don't know how much is a

509  
00:41:10,069 --> 00:41:07,740  
contribution of the title so that's why

510  
00:41:12,349 --> 00:41:10,079  
I am asking you if you had considered

511  
00:41:22,810 --> 00:41:12,359  
this um we haven't considered this

512  
00:41:27,589 --> 00:41:26,390  
yeah I don't know if it has like a huge

513  
00:41:29,630 --> 00:41:27,599

um

514

00:41:32,270 --> 00:41:29,640

so so the title

515

00:41:34,310 --> 00:41:32,280

I don't think that we'll have uh like a

516

00:41:36,770 --> 00:41:34,320

large effect which is why we've left it

517

00:41:38,930 --> 00:41:36,780

out yeah yeah also the bank of the

518

00:41:40,790 --> 00:41:38,940

distance between the Titan and Saturn so

519

00:41:46,370 --> 00:41:40,800

yeah I don't know that's why I was

520

00:41:46,380 --> 00:41:49,069

one more question

521

00:41:53,870 --> 00:41:50,690

so uh

522

00:41:56,210 --> 00:41:53,880

um I'm not a planetary geologist but I I

523

00:41:57,410 --> 00:41:56,220

do know that one of the limitations for

524

00:41:59,089 --> 00:41:57,420

our understanding of the interior of

525

00:42:02,510 --> 00:41:59,099

Mars with the Insight mission was that

526

00:42:05,210 --> 00:42:02,520

we only had a single seismometer yeah

527

00:42:07,310 --> 00:42:05,220

um in your data are you modeling uh

528

00:42:09,349 --> 00:42:07,320

basically seismology

529

00:42:11,450 --> 00:42:09,359

being measured by a single seismometer

530

00:42:13,069 --> 00:42:11,460

and you think having multiple

531

00:42:15,109 --> 00:42:13,079

seismometers on the surface of Titan

532

00:42:16,550 --> 00:42:15,119

would give you further resolution in

533

00:42:18,650 --> 00:42:16,560

terms of the thickness of methane

534

00:42:22,069 --> 00:42:18,660

clathrate lid

535

00:42:24,230 --> 00:42:22,079

um yeah 100 it would be amazing to have

536

00:42:27,170 --> 00:42:24,240

multiple seismometers

537

00:42:29,030 --> 00:42:27,180

um on Mars also on Titan but I think

538

00:42:31,310 --> 00:42:29,040

just with experimental Mission

539

00:42:34,849 --> 00:42:31,320

constraints like they can only have one

540

00:42:36,710 --> 00:42:34,859

have you done any modeling to see if you

541

00:42:39,349 --> 00:42:36,720

could get further resolution with

542

00:42:41,030 --> 00:42:39,359

multiple seismometers

543

00:42:44,150 --> 00:42:41,040

um so it's not so it's not really about

544

00:42:45,530 --> 00:42:44,160

like getting the resolution with

545

00:42:47,390 --> 00:42:45,540

um so we can generate perfect

546

00:42:49,849 --> 00:42:47,400

seismograms

547

00:42:51,170 --> 00:42:49,859

um it's just how well we'll be able to

548

00:42:52,490 --> 00:42:51,180

see

549

00:42:54,650 --> 00:42:52,500

um and detect

550

00:42:57,050 --> 00:42:54,660

um things I see it's easier to like

551  
00:42:59,750 --> 00:42:57,060  
triangulate events and things with

552  
00:43:02,870 --> 00:42:59,760  
um when you have multiple seismometers

553  
00:43:05,030 --> 00:43:02,880  
um but yeah we can essentially if we we

554  
00:43:07,250 --> 00:43:05,040  
could see like deeper events if we have

555  
00:43:09,290 --> 00:43:07,260  
more seismometers we'd have just greater

556  
00:43:11,990 --> 00:43:09,300  
sensitivity overall

557  
00:43:14,450 --> 00:43:12,000  
um but we unfortunately don't have that

558  
00:43:18,230 --> 00:43:14,460  
yeah so we have to do what we can with

559  
00:43:28,370 --> 00:43:19,890  
thank you Andrea yeah

560  
00:43:43,809 --> 00:43:30,890  
so our next speaker is Hector Delgado

561  
00:43:49,250 --> 00:43:47,210  
good morning oh God

562  
00:43:51,109 --> 00:43:49,260  
good morning everybody uh my name is

563  
00:43:54,349 --> 00:43:51,119

Hector uh I'm gonna be talking about the

564

00:43:55,790 --> 00:43:54,359

climates of gl513b this is a work I've

565

00:43:57,710 --> 00:43:55,800

been doing with Rory Barnes from

566

00:43:59,690 --> 00:43:57,720

University of Washington and Russell

567

00:44:01,550 --> 00:43:59,700

Dietrich and Marina

568

00:44:03,230 --> 00:44:01,560

uh to give you an outline I'm gonna

569

00:44:06,950 --> 00:44:03,240

first give you an introduction and

570

00:44:08,870 --> 00:44:06,960

convince you why we study gl514b uh I'm

571

00:44:10,130 --> 00:44:08,880

gonna show you what are the factors that

572

00:44:12,109 --> 00:44:10,140

we consider that affect availability

573

00:44:14,569 --> 00:44:12,119

then I'll show you the methods that we

574

00:44:16,370 --> 00:44:14,579

use and then the results follow my

575

00:44:19,010 --> 00:44:16,380

conclusion and the Future Works that are

576

00:44:22,370 --> 00:44:19,020

deemed important to continue doing

577

00:44:24,470 --> 00:44:22,380

so we study this planet in 2022 uh Maria

578

00:44:25,510 --> 00:44:24,480

damaso and his collaborators they

579

00:44:28,370 --> 00:44:25,520

discover

580

00:44:30,829 --> 00:44:28,380

gl514b and what's particular about it

581

00:44:33,829 --> 00:44:30,839

it's that it has a high eccentricity

582

00:44:35,930 --> 00:44:33,839

eccentricity it's how circular the orbit

583

00:44:37,849 --> 00:44:35,940

is and when it's a higher centricity

584

00:44:40,670 --> 00:44:37,859

that means that the orbit is kind of

585

00:44:43,730 --> 00:44:40,680

like an oval shape and usually when we

586

00:44:46,609 --> 00:44:43,740

study exoplanets we look for planets

587

00:44:48,890 --> 00:44:46,619

that are within the habitable zone and

588

00:44:50,630 --> 00:44:48,900

this planet because it's very oval shape

589

00:44:51,890 --> 00:44:50,640

it kind of Falls in and out of the Habit

590

00:44:54,470 --> 00:44:51,900

also so that makes it a particular

591

00:44:56,150 --> 00:44:54,480

object to study it also as you can see

592

00:44:58,250 --> 00:44:56,160

from the properties it also orbits a

593

00:45:00,770 --> 00:44:58,260

Android star which is one of which is

594

00:45:04,190 --> 00:45:00,780

the most abundant star in our galaxy and

595

00:45:06,650 --> 00:45:04,200

universe and with that in mind uh when

596

00:45:08,809 --> 00:45:06,660

we look at the uh the multiple orbits

597

00:45:10,609 --> 00:45:08,819

that could happen in this planet uh

598

00:45:12,650 --> 00:45:10,619

these are just simulations of what are

599

00:45:16,370 --> 00:45:12,660

0.45 eccentricity or B would look like

600

00:45:18,050 --> 00:45:16,380

uh we see that they all go in in and out

601  
00:45:19,370 --> 00:45:18,060  
of this green shaded region which is the

602  
00:45:22,190 --> 00:45:19,380  
habitable zone that we can see that the

603  
00:45:25,250 --> 00:45:22,200  
habitable is one of the of the star and

604  
00:45:27,290 --> 00:45:25,260  
the dash line is just the the best fit

605  
00:45:28,670 --> 00:45:27,300  
orbit we still see it that all of them

606  
00:45:30,950 --> 00:45:28,680  
go through in and out so that's what

607  
00:45:32,510 --> 00:45:30,960  
makes it uh very important to study for

608  
00:45:33,530 --> 00:45:32,520  
habitability since we've never done that

609  
00:45:35,770 --> 00:45:33,540  
before

610  
00:45:38,150 --> 00:45:35,780  
and another reason why we want to study

611  
00:45:40,490 --> 00:45:38,160  
gl519b in this graph I'm showing you

612  
00:45:43,370 --> 00:45:40,500  
here a plot of the eccentricity over the

613  
00:45:45,170 --> 00:45:43,380

orbital period of the planet so how long

614

00:45:48,290 --> 00:45:45,180

it takes the planet to go around the its

615

00:45:50,630 --> 00:45:48,300

Hoster the size of the of the bubbles it

616

00:45:52,069 --> 00:45:50,640

shows how much solar installation or how

617

00:45:54,770 --> 00:45:52,079

much of radiation from the start it's

618

00:45:56,630 --> 00:45:54,780

falling into into the planet uh on the

619

00:45:58,190 --> 00:45:56,640

top right corner you can see the bubble

620

00:46:00,710 --> 00:45:58,200

for what would be like an earth

621

00:46:02,510 --> 00:46:00,720

installation so how much uh sunlight we

622

00:46:05,150 --> 00:46:02,520

receive the bigger the bubble the more

623

00:46:07,309 --> 00:46:05,160

radiation the planet is receiving uh

624

00:46:09,890 --> 00:46:07,319

gray gray dots represents we don't have

625

00:46:13,309 --> 00:46:09,900

data for for the installation so they

626  
00:46:15,650 --> 00:46:13,319  
don't show any any uh any information

627  
00:46:18,230 --> 00:46:15,660  
about that but in particular when we

628  
00:46:19,490 --> 00:46:18,240  
look at gl514b which is in the middle uh

629  
00:46:21,710 --> 00:46:19,500  
in the middle of these graphs on the top

630  
00:46:24,470 --> 00:46:21,720  
side we see that it's almost unique to

631  
00:46:26,930 --> 00:46:24,480  
it and when we have an orbital period

632  
00:46:30,890 --> 00:46:26,940  
that long around an mdorf it gives us a

633  
00:46:32,150 --> 00:46:30,900  
uh an idea uh a better view to use Next

634  
00:46:34,790 --> 00:46:32,160  
Generation telescopes such as ground

635  
00:46:36,530 --> 00:46:34,800  
telescopes to to putting them and be

636  
00:46:38,150 --> 00:46:36,540  
able to directly observe them if the

637  
00:46:39,650 --> 00:46:38,160  
planet is too close to the star the

638  
00:46:42,170 --> 00:46:39,660

planet would be really hard to to see

639

00:46:43,550 --> 00:46:42,180

with with direct observation uh there's

640

00:46:46,010 --> 00:46:43,560

another planet that is really far away

641

00:46:47,569 --> 00:46:46,020

which we see it at 250 orbital periods

642

00:46:49,130 --> 00:46:47,579

on the right side but it has a lower

643

00:46:50,809 --> 00:46:49,140

eccentricity so that way that's why we

644

00:46:53,390 --> 00:46:50,819

don't care much to study that one there

645

00:46:55,730 --> 00:46:53,400

is a planet with 0.5 uh greater than 0.5

646

00:46:58,730 --> 00:46:55,740

x in 360 but it has a shorter orbital

647

00:47:00,349 --> 00:46:58,740

period uh than gl514me so it might be

648

00:47:02,030 --> 00:47:00,359

really hard to direct observe and we

649

00:47:03,890 --> 00:47:02,040

want a planet that we can study in the

650

00:47:05,809 --> 00:47:03,900

future

651  
00:47:08,630 --> 00:47:05,819  
and with that in mind the Next

652  
00:47:10,790 --> 00:47:08,640  
Generation telescope such as the uh such

653  
00:47:14,030 --> 00:47:10,800  
as the oh my God uh the extremely large

654  
00:47:17,089 --> 00:47:14,040  
telescope uh it it would be a telescope

655  
00:47:19,849 --> 00:47:17,099  
that should be able to observe uh gl514b

656  
00:47:21,650 --> 00:47:19,859  
this graph is just showing uh what is

657  
00:47:23,390 --> 00:47:21,660  
the maximum angular separation that the

658  
00:47:25,609 --> 00:47:23,400  
planet needs in order to be observed and

659  
00:47:27,950 --> 00:47:25,619  
the planet to start flux ratio uh

660  
00:47:29,569 --> 00:47:27,960  
meaning that the bigger planet to start

661  
00:47:31,910 --> 00:47:29,579  
fluctuation that means we can observe it

662  
00:47:33,829 --> 00:47:31,920  
better and in the Dutch line that

663  
00:47:35,750 --> 00:47:33,839

represents the boundary to be observed

664

00:47:37,730 --> 00:47:35,760

uh to to the planets that could be

665

00:47:39,890 --> 00:47:37,740

observed with the elt the extremely

666

00:47:42,170 --> 00:47:39,900

large telescope and we expect that

667

00:47:45,950 --> 00:47:42,180

gl514me will fall fall within that

668

00:47:47,870 --> 00:47:45,960

boundary so we will plan to use elt to

669

00:47:50,750 --> 00:47:47,880

observe this planet

670

00:47:53,210 --> 00:47:50,760

now I hope I convinced you why study Geo

671

00:47:54,470 --> 00:47:53,220

514b so now uh I want to talk about like

672

00:47:56,030 --> 00:47:54,480

what are some factors affecting

673

00:47:57,829 --> 00:47:56,040

habitability

674

00:47:59,030 --> 00:47:57,839

um so there's many factors when we talk

675

00:48:02,390 --> 00:47:59,040

about habitability there's so many

676

00:48:04,370 --> 00:48:02,400

things that we can think of uh but I we

677

00:48:07,190 --> 00:48:04,380

focus on the ones that we've seen that

678

00:48:09,589 --> 00:48:07,200

in other papers that have shown that uh

679

00:48:11,809 --> 00:48:09,599

these are the most that affect an impact

680

00:48:13,309 --> 00:48:11,819

the availability and these are the

681

00:48:15,410 --> 00:48:13,319

eccentricity that I mentioned is how

682

00:48:17,150 --> 00:48:15,420

oval or secular that orbit is the

683

00:48:19,550 --> 00:48:17,160

obliquity in which is that tilt of the

684

00:48:22,550 --> 00:48:19,560

rotational axis from the plane of of

685

00:48:25,130 --> 00:48:22,560

orbit from the star system the Precision

686

00:48:27,530 --> 00:48:25,140

angle is the angle of wobbling of that

687

00:48:30,109 --> 00:48:27,540

rotation axis and the partial pressure

688

00:48:31,990 --> 00:48:30,119

of CO2 which is how much CO2 is built up

689

00:48:35,630 --> 00:48:32,000

in the in the atmosphere of the planet

690

00:48:37,069 --> 00:48:35,640

and uh difficulties I told me to talk I

691

00:48:39,170 --> 00:48:37,079

don't go into much details as to why

692

00:48:41,750 --> 00:48:39,180

them but those are the papers that we

693

00:48:43,250 --> 00:48:41,760

mostly Focus uh show the uh these are

694

00:48:46,609 --> 00:48:43,260

the factors affecting habitability that

695

00:48:50,569 --> 00:48:46,619

we want to use for gl514me

696

00:48:53,450 --> 00:48:50,579

we use uh software called V Planet which

697

00:48:55,370 --> 00:48:53,460

is an open source code that has 11 11

698

00:48:57,650 --> 00:48:55,380

physical processes that simulate

699

00:49:00,950 --> 00:48:57,660

habitability for our planet uh it

700

00:49:03,470 --> 00:49:00,960

includes uh binary systems or includes

701

00:49:05,150 --> 00:49:03,480

the the radiation for the star the or

702

00:49:07,069 --> 00:49:05,160

the disturbances in the Orbee the

703

00:49:09,050 --> 00:49:07,079

services in the rotation many others but

704

00:49:11,329 --> 00:49:09,060

they want the one part that we use from

705

00:49:13,790 --> 00:49:11,339

the planet is the one called Poise which

706

00:49:15,470 --> 00:49:13,800

is an energy balance model and what it

707

00:49:19,450 --> 00:49:15,480

essentially means this graph is a good

708

00:49:22,849 --> 00:49:19,460

explanation I did not do this graph uh

709

00:49:25,190 --> 00:49:22,859

facilitated and what an idea in in

710

00:49:27,410 --> 00:49:25,200

essence what it is it's a balance of all

711

00:49:29,210 --> 00:49:27,420

the incoming solar radiation that comes

712

00:49:30,829 --> 00:49:29,220

to the planet and how much is that it's

713

00:49:34,250 --> 00:49:30,839

either absorbed by the planet or

714

00:49:37,370 --> 00:49:34,260

reflected back to the two space uh Poise

715

00:49:38,750 --> 00:49:37,380

does now is a cloud-free cloud-free uh

716

00:49:42,470 --> 00:49:38,760

energy balance model so that we don't

717

00:49:44,329 --> 00:49:42,480

take into account the the reflected uh

718

00:49:46,190 --> 00:49:44,339

sunlight by the by clouds in the

719

00:49:48,230 --> 00:49:46,200

atmosphere so that means that we mostly

720

00:49:49,550 --> 00:49:48,240

focus in in two parts of the of the

721

00:49:52,010 --> 00:49:49,560

energy balance model which is how much

722

00:49:53,930 --> 00:49:52,020

is absorbed by the by the by the surface

723

00:49:55,309 --> 00:49:53,940

of the planet and on the right side top

724

00:49:57,650 --> 00:49:55,319

side you can see that it says are going

725

00:50:00,410 --> 00:49:57,660

along with radiation how much of that is

726

00:50:04,130 --> 00:50:00,420

being radiated by by the atmosphere

727

00:50:07,250 --> 00:50:04,140

itself in in longer wavelengths

728

00:50:10,910 --> 00:50:07,260

uh in in essence this is the the

729

00:50:14,089 --> 00:50:10,920

equation that we use uh to explain it to

730

00:50:16,550 --> 00:50:14,099

explain it in a in a easy way I would

731

00:50:18,170 --> 00:50:16,560

say that the first term is it represents

732

00:50:20,569 --> 00:50:18,180

that absorption of the heat from the

733

00:50:22,670 --> 00:50:20,579

surface uh the second term represents

734

00:50:24,109 --> 00:50:22,680

how much is being dissipated throughout

735

00:50:26,210 --> 00:50:24,119

the atmosphere so atmospheric

736

00:50:29,030 --> 00:50:26,220

circulation of the heat uh the third

737

00:50:29,990 --> 00:50:29,040

term is just shows the irradiation to

738

00:50:32,329 --> 00:50:30,000

space

739

00:50:33,589 --> 00:50:32,339

and that should all of that although all

740

00:50:35,150 --> 00:50:33,599

of that should balance to the fourth

741

00:50:36,650 --> 00:50:35,160

term which is how much of income in

742

00:50:37,849 --> 00:50:36,660

solar radiation is falling into the

743

00:50:40,849 --> 00:50:37,859

planet

744

00:50:43,609 --> 00:50:40,859

um so another thing that Poise does and

745

00:50:45,109 --> 00:50:43,619

this is good to know is that it not it's

746

00:50:48,710 --> 00:50:45,119

not only an energy balance model but it

747

00:50:50,630 --> 00:50:48,720

also calculates uh the ice sheets or how

748

00:50:52,849 --> 00:50:50,640

much ice it's flowing around the planet

749

00:50:54,650 --> 00:50:52,859

so is the planet covering full eyes is

750

00:50:56,569 --> 00:50:54,660

the planet it's just ice free meaning

751

00:50:59,329 --> 00:50:56,579

that it's all water or is the planet has

752

00:51:01,490 --> 00:50:59,339

a combination of polar caps or other

753

00:51:03,589 --> 00:51:01,500

types of ice configurations which are

754

00:51:05,809 --> 00:51:03,599

really important for habitability since

755

00:51:08,450 --> 00:51:05,819

uh Earth uh Earth we've seen Earth

756

00:51:10,670 --> 00:51:08,460

throughout time has how much the ice has

757

00:51:13,549 --> 00:51:10,680

changed in that surface

758

00:51:15,530 --> 00:51:13,559

um and another part of the of the

759

00:51:17,630 --> 00:51:15,540

v-planet uh that we think of is that

760

00:51:20,030 --> 00:51:17,640

outgoing longer variation there are many

761

00:51:21,890 --> 00:51:20,040

many ways there are many theories on how

762

00:51:24,290 --> 00:51:21,900

do we calculate that how much of that

763

00:51:26,030 --> 00:51:24,300

radiation is being dissipated to space

764

00:51:29,870 --> 00:51:26,040

um there's uh in the planet there's

765

00:51:32,150 --> 00:51:29,880

three of them uh from spigo 2009 and

766

00:51:34,609 --> 00:51:32,160

Williams and casting 1997 and Northern

767

00:51:38,990 --> 00:51:34,619

googly 1979.

768

00:51:40,730 --> 00:51:39,000

so spigo and and north and Coakley those

769

00:51:42,410 --> 00:51:40,740

two are going along with radiation

770

00:51:45,170 --> 00:51:42,420

they're just as a function of

771

00:51:47,270 --> 00:51:45,180

temperature and and Williamson Casino

772

00:51:49,609 --> 00:51:47,280

includes a component of partial pressure

773

00:51:51,710 --> 00:51:49,619

of CO2 and we can see in this graph how

774

00:51:55,670 --> 00:51:51,720

much of that outgoing normal radiation

775

00:51:57,770 --> 00:51:55,680

over surface temperature it changes uh

776  
00:51:59,690 --> 00:51:57,780  
um Hing is a functional temperature but

777  
00:52:01,790 --> 00:51:59,700  
with the difference that Williams and

778  
00:52:04,190 --> 00:52:01,800  
casting when we change the partial

779  
00:52:06,490 --> 00:52:04,200  
pressure of CO<sub>2</sub> in this case I'm having

780  
00:52:08,049 --> 00:52:06,500  
a partial pressure of simulating Earth's

781  
00:52:10,849 --> 00:52:08,059  
CO<sub>2</sub>

782  
00:52:12,849 --> 00:52:10,859  
abundance in the atmosphere and we see

783  
00:52:15,530 --> 00:52:12,859  
that it kind of it gives a more

784  
00:52:17,210 --> 00:52:15,540  
realistic version of how much of that

785  
00:52:20,390 --> 00:52:17,220  
radiation is being dissipated to to

786  
00:52:22,790 --> 00:52:20,400  
space so that means for our purpose of

787  
00:52:25,309 --> 00:52:22,800  
this of this study we use uh Williams

788  
00:52:28,370 --> 00:52:25,319

and casting 1997 model to simulate how

789

00:52:31,670 --> 00:52:28,380

much radiation is being dissipated

790

00:52:33,650 --> 00:52:31,680

yeah oh and and to say the uh to say

791

00:52:36,010 --> 00:52:33,660

that this William and casting model is

792

00:52:39,410 --> 00:52:36,020

only valid from uh negative

793

00:52:41,690 --> 00:52:39,420

83.15 degrees Celsius to 86.85 degrees

794

00:52:44,210 --> 00:52:41,700

Celsius meaning that anything that goes

795

00:52:47,030 --> 00:52:44,220

if the planet gets too cold or too hot

796

00:52:48,650 --> 00:52:47,040

from those boundaries that means that uh

797

00:52:51,650 --> 00:52:48,660

our calculations of the outgoing lower

798

00:52:53,870 --> 00:52:51,660

radiation are not exactly

799

00:52:55,370 --> 00:52:53,880

um accurate So within them as if it's

800

00:52:57,770 --> 00:52:55,380

too cold that the planet is just

801  
00:52:59,390 --> 00:52:57,780  
completely as Noble and if it's too hot

802  
00:53:02,510 --> 00:52:59,400  
we just demean as a planet completely

803  
00:53:07,069 --> 00:53:05,089  
in terms of the of many other parameters

804  
00:53:09,829 --> 00:53:07,079  
so we're talking about partial pressure

805  
00:53:11,329 --> 00:53:09,839  
CO2 eccentricity obliquity uh and

806  
00:53:13,069 --> 00:53:11,339  
precision angle there's other other

807  
00:53:15,589 --> 00:53:13,079  
parameters that go into an energy

808  
00:53:18,530 --> 00:53:15,599  
balance model and an ice sheet flow

809  
00:53:20,930 --> 00:53:18,540  
diagram so uh here I am just showing you

810  
00:53:23,450 --> 00:53:20,940  
most of the other parameters some some

811  
00:53:25,970 --> 00:53:23,460  
of them are arbitrary others are Earth's

812  
00:53:27,290 --> 00:53:25,980  
value uh so you know as every model we

813  
00:53:29,750 --> 00:53:27,300

had to make assumptions and these are

814

00:53:31,430 --> 00:53:29,760

some of the assumptions for example uh

815

00:53:33,230 --> 00:53:31,440

the ebm meaning the energy balance model

816

00:53:36,109 --> 00:53:33,240

we run it seasonally instead of annually

817

00:53:38,390 --> 00:53:36,119

so every season we check uh that we

818

00:53:41,210 --> 00:53:38,400

check that energy balance we run it

819

00:53:43,069 --> 00:53:41,220

every for four years uh so it's run for

820

00:53:45,710 --> 00:53:43,079

four years and we run it every 500 years

821

00:53:47,870 --> 00:53:45,720

to calculate it and uh we use the

822

00:53:50,809 --> 00:53:47,880

Wheelhouse in casein olr model which is

823

00:53:52,849 --> 00:53:50,819

outgoing radiation the initial Global

824

00:53:55,309 --> 00:53:52,859

temperature we use 14.85 degrees Celsius

825

00:53:57,410 --> 00:53:55,319

which represents a pretty pre-industrial

826

00:53:59,270 --> 00:53:57,420

Earth's temperature

827

00:54:01,910 --> 00:53:59,280

we have the deposition rate of snow

828

00:54:03,290 --> 00:54:01,920

which is that's from Earth's value uh

829

00:54:05,329 --> 00:54:03,300

and then the heat capacity of the land

830

00:54:07,730 --> 00:54:05,339

of the water and the albedos they all

831

00:54:10,010 --> 00:54:07,740

come also from Earth's value

832

00:54:13,730 --> 00:54:10,020

um now the land fraction is analogous is

833

00:54:16,849 --> 00:54:13,740

similar to it so uh so we use a 25 Lan

834

00:54:19,730 --> 00:54:16,859

and the 75 is just water cover uh it's

835

00:54:26,630 --> 00:54:23,210

to outdo our uh our our simulations we

836

00:54:29,809 --> 00:54:26,640

divide it into four simulations uh we

837

00:54:31,910 --> 00:54:29,819

first wanted to find values of CO<sub>2</sub> uh

838

00:54:33,470 --> 00:54:31,920

eccentricity obliquity and precision

839

00:54:34,790 --> 00:54:33,480

angle that meet the affiliate protocol

840

00:54:37,130 --> 00:54:34,800

I'll explain to you what the file

841

00:54:38,750 --> 00:54:37,140

protocol is uh the second simulation we

842

00:54:41,270 --> 00:54:38,760

studied the latitudinal temperature for

843

00:54:42,829 --> 00:54:41,280

various eccentricities the third one we

844

00:54:44,690 --> 00:54:42,839

did a parameter sweep of eccentricity

845

00:54:47,270 --> 00:54:44,700

and obliquities and therefore one with

846

00:54:49,309 --> 00:54:47,280

the parameter sweep of CO<sub>2</sub> and obliquity

847

00:54:51,230 --> 00:54:49,319

uh all of this we run all the

848

00:54:54,829 --> 00:54:51,240

simulations for one million years and I

849

00:54:58,069 --> 00:54:54,839

did a total of 960 simulations why 960.

850

00:54:59,870 --> 00:54:58,079

just because no specific reason

851  
00:55:01,430 --> 00:54:59,880  
um and all of these are just static

852  
00:55:02,990 --> 00:55:01,440  
simulations meaning that the obliquity

853  
00:55:04,910 --> 00:55:03,000  
eccentricity and precision angle of the

854  
00:55:06,770 --> 00:55:04,920  
planet are not evolving over time so

855  
00:55:08,809 --> 00:55:06,780  
that means that for future work just uh

856  
00:55:10,609 --> 00:55:08,819  
spoiler we want to do a dynamic

857  
00:55:12,349 --> 00:55:10,619  
evolution of how we see this

858  
00:55:14,089 --> 00:55:12,359  
eccentricity of liquidum precision angle

859  
00:55:15,950 --> 00:55:14,099  
evolve because we see that on Earth we

860  
00:55:18,710 --> 00:55:15,960  
see those values changes

861  
00:55:20,450 --> 00:55:18,720  
for the first one the the file protocol

862  
00:55:23,030 --> 00:55:20,460  
is just a functionality of ice

863  
00:55:24,589 --> 00:55:23,040

latitudinal ABM tenacity so it's a

864

00:55:28,190 --> 00:55:24,599

protocol an intern comparison project

865

00:55:29,809 --> 00:55:28,200

from the Cuisines uh project and and

866

00:55:32,569 --> 00:55:29,819

what they want is to do an intern

867

00:55:34,490 --> 00:55:32,579

comparison on the different EVMS and the

868

00:55:37,730 --> 00:55:34,500

first Benchmark case is to achieve

869

00:55:39,589 --> 00:55:37,740

Global mean surface of 288 Cummins and

870

00:55:41,390 --> 00:55:39,599

that's what we did and we look for what

871

00:55:43,190 --> 00:55:41,400

are those values and we found many

872

00:55:45,470 --> 00:55:43,200

possibilities but this one I'm showing

873

00:55:47,329 --> 00:55:45,480

you here is just the centricity of 0.45

874

00:55:49,130 --> 00:55:47,339

and obliquity of three degrees a

875

00:55:50,870 --> 00:55:49,140

Precision angle of 90 degrees and a

876

00:55:53,270 --> 00:55:50,880

partial pressure of CO2 or seven seven

877

00:55:56,690 --> 00:55:53,280

bars we noticed that 7 bar CO2 is the

878

00:55:58,309 --> 00:55:56,700

one that gives the most uh uh the most

879

00:56:01,549 --> 00:55:58,319

stable climates throughout the different

880

00:56:04,609 --> 00:56:01,559

bars uh uh pressure pressure of CO2 in

881

00:56:06,950 --> 00:56:04,619

here uh I'm just showing you how those

882

00:56:10,130 --> 00:56:06,960

the in the first panel is the insulation

883

00:56:11,809 --> 00:56:10,140

is being received per latitude on the

884

00:56:13,370 --> 00:56:11,819

say on the top right panel is the

885

00:56:16,430 --> 00:56:13,380

surface temperature how it varies on the

886

00:56:18,890 --> 00:56:16,440

bottom left is a is the ice melon ice

887

00:56:21,290 --> 00:56:18,900

mass balance meaning that a clear color

888

00:56:23,569 --> 00:56:21,300

ice is being deposited dark color is

889

00:56:25,309 --> 00:56:23,579

being lost and on the right we have the

890

00:56:27,530 --> 00:56:25,319

outgoing lower radiation and what we see

891

00:56:29,030 --> 00:56:27,540

is that all of this uh correlates so we

892

00:56:31,490 --> 00:56:29,040

have a validation of our code that is

893

00:56:32,930 --> 00:56:31,500

working as issue uh so that's why we

894

00:56:35,870 --> 00:56:32,940

wanted to do this as our first

895

00:56:37,309 --> 00:56:35,880

simulation we're just trying to like uh

896

00:56:38,109 --> 00:56:37,319

do kind of like a sanity shake for a

897

00:56:40,670 --> 00:56:38,119

code

898

00:56:42,950 --> 00:56:40,680

we then did a studio latitudinal

899

00:56:44,930 --> 00:56:42,960

temperature for various eccentricities

900

00:56:47,930 --> 00:56:44,940

and in here I'm just showing remember

901  
00:56:50,450 --> 00:56:47,940  
that eccentricity is 0.45 but if we look

902  
00:56:53,870 --> 00:56:50,460  
at the error value of of their

903  
00:56:56,210 --> 00:56:53,880  
calculation is plus minus 0.4.15 to 0.14

904  
00:56:57,950 --> 00:56:56,220  
so if we want to study this to three

905  
00:57:01,430 --> 00:56:57,960  
sigma confidence that means we have to

906  
00:57:03,470 --> 00:57:01,440  
do a range of of 0.03 eccentricity to

907  
00:57:04,670 --> 00:57:03,480  
0.9 eccentricity so that's what I'm

908  
00:57:07,190 --> 00:57:04,680  
showing here how the different

909  
00:57:08,690 --> 00:57:07,200  
temperatures uh of the planet vary

910  
00:57:10,609 --> 00:57:08,700  
through the one million year calculation

911  
00:57:12,470 --> 00:57:10,619  
on the top one it looks weird yes it is

912  
00:57:15,650 --> 00:57:12,480  
weird and it's because the simulation

913  
00:57:17,569 --> 00:57:15,660

gets too cold and it goes out of

914

00:57:19,910 --> 00:57:17,579

boundary for our simulation of the

915

00:57:22,849 --> 00:57:19,920

Williams and casting so that means the

916

00:57:25,010 --> 00:57:22,859

plan is just really cool and it doesn't

917

00:57:26,089 --> 00:57:25,020

um it doesn't get to to run anymore

918

00:57:28,670 --> 00:57:26,099

because it just fell out of the

919

00:57:30,109 --> 00:57:28,680

boundaries so for that one uh the planet

920

00:57:32,990 --> 00:57:30,119

falls out of boundaries as a noble State

921

00:57:34,609 --> 00:57:33,000

the second one is uh we get a global

922

00:57:36,710 --> 00:57:34,619

mean surface temperature of 26 degrees

923

00:57:39,170 --> 00:57:36,720

so it's really hot meaning it's a nice

924

00:57:41,870 --> 00:57:39,180

free state and for the last one we have

925

00:57:42,890 --> 00:57:41,880

a 0.9 eccentricity but the planet gets

926  
00:57:46,430 --> 00:57:42,900  
too close to the star of the beginning

927  
00:57:47,450 --> 00:57:46,440  
so it's it's so hot that it's just for a

928  
00:57:50,210 --> 00:57:47,460  
lot of boundaries from the other side

929  
00:57:52,010 --> 00:57:50,220  
however because the planet eccentricity

930  
00:57:53,930 --> 00:57:52,020  
is so long that means its Winters are

931  
00:57:56,089 --> 00:57:53,940  
very long so when we're able to lower

932  
00:57:57,770 --> 00:57:56,099  
the eccentricity so that the code could

933  
00:57:59,329 --> 00:57:57,780  
run we see that the global mean

934  
00:58:01,609 --> 00:57:59,339  
temperature is about six degrees so it's

935  
00:58:03,410 --> 00:58:01,619  
not that warm so it's a we get as a

936  
00:58:05,390 --> 00:58:03,420  
noble State even though it's a global

937  
00:58:08,329 --> 00:58:05,400  
temperature of six degrees

938  
00:58:09,530 --> 00:58:08,339

solution simulation 3 and Amazon uh this

939

00:58:10,970 --> 00:58:09,540

is just a parameter sweep of

940

00:58:14,510 --> 00:58:10,980

eccentricities and obliquities how those

941

00:58:16,309 --> 00:58:14,520

eccentricity obliquity affects the uh

942

00:58:18,470 --> 00:58:16,319

the state of the planet we see ice

943

00:58:20,569 --> 00:58:18,480

freeze the dark blue uh snowball will be

944

00:58:22,309 --> 00:58:20,579

the gray part purple is a polar ice cap

945

00:58:23,510 --> 00:58:22,319

ice caps and the outer boundaries is a

946

00:58:26,210 --> 00:58:23,520

region whether it's too hot or too cold

947

00:58:27,290 --> 00:58:26,220

and we see that at least polar ice caps

948

00:58:29,030 --> 00:58:27,300

are formed this is important because

949

00:58:30,950 --> 00:58:29,040

Earth has ice caps so that's what we're

950

00:58:33,410 --> 00:58:30,960

trying to achieve if we can see ice caps

951  
00:58:34,670 --> 00:58:33,420  
in the planet uh so this shows up for

952  
00:58:36,349 --> 00:58:34,680  
different accents region of obliquity

953  
00:58:38,210 --> 00:58:36,359  
that happens

954  
00:58:39,289 --> 00:58:38,220  
and we look at the global mean

955  
00:58:41,990 --> 00:58:39,299  
temperature for those different

956  
00:58:45,770 --> 00:58:42,000  
centricities and obliquities and in we

957  
00:58:48,589 --> 00:58:45,780  
get a 14.85 degree celsius at Atomic

958  
00:58:50,030 --> 00:58:48,599  
Century 0.4 2.5 regardless of the

959  
00:58:51,589 --> 00:58:50,040  
obliquity so we get kind of like a

960  
00:58:53,690 --> 00:58:51,599  
stable Clement irregardless of

961  
00:58:56,150 --> 00:58:53,700  
obligatory for different eccentricities

962  
00:58:57,829 --> 00:58:56,160  
lastly we did a primary sweep of this

963  
00:58:59,809 --> 00:58:57,839

time instead of changing eccentricity we

964

00:59:01,849 --> 00:58:59,819

change the CO2 and we also see that

965

00:59:04,309 --> 00:59:01,859

polar ice caps are formed and on the

966

00:59:05,809 --> 00:59:04,319

right side we get uh we see that how

967

00:59:09,049 --> 00:59:05,819

many of those simulations are either

968

00:59:10,549 --> 00:59:09,059

polar cups uh ice free or Noble and we

969

00:59:12,770 --> 00:59:10,559

see that a lot of them are ice free and

970

00:59:14,690 --> 00:59:12,780

snowball uh there's very little of polar

971

00:59:17,089 --> 00:59:14,700

caps but there is still a glimmer of

972

00:59:20,210 --> 00:59:17,099

hope because they still form so that's a

973

00:59:21,950 --> 00:59:20,220

good thing that happens and and then

974

00:59:24,170 --> 00:59:21,960

I'll leave you to the conclusions so I

975

00:59:28,730 --> 00:59:24,180

just want to cut it there but in essence

976  
00:59:30,589 --> 00:59:28,740  
we did find uh temperature uh conditions

977  
00:59:33,410 --> 00:59:30,599  
that can give a temporary climate such

978  
00:59:35,030 --> 00:59:33,420  
as pre-industrial Earth 7 bar CO2 would

979  
00:59:37,730 --> 00:59:35,040  
be suggest that is the most stable one

980  
00:59:39,230 --> 00:59:37,740  
for to create those polar ice caps most

981  
00:59:41,990 --> 00:59:39,240  
of the planet states are funny they're

982  
00:59:44,390 --> 00:59:42,000  
iceable or snowball and precision angle

983  
00:59:46,130 --> 00:59:44,400  
does not impact much the eye state of

984  
00:59:47,930 --> 00:59:46,140  
the planet and we don't need direct

985  
00:59:50,510 --> 00:59:47,940  
observations to assess the habitability

986  
00:59:51,280 --> 00:59:50,520  
of gl5 for Timmy and I'll leave you

987  
00:59:57,230 --> 00:59:51,290  
there thank you

988  
00:59:59,809 --> 00:59:57,240

[Applause]

989

01:00:03,349 --> 00:59:59,819

okay sorry so we have time for one quick

990

01:00:06,950 --> 01:00:05,089

uh great talk

991

01:00:08,930 --> 01:00:06,960

um so it seems like you're suggesting

992

01:00:11,390 --> 01:00:08,940

that uh snowball state is a is a

993

01:00:14,170 --> 01:00:11,400

permanent State and I'm curious as to

994

01:00:16,309 --> 01:00:14,180

whether or not your simulation show any

995

01:00:18,770 --> 01:00:16,319

deviation from that

996

01:00:21,710 --> 01:00:18,780

um because you know we know that that's

997

01:00:23,390 --> 01:00:21,720

a state that has been influxing our

998

01:00:25,130 --> 01:00:23,400

planet so I just I wonder

999

01:00:27,650 --> 01:00:25,140

if your simulations can account for

1000

01:00:31,069 --> 01:00:27,660

coming out of a snowball State yeah so

1001

01:00:33,410 --> 01:00:31,079

this so at least the simulation what so

1002

01:00:34,730 --> 01:00:33,420

what is showing is that the uh what I'm

1003

01:00:37,130 --> 01:00:34,740

showing here on the on this histogram

1004

01:00:40,370 --> 01:00:37,140

plot is the last state at the at the end

1005

01:00:42,049 --> 01:00:40,380

of the simulation uh but uh papers have

1006

01:00:45,950 --> 01:00:42,059

shown that one million year is a good

1007

01:00:48,829 --> 01:00:45,960

enough time for c for uh simulations uh

1008

01:00:50,030 --> 01:00:48,839

for climates to stabilize the thing is

1009

01:00:51,770 --> 01:00:50,040

that because we're doing a static

1010

01:00:53,750 --> 01:00:51,780

Evolution we don't expect it to change

1011

01:00:55,069 --> 01:00:53,760

but if we add the dynamic part which is

1012

01:00:56,750 --> 01:00:55,079

like changing in obliquity and

1013

01:00:58,730 --> 01:00:56,760

eccentricity and precision I go while

1014

01:01:00,589 --> 01:00:58,740

we're evolving the planet then that

1015

01:01:01,970 --> 01:01:00,599

could that could change uh and it could

1016

01:01:03,589 --> 01:01:01,980

be it could have been like a snowball

1017

01:01:05,210 --> 01:01:03,599

State at one point and then change to

1018

01:01:06,770 --> 01:01:05,220

something else but for this for the

1019

01:01:08,870 --> 01:01:06,780

static ones we're not we're not

1020

01:01:17,480 --> 01:01:08,880

expecting this to change since there's

1021

01:01:17,490 --> 01:01:26,630

[Applause]

1022

01:01:37,250 --> 01:01:28,490

Karen next speaker is Evelyn McDonald

1023

01:01:39,829 --> 01:01:38,430

foreign

1024

01:01:42,829 --> 01:01:39,839

[Music]

1025

01:01:45,410 --> 01:01:42,839

thank you uh can everyone hear me

1026

01:01:47,089 --> 01:01:45,420

excellent all right Hi I'm Evelyn I'm a

1027

01:01:48,589 --> 01:01:47,099

PhD candidate at the University of

1028

01:01:50,150 --> 01:01:48,599

Toronto and I'd like to talk about some

1029

01:01:52,609 --> 01:01:50,160

simulation work that I've been doing

1030

01:01:54,049 --> 01:01:52,619

with my collaborators they're funded by

1031

01:01:57,530 --> 01:01:54,059

answer

1032

01:01:59,829 --> 01:01:57,540

so I work on Emirates which for the

1033

01:02:03,049 --> 01:01:59,839

purposes of this talk I'm defining as

1034

01:02:05,930 --> 01:02:03,059

roughly earth-sized rocky planets in the

1035

01:02:08,390 --> 01:02:05,940

habitable zone of an M dwarf star and so

1036

01:02:09,890 --> 01:02:08,400

because because the star is small the

1037

01:02:11,930 --> 01:02:09,900

planet is close to the star so we assume

1038

01:02:14,990 --> 01:02:11,940

it's totally locked

1039

01:02:17,390 --> 01:02:15,000

um so this this diagram over here just

1040

01:02:20,930 --> 01:02:17,400

kind of shows what that looks like

1041

01:02:22,730 --> 01:02:20,940

so we have the star somewhere over here

1042

01:02:24,710 --> 01:02:22,740

um light from the Star hitting the

1043

01:02:25,849 --> 01:02:24,720

planet at the sub Starlet point which is

1044

01:02:27,170 --> 01:02:25,859

always at the same place because the

1045

01:02:30,410 --> 01:02:27,180

planet has a permanent day and night

1046

01:02:32,030 --> 01:02:30,420

side and the Terminator is kind of a

1047

01:02:33,890 --> 01:02:32,040

cool word for the divining line between

1048

01:02:35,750 --> 01:02:33,900

the day side and the night side so just

1049

01:02:37,309 --> 01:02:35,760

kind of keep that in mind I'll be using

1050

01:02:39,230 --> 01:02:37,319

some of these terms

1051  
01:02:40,970 --> 01:02:39,240  
now the base assumption is that these

1052  
01:02:44,870 --> 01:02:40,980  
planets have what we call an eyeball

1053  
01:02:46,670 --> 01:02:44,880  
climate so again we have the star here

1054  
01:02:49,309 --> 01:02:46,680  
the assumption is that the night side is

1055  
01:02:51,589 --> 01:02:49,319  
frozen and part of the day side is

1056  
01:02:53,450 --> 01:02:51,599  
unfrozen near the sub Stellar point

1057  
01:02:55,130 --> 01:02:53,460  
where it receives the most radiation and

1058  
01:02:57,470 --> 01:02:55,140  
you would assume that's a circle this is

1059  
01:03:00,650 --> 01:02:57,480  
actually an oversimplification but it's

1060  
01:03:02,030 --> 01:03:00,660  
kind of a good starting point

1061  
01:03:04,490 --> 01:03:02,040  
so

1062  
01:03:06,109 --> 01:03:04,500  
I have a few questions that I'd like to

1063  
01:03:07,910 --> 01:03:06,119

be trying to answer today

1064

01:03:10,490 --> 01:03:07,920

first of all how does Lan configuration

1065

01:03:11,690 --> 01:03:10,500

affect Emirates climates how does the

1066

01:03:14,450 --> 01:03:11,700

mass of the atmosphere affect their

1067

01:03:16,849 --> 01:03:14,460

climates I'll be answering those using a

1068

01:03:20,569 --> 01:03:16,859

3D GCM General circulation model called

1069

01:03:22,010 --> 01:03:20,579

exoplasm and then the next part is can

1070

01:03:24,109 --> 01:03:22,020

we tell these climates apart and

1071

01:03:26,930 --> 01:03:24,119

observations I'll be using a radiative

1072

01:03:30,770 --> 01:03:26,940

transfer model based on my exoplasm

1073

01:03:35,210 --> 01:03:33,289

so to start I'd like to talk about land

1074

01:03:37,609 --> 01:03:35,220

configuration

1075

01:03:39,710 --> 01:03:37,619

and so if the recall the eyeball climate

1076

01:03:43,190 --> 01:03:39,720

we kind of have a cartoon of this here

1077

01:03:46,190 --> 01:03:43,200

the idea is what happens if we put land

1078

01:03:48,349 --> 01:03:46,200

in that warm deglaciated region because

1079

01:03:49,490 --> 01:03:48,359

that's the region that's probably the

1080

01:03:52,190 --> 01:03:49,500

most interesting

1081

01:03:52,970 --> 01:03:52,200

but what's going on in the surface there

1082

01:03:59,510 --> 01:03:52,980

um

1083

01:04:01,430 --> 01:03:59,520

so I've done this in a systematic way

1084

01:04:04,250 --> 01:04:01,440

as I'm showing over here

1085

01:04:06,710 --> 01:04:04,260

basically we have two opposite continent

1086

01:04:08,329 --> 01:04:06,720

configurations where either all of the

1087

01:04:10,130 --> 01:04:08,339

land is in a circle at the substellar

1088

01:04:13,069 --> 01:04:10,140

point so that's the substellar continent

1089

01:04:16,490 --> 01:04:13,079

over here with ocean everywhere else and

1090

01:04:18,829 --> 01:04:16,500

if if the ocean is cold there's ice

1091

01:04:21,289 --> 01:04:18,839

instead of open water and then the

1092

01:04:23,270 --> 01:04:21,299

opposite sub Cellar ocean putting land

1093

01:04:26,930 --> 01:04:23,280

everywhere except for a circle at the

1094

01:04:29,150 --> 01:04:26,940

substellar point where there's water

1095

01:04:31,490 --> 01:04:29,160

we vary the size of the circle in all of

1096

01:04:32,390 --> 01:04:31,500

these simulations going from zero to 100

1097

01:04:34,250 --> 01:04:32,400

percent

1098

01:04:49,789 --> 01:04:34,260

so

1099

01:04:51,829 --> 01:04:49,799

when we run the climate model with these

1100

01:04:54,710 --> 01:04:51,839

there's a lot going on here so let's

1101

01:04:56,150 --> 01:04:54,720

let's just take it slowly on the on the

1102

01:04:59,990 --> 01:04:56,160

left here we have substellar continent

1103

01:05:03,130 --> 01:05:00,000

models with different land fractions

1104

01:05:05,210 --> 01:05:03,140

so this First Column is the land map

1105

01:05:06,710 --> 01:05:05,220

just looking straight down at the center

1106

01:05:08,750 --> 01:05:06,720

of the day side with the night side not

1107

01:05:10,430 --> 01:05:08,760

shown

1108

01:05:13,069 --> 01:05:10,440

and the second column here shows the

1109

01:05:15,589 --> 01:05:13,079

precipitation and evaporation so red is

1110

01:05:18,349 --> 01:05:15,599

evaporation blue is precipitation you'll

1111

01:05:19,970 --> 01:05:18,359

notice it always rains at the substellar

1112

01:05:22,010 --> 01:05:19,980

point and water evaporates from the

1113

01:05:24,289 --> 01:05:22,020

ocean everywhere else on the day side

1114

01:05:26,510 --> 01:05:24,299

and this is true for these ones these

1115

01:05:28,609 --> 01:05:26,520

substellar Ocean Models as well you get

1116

01:05:30,130 --> 01:05:28,619

clouds and precipitation in the middle

1117

01:05:32,690 --> 01:05:30,140

of the day side and over ocean

1118

01:05:36,230 --> 01:05:32,700

regardless of where the land is

1119

01:05:38,450 --> 01:05:36,240

so the water comes toward the center of

1120

01:05:40,910 --> 01:05:38,460

the planet where it's warmest Rises it

1121

01:05:43,190 --> 01:05:40,920

condenses out and you get rain

1122

01:05:48,349 --> 01:05:43,200

so

1123

01:05:50,750 --> 01:05:48,359

temperatures depending on how much land

1124

01:05:53,089 --> 01:05:50,760

there is with high land fraction planets

1125

01:05:54,829 --> 01:05:53,099

having hot and dry day sides which is

1126

01:05:56,030 --> 01:05:54,839

what's shown in this column here so

1127

01:05:57,950 --> 01:05:56,040

these are some pretty significant

1128

01:05:59,930 --> 01:05:57,960

climate differences

1129

01:06:02,390 --> 01:05:59,940

um

1130

01:06:04,549 --> 01:06:02,400

like on a spatially resolved level

1131

01:06:06,470 --> 01:06:04,559

this is what this looks like globally

1132

01:06:09,410 --> 01:06:06,480

on the x-axis we have dayside land

1133

01:06:12,349 --> 01:06:09,420

fraction so the size of of the circle

1134

01:06:14,329 --> 01:06:12,359

for these two landmap types and on the

1135

01:06:16,250 --> 01:06:14,339

y-axis we have temperature on the left

1136

01:06:16,970 --> 01:06:16,260

and water vapor on the right

1137

01:06:18,710 --> 01:06:16,980

um

1138

01:06:20,930 --> 01:06:18,720

you'll notice that there's the largest

1139

01:06:22,370 --> 01:06:20,940

discrepancy between the two partial

1140

01:06:23,510 --> 01:06:22,380

dayside land cover

1141

01:06:26,210 --> 01:06:23,520

so

1142

01:06:27,829 --> 01:06:26,220

when it when it's not an aquaplanet or a

1143

01:06:29,809 --> 01:06:27,839

land Planet somewhere in between it

1144

01:06:31,970 --> 01:06:29,819

really matters a lot where the land is

1145

01:06:33,829 --> 01:06:31,980

because that influences the amount of

1146

01:06:35,329 --> 01:06:33,839

ice-free ocean that's available on the

1147

01:06:37,250 --> 01:06:35,339

planet for evaporation and putting

1148

01:06:39,410 --> 01:06:37,260

moisture into the atmosphere and these

1149

01:06:40,609 --> 01:06:39,420

curves kind of follow each other

1150

01:06:42,589 --> 01:06:40,619

so

1151

01:06:45,710 --> 01:06:42,599

this is already a climate uncertainty

1152

01:06:46,970 --> 01:06:45,720

that we need to kind of think about

1153

01:06:49,010 --> 01:06:46,980

um

1154

01:06:51,349 --> 01:06:49,020

now let's make it more complicated by

1155

01:06:52,609 --> 01:06:51,359

changing another parameter the mass of

1156

01:06:54,470 --> 01:06:52,619

the atmosphere so like land

1157

01:06:55,849 --> 01:06:54,480

configuration that's not necessarily

1158

01:06:56,809 --> 01:06:55,859

something we can know about a planet in

1159

01:06:59,990 --> 01:06:56,819

advance

1160

01:07:01,549 --> 01:07:00,000

so I varied it in my simulations the

1161

01:07:03,289 --> 01:07:01,559

idea is

1162

01:07:04,609 --> 01:07:03,299

basically make the atmosphere thicker or

1163

01:07:05,569 --> 01:07:04,619

smaller that's what I've tried to show

1164

01:07:07,370 --> 01:07:05,579

over here

1165

01:07:10,190 --> 01:07:07,380

and

1166

01:07:12,370 --> 01:07:10,200

these are the same curves that were on

1167

01:07:15,230 --> 01:07:12,380

the previous slide but this time

1168

01:07:17,809 --> 01:07:15,240

for a range of pressures

1169

01:07:19,190 --> 01:07:17,819

so increasing the amount of N<sub>2</sub> in the

1170

01:07:19,849 --> 01:07:19,200

atmosphere

1171

01:07:21,770 --> 01:07:19,859

um

1172

01:07:23,630 --> 01:07:21,780

and again you get

1173

01:07:25,490 --> 01:07:23,640

the same land fraction and land

1174

01:07:27,589 --> 01:07:25,500

configuration dependence

1175

01:07:29,510 --> 01:07:27,599

but in addition to that the curves are

1176

01:07:32,630 --> 01:07:29,520

shifted up or down depending on the

1177

01:07:35,930 --> 01:07:32,640

pressure so they overlap it's very

1178

01:07:37,490 --> 01:07:35,940

confusing we

1179

01:07:39,349 --> 01:07:37,500

like there's clearly some climate

1180

01:07:42,589 --> 01:07:39,359

effects here that need to be paid

1181

01:07:44,630 --> 01:07:42,599

attention to and so then the next thing

1182

01:07:46,190 --> 01:07:44,640

we want to know is can we ever know this

1183

01:07:47,809 --> 01:07:46,200

stuff can we tell these apart in

1184

01:07:49,910 --> 01:07:47,819

observations

1185

01:07:52,370 --> 01:07:49,920

so the way these planets will be

1186

01:07:56,029 --> 01:07:52,380

observed is with Transit spectroscopy

1187

01:07:58,430 --> 01:07:56,039

which is what jwst will do

1188

01:07:59,930 --> 01:07:58,440

um I have a kind of image of what that

1189

01:08:01,970 --> 01:07:59,940

looks like basically when the planet

1190

01:08:04,010 --> 01:08:01,980

passes between the Observer and the star

1191

01:08:06,770 --> 01:08:04,020

it blocks out some of the Stars light

1192

01:08:08,510 --> 01:08:06,780

which is measurable and there's a

1193

01:08:10,430 --> 01:08:08,520

wavelength dependent contribution to the

1194

01:08:12,410 --> 01:08:10,440

amount of light blocked depending on the

1195

01:08:14,150 --> 01:08:12,420

molecules in the atmosphere and where

1196

01:08:17,150 --> 01:08:14,160

they scatter and absorb

1197

01:08:18,829 --> 01:08:17,160

So based on what wavelengths block the

1198

01:08:20,570 --> 01:08:18,839

most light we can tell what's in the

1199

01:08:22,789 --> 01:08:20,580

atmosphere this is really hard to do for

1200

01:08:24,169 --> 01:08:22,799

small planets but this is like the

1201

01:08:25,430 --> 01:08:24,179

theory of it

1202

01:08:27,110 --> 01:08:25,440

so

1203

01:08:29,390 --> 01:08:27,120

the question then because most of the

1204

01:08:31,010 --> 01:08:29,400

water if you'll recall was at the sub

1205

01:08:33,530 --> 01:08:31,020

Stellar point is how much water is

1206

01:08:35,150 --> 01:08:33,540

making it to the Terminator because the

1207

01:08:36,890 --> 01:08:35,160

Terminator

1208

01:08:39,410 --> 01:08:36,900

um sorry

1209

01:08:40,789 --> 01:08:39,420

the the Terminator is where

1210

01:08:42,050 --> 01:08:40,799

like we're getting actually the photons

1211

01:08:43,370 --> 01:08:42,060

from we can't directly image the

1212

01:08:48,050 --> 01:08:43,380

substellar point so we're getting the

1213

01:08:53,030 --> 01:08:51,349

so I have some profiles here of specific

1214

01:08:55,189 --> 01:08:53,040

humidity for the two different types of

1215

01:08:56,329 --> 01:08:55,199

land map this is just all at the same

1216

01:09:01,010 --> 01:08:56,339

pressure

1217

01:09:03,890 --> 01:09:01,020

upward in the atmosphere on the y-axis

1218

01:09:06,410 --> 01:09:03,900

and specific humidity on the x-axis

1219

01:09:08,630 --> 01:09:06,420

for near the substellar point and near

1220

01:09:10,849 --> 01:09:08,640

the Terminator so looking

1221

01:09:13,490 --> 01:09:10,859

her relationship between

1222

01:09:15,950 --> 01:09:13,500

the amount of water in the Rainy Zone

1223

01:09:18,050 --> 01:09:15,960

and the amount of water we can see

1224

01:09:19,370 --> 01:09:18,060

um subcellular Ocean Models

1225

01:09:21,050 --> 01:09:19,380

all look pretty much the same which

1226

01:09:23,090 --> 01:09:21,060

makes sense there's water there

1227

01:09:25,249 --> 01:09:23,100

there's a bit less at the Terminator but

1228

01:09:26,689 --> 01:09:25,259

it's still there for the substellar

1229

01:09:29,329 --> 01:09:26,699

continent models the ones with a lot of

1230

01:09:31,130 --> 01:09:29,339

land have much less water at the

1231

01:09:33,650 --> 01:09:31,140

Terminator but still some

1232

01:09:35,630 --> 01:09:33,660

so maybe we can tell the difference

1233

01:09:38,329 --> 01:09:35,640

so now I've I'd like to show some

1234

01:09:41,630 --> 01:09:38,339

synthetic Transit Spectra I've made

1235

01:09:44,150 --> 01:09:41,640

using only water so I've ignored all

1236

01:09:46,849 --> 01:09:44,160

other possible things that could

1237

01:09:49,490 --> 01:09:46,859

contribute to this so on the x-axis we

1238

01:09:52,189 --> 01:09:49,500

have wavelength that the instrument is

1239

01:09:54,830 --> 01:09:52,199

observing at and on the y-axis we have

1240

01:09:57,890 --> 01:09:54,840

what I've defined as amplitude so

1241

01:10:00,229 --> 01:09:57,900

basically the difference between the

1242

01:10:03,229 --> 01:10:00,239

transit depth that you get so the amount

1243

01:10:05,390 --> 01:10:03,239

of light block from the star and the the

1244

01:10:08,150 --> 01:10:05,400

minimum amount so either the amount just

1245

01:10:10,970 --> 01:10:08,160

by the rocky planet itself or the lowest

1246

01:10:12,530 --> 01:10:10,980

cloud deck or the lowest part that that

1247

01:10:14,330 --> 01:10:12,540

would be visible

1248

01:10:16,310 --> 01:10:14,340

because it's really this difference that

1249

01:10:18,530 --> 01:10:16,320

we're looking to measure more so than

1250

01:10:20,750 --> 01:10:18,540

the actual size of the planet itself so

1251

01:10:24,050 --> 01:10:20,760

these are just for a few selected

1252

01:10:27,229 --> 01:10:24,060

simulations from my parameter space

1253

01:10:28,070 --> 01:10:27,239

and so varying only the land and the

1254

01:10:30,350 --> 01:10:28,080

pressure

1255

01:10:32,810 --> 01:10:30,360

we get quite a sizable difference in

1256

01:10:34,070 --> 01:10:32,820

these water vapor spectral features

1257

01:10:36,169 --> 01:10:34,080

so these could

1258

01:10:39,229 --> 01:10:36,179

these are kind of a range of what a

1259

01:10:41,090 --> 01:10:39,239

specific Planet might produce

1260

01:10:43,250 --> 01:10:41,100

um then on the bottom we have the Cloudy

1261

01:10:44,689 --> 01:10:43,260

version so these same ones but with

1262

01:10:47,090 --> 01:10:44,699

clouds included in the radiative

1263

01:10:48,950 --> 01:10:47,100

transfer and

1264

01:10:51,110 --> 01:10:48,960

you'll notice that the features are

1265

01:10:53,890 --> 01:10:51,120

smaller but also they're not all

1266

01:10:56,750 --> 01:10:53,900

affected the same way depending on

1267

01:10:59,450 --> 01:10:56,760

where like how many how many clouds are

1268

01:11:02,030 --> 01:10:59,460

at the Terminator which varies depending

1269

01:11:03,830 --> 01:11:02,040

on different factors so it's a bit

1270

01:11:06,530 --> 01:11:03,840

confusing

1271

01:11:11,390 --> 01:11:08,870

I'd like to just focus on on this

1272

01:11:14,209 --> 01:11:11,400

feature though so

1273

01:11:19,430 --> 01:11:14,219

I'd like to show like basically the top

1274

01:11:21,470 --> 01:11:19,440

of this feature for a variety of models

1275

01:11:23,390 --> 01:11:21,480

and that's what this looks like on the

1276

01:11:27,530 --> 01:11:23,400

left we have the cloud free version on

1277

01:11:31,250 --> 01:11:29,510

again these curves kind of follow the

1278

01:11:33,290 --> 01:11:31,260

same shape as the temperature and water

1279

01:11:34,850 --> 01:11:33,300

vapor from a few slides ago

1280

01:11:38,530 --> 01:11:34,860

but

1281

01:11:42,169 --> 01:11:38,540

when you add clouds it gets a lot worse

1282

01:11:43,729 --> 01:11:42,179

unfortunately basically

1283

01:11:46,130 --> 01:11:43,739

there's there's like some correlations

1284

01:11:49,189 --> 01:11:46,140

in a cloud-free version these high

1285

01:11:51,110 --> 01:11:49,199

pressure low land models have much

1286

01:11:53,330 --> 01:11:51,120

taller spectral features so you might be

1287

01:11:54,709 --> 01:11:53,340

able to detect that or tell the

1288

01:11:57,110 --> 01:11:54,719

difference but then when we add clouds

1289

01:11:58,970 --> 01:11:57,120

what happens is that these Waters these

1290

01:12:02,209 --> 01:11:58,980

models with the most water vapor are

1291

01:12:03,830 --> 01:12:02,219

also the cloudiest of the Terminator and

1292

01:12:05,270 --> 01:12:03,840

consequently

1293

01:12:10,070 --> 01:12:05,280

the

1294

01:12:12,290 --> 01:12:10,080

spectrum is much higher so

1295

01:12:14,450 --> 01:12:12,300

like that it gets like artificially

1296

01:12:17,390 --> 01:12:14,460

subdued so it looks like these dry

1297

01:12:19,370 --> 01:12:17,400

models over here have the most water but

1298

01:12:21,050 --> 01:12:19,380

that's not actually true

1299

01:12:22,250 --> 01:12:21,060

so observing this

1300

01:12:23,810 --> 01:12:22,260

it's going to be very hard to tell

1301  
01:12:24,950 --> 01:12:23,820  
what's going on on the surface of the

1302  
01:12:28,970 --> 01:12:24,960  
planet

1303  
01:12:33,410 --> 01:12:31,550  
try to end on a happy note

1304  
01:12:36,050 --> 01:12:33,420  
um there's a huge range of climates here

1305  
01:12:37,970 --> 01:12:36,060  
we can't necessarily tell them apart but

1306  
01:12:40,070 --> 01:12:37,980  
a lot of them could be habitable and we

1307  
01:12:41,090 --> 01:12:40,080  
might be able to detect water in some of

1308  
01:12:42,890 --> 01:12:41,100  
them

1309  
01:12:44,630 --> 01:12:42,900  
so

1310  
01:12:47,450 --> 01:12:44,640  
like I'm still like cautiously

1311  
01:12:50,330 --> 01:12:47,460  
optimistic I guess but

1312  
01:12:51,649 --> 01:12:50,340  
it's it's more important I think to

1313  
01:12:54,410 --> 01:12:51,659

account for the fact that there are

1314

01:12:55,729 --> 01:12:54,420

these unknowns instead of just trying to

1315

01:12:58,010 --> 01:12:55,739

make assumptions about what's going on

1316

01:12:59,930 --> 01:12:58,020

on the surface of the planet based on

1317

01:13:01,970 --> 01:12:59,940

its Transit Spectrum

1318

01:13:04,100 --> 01:13:01,980

I'll stop here and I'm happy to take any

1319

01:13:18,830 --> 01:13:04,110

questions

1320

01:13:22,970 --> 01:13:20,870

hi uh great talk

1321

01:13:25,010 --> 01:13:22,980

um really interesting stuff so I'm

1322

01:13:28,250 --> 01:13:25,020

wondering about you have these simulated

1323

01:13:31,610 --> 01:13:28,260

Transit Spectra I'm

1324

01:13:34,490 --> 01:13:31,620

and it looks a little uh pessimistic

1325

01:13:36,530 --> 01:13:34,500

based on how close those lines are but

1326

01:13:39,830 --> 01:13:36,540

JWST has been delivering some

1327

01:13:42,950 --> 01:13:39,840

exquisitely Precision precise Spectra so

1328

01:13:45,110 --> 01:13:42,960

I'm wondering if you have plans to model

1329

01:13:46,970 --> 01:13:45,120

like the noise properties and stuff and

1330

01:13:48,770 --> 01:13:46,980

it like actually simulate JWST

1331

01:13:50,090 --> 01:13:48,780

observations of these kind of things to

1332

01:13:52,370 --> 01:13:50,100

see if you can actually distinguish

1333

01:13:54,649 --> 01:13:52,380

maybe a few things because the trans

1334

01:13:56,390 --> 01:13:54,659

inspector are so precise

1335

01:13:57,590 --> 01:13:56,400

um because of this incredible instrument

1336

01:13:59,209 --> 01:13:57,600

that we have

1337

01:14:00,950 --> 01:13:59,219

yeah it would be good to add some

1338

01:14:03,590 --> 01:14:00,960

instrumental noise to them it's also

1339

01:14:05,209 --> 01:14:03,600

really hard to do that accurately

1340

01:14:07,250 --> 01:14:05,219

um there's like

1341

01:14:09,290 --> 01:14:07,260

it's it's harder to get precise Spectra

1342

01:14:11,390 --> 01:14:09,300

for these smaller stars like most of

1343

01:14:13,490 --> 01:14:11,400

what's been coming so far is or sorry

1344

01:14:16,729 --> 01:14:13,500

smaller planets bigger bigger planets

1345

01:14:18,410 --> 01:14:16,739

are easier to get like good data from

1346

01:14:20,689 --> 01:14:18,420

but yeah there's

1347

01:14:22,610 --> 01:14:20,699

um there's more Photon noise in the far

1348

01:14:24,169 --> 01:14:22,620

or mid infrared compared to the near

1349

01:14:25,910 --> 01:14:24,179

infrared so I think it'd be good to

1350

01:14:28,310 --> 01:14:25,920

focus on that but

1351

01:14:30,050 --> 01:14:28,320

yeah it would be

1352

01:14:31,850 --> 01:14:30,060

like it might be possible to tell some

1353

01:14:32,990 --> 01:14:31,860

of them apart but it would be a good

1354

01:14:38,209 --> 01:14:33,000

thing to look into thanks for the

1355

01:14:42,950 --> 01:14:41,330

Taylor plattner at Georgia Tech great

1356

01:14:44,450 --> 01:14:42,960

talk also just wanted to say all the

1357

01:14:45,590 --> 01:14:44,460

other talks were very interesting this

1358

01:14:47,510 --> 01:14:45,600

morning

1359

01:14:49,310 --> 01:14:47,520

um and it's super cool I used to do

1360

01:14:51,590 --> 01:14:49,320

exoplanet stuff when I was in undergrad

1361

01:14:53,570 --> 01:14:51,600

so you're taking me back to I guess my

1362

01:14:57,410 --> 01:14:53,580

old days sounds like I'm an old person

1363

01:14:59,390 --> 01:14:57,420

um but uh I had a question on you know I

1364

01:15:01,669 --> 01:14:59,400

know you're doing simulations but are

1365

01:15:06,709 --> 01:15:01,679

you going to eventually like

1366

01:15:08,570 --> 01:15:06,719

look at specific planets and if so do

1367

01:15:11,030 --> 01:15:08,580

you have like a I don't know there's

1368

01:15:13,130 --> 01:15:11,040

kind of like I used to do this like uh

1369

01:15:15,290 --> 01:15:13,140

development like a prototype instrument

1370

01:15:17,330 --> 01:15:15,300

to put on ground-based telescope to like

1371

01:15:18,290 --> 01:15:17,340

vet out interesting planets so I didn't

1372

01:15:21,350 --> 01:15:18,300

know if you

1373

01:15:23,209 --> 01:15:21,360

had like a I don't know anything to like

1374

01:15:25,310 --> 01:15:23,219

vet out interesting planets to you like

1375

01:15:26,930 --> 01:15:25,320

with jwst or with any other like

1376

01:15:28,310 --> 01:15:26,940

telescope

1377

01:15:30,709 --> 01:15:28,320

um sorry if that's a terrible question

1378

01:15:33,649 --> 01:15:30,719

but just curious no it's an interesting

1379

01:15:35,330 --> 01:15:33,659

point I'm not an observer I'm mostly

1380

01:15:38,930 --> 01:15:35,340

just waiting excitedly for other people

1381

01:15:40,310 --> 01:15:38,940

to get data and like I would say the one

1382

01:15:43,550 --> 01:15:40,320

I'm most excited about is probably

1383

01:15:45,350 --> 01:15:43,560

Trappist 20 but excited and apprehensive

1384

01:15:46,910 --> 01:15:45,360

at the same time because it'll be really

1385

01:15:49,850 --> 01:15:46,920

sad if they don't find an atmosphere on

1386

01:15:52,130 --> 01:15:49,860

it but yeah ground ground-based

1387

01:15:54,229 --> 01:15:52,140

observations would be like another

1388

01:15:55,430 --> 01:15:54,239

good way to to look at these planets

1389

01:15:59,750 --> 01:15:55,440

because you can get such a bigger

1390

01:16:01,970 --> 01:15:59,760

telescope okay it is with jwst how often

1391

01:16:03,169 --> 01:16:01,980

is it like looking at like if you had

1392

01:16:05,450 --> 01:16:03,179

some planner that you're really

1393

01:16:07,790 --> 01:16:05,460

interested in how often it is it like

1394

01:16:09,590 --> 01:16:07,800

looking at that planet or would you like

1395

01:16:11,330 --> 01:16:09,600

I don't know I know Tess was another one

1396

01:16:13,310 --> 01:16:11,340

that people like were really excited

1397

01:16:16,430 --> 01:16:13,320

about so I didn't know if that was

1398

01:16:19,669 --> 01:16:16,440

easier to like get

1399

01:16:21,169 --> 01:16:19,679

data like to see that same Planet more

1400

01:16:24,470 --> 01:16:21,179

and I know yeah like you were saying

1401

01:16:27,110 --> 01:16:24,480

it's not as great everybody loves JW wst

1402

01:16:29,990 --> 01:16:27,120

for a reason yeah well Tess is a planet

1403

01:16:31,729 --> 01:16:30,000

finder so it it's found a bunch of

1404

01:16:34,550 --> 01:16:31,739

candidates

1405

01:16:36,649 --> 01:16:34,560

um so like anything that starts with toi

1406

01:16:38,209 --> 01:16:36,659

I mean tests object of interest is what

1407

01:16:40,490 --> 01:16:38,219

they're called

1408

01:16:42,290 --> 01:16:40,500

um and then jwst is kind of needed or

1409

01:16:43,310 --> 01:16:42,300

that's like some large telescope is

1410

01:16:44,810 --> 01:16:43,320

needed for follow-up to actually

1411

01:16:46,550 --> 01:16:44,820

characterize their atmospheres because

1412

01:16:48,770 --> 01:16:46,560

it's much easier to find the planets

1413

01:16:51,350 --> 01:16:48,780

than to see what's in their atmospheres

1414

01:16:53,390 --> 01:16:51,360

especially with such thin ones

1415

01:16:55,310 --> 01:16:53,400

did that answer the question

1416

01:16:58,370 --> 01:16:55,320

yeah yeah

1417

01:17:03,709 --> 01:16:58,380

good talk thank you thank you so much

1418

01:17:08,209 --> 01:17:06,530

all right that was also super I'm pretty

1419

01:17:10,669 --> 01:17:08,219

far removed from this exoplanet stuff

1420

01:17:12,229 --> 01:17:10,679

because this is sick so um I I have a

1421

01:17:13,729 --> 01:17:12,239

question that I apologize for my

1422

01:17:15,410 --> 01:17:13,739

inability to ask a more specific

1423

01:17:18,530 --> 01:17:15,420

question about your work that's just a

1424

01:17:20,930 --> 01:17:18,540

lack of my understanding but um I'm

1425

01:17:23,930 --> 01:17:20,940

curious that they were talking about how

1426

01:17:27,050 --> 01:17:23,940

like this Exquisite Precision with jwst

1427

01:17:29,930 --> 01:17:27,060

and and all this stuff and so is how far

1428

01:17:32,450 --> 01:17:29,940

off well I'll preface by by saying

1429

01:17:34,070 --> 01:17:32,460

um the past couple of decades as I'm

1430

01:17:35,570 --> 01:17:34,080

sure you're aware our understanding of

1431

01:17:38,270 --> 01:17:35,580

planetary habitability has really

1432

01:17:39,770 --> 01:17:38,280

shifted with the uh our increased

1433

01:17:41,750 --> 01:17:39,780

understanding of these icy moons in our

1434

01:17:46,970 --> 01:17:41,760

solar system and things like that

1435

01:17:47,590 --> 01:17:46,980

um how far off is our ability to examine

1436

01:17:50,570 --> 01:17:47,600

um

1437

01:17:52,910 --> 01:17:50,580

moons of exoplanets given like a small

1438

01:17:54,890 --> 01:17:52,920

enough star or something like that or is

1439

01:17:56,810 --> 01:17:54,900

that just like so far off from reality

1440

01:17:59,770 --> 01:17:56,820

given their technological abilities at

1441

01:18:02,450 --> 01:17:59,780

the moment I would say it's it's far off

1442

01:18:03,950 --> 01:18:02,460

unfortunate like yeah the problem is

1443

01:18:05,450 --> 01:18:03,960

that you have to like detect the planet

1444

01:18:08,090 --> 01:18:05,460

and then the moon going around the

1445

01:18:09,890 --> 01:18:08,100

planet and it's they're just really hard

1446

01:18:10,910 --> 01:18:09,900

to find and they'll be even harder to

1447

01:18:12,410 --> 01:18:10,920

observe

1448

01:18:15,050 --> 01:18:12,420

which is unfortunate because I bet

1449

01:18:16,850 --> 01:18:15,060

xomoons are really cool

1450

01:18:18,110 --> 01:18:16,860

and that would also deal with the tidal

1451

01:18:23,090 --> 01:18:18,120

locking problem

1452

01:18:25,250 --> 01:18:23,100

like like if an axumun was orbiting

1453

01:18:27,350 --> 01:18:25,260

tidally locked Planet the moon will not

1454

01:18:28,729 --> 01:18:27,360

be tidally locked to the star so it

1455

01:18:31,130 --> 01:18:28,739

could have day night cycles but they're

1456

01:18:32,930 --> 01:18:31,140

just really hard to observe

1457

01:18:34,729 --> 01:18:32,940

yeah thanks for that that would be

1458

01:18:36,290 --> 01:18:34,739

really cool

1459

01:18:37,080 --> 01:18:36,300

thank you for the talk everything well

1460

01:18:44,570 --> 01:18:37,090

thank you

1461

01:18:46,790 --> 01:18:44,580

[Applause]

1462

01:18:54,649 --> 01:18:46,800

okay our next speaker is Zachary Fred

1463

01:18:54,659 --> 01:18:59,450

thank you

1464

01:19:04,610 --> 01:19:02,149

hello can everyone hear me

1465

01:19:06,169 --> 01:19:04,620

so my name's Zach and I'm really excited

1466

01:19:08,930 --> 01:19:06,179

today to present on some of the work

1467

01:19:11,390 --> 01:19:08,940

I've done so far during my PhD which is

1468

01:19:12,770 --> 01:19:11,400

mostly looking into machine learning of

1469

01:19:14,750 --> 01:19:12,780

the chemical inventory and rare

1470

01:19:20,149 --> 01:19:14,760

isotopologues of the protostellar source

1471

01:19:22,130 --> 01:19:20,159

IRAs excuse me 16293 2422b

1472

01:19:24,590 --> 01:19:22,140

so first of all Let me give just a very

1473

01:19:26,689 --> 01:19:24,600

high level overview of what supervised

1474

01:19:29,930 --> 01:19:26,699

machine learning for regression is so

1475

01:19:32,870 --> 01:19:29,940

the overall goal in this process is to

1476

01:19:35,270 --> 01:19:32,880

learn a set of model parameters that can

1477

01:19:37,610 --> 01:19:35,280

be best used to map some input features

1478

01:19:40,130 --> 01:19:37,620

some X values to some relevant

1479

01:19:42,550 --> 01:19:40,140

properties some y values just the

1480

01:19:45,050 --> 01:19:42,560

simplest and oversimplified possible

1481

01:19:46,490 --> 01:19:45,060

example of this process is just 2D

1482

01:19:49,610 --> 01:19:46,500

linear regressions something that could

1483

01:19:51,350 --> 01:19:49,620

be modeled by  $y$  equals  $MX$  plus  $b$  and

1484

01:19:54,050 --> 01:19:51,360

what you do in this process is you

1485

01:19:57,530 --> 01:19:54,060

provide the model with training data in

1486

01:19:59,930 --> 01:19:57,540

the form of X Y Pairs and what it does

1487

01:20:02,149 --> 01:19:59,940

is it learns the model parameters in

1488

01:20:04,550 --> 01:20:02,159

this case the m and the B that can best

1489

01:20:06,890 --> 01:20:04,560

map those inputs to those outputs in a

1490

01:20:09,410 --> 01:20:06,900

way that minimizes some sort of loss

1491

01:20:11,030 --> 01:20:09,420

function and while this is a very

1492

01:20:13,370 --> 01:20:11,040

oversimplified view of this whole

1493

01:20:15,350 --> 01:20:13,380

approach it can also be very effective

1494

01:20:17,990 --> 01:20:15,360

for high dimensional inputs and also

1495

01:20:20,090 --> 01:20:18,000

include very complex non-linear models

1496

01:20:21,770 --> 01:20:20,100

as well so

1497

01:20:25,130 --> 01:20:21,780

now getting into the problem that I'm

1498

01:20:26,689 --> 01:20:25,140

trying to tackle with this approach so

1499

01:20:28,970 --> 01:20:26,699

the overarching goal behind most the

1500

01:20:31,070 --> 01:20:28,980

work I've done so far is suggesting

1501

01:20:33,770 --> 01:20:31,080

likely molecular candidates for

1502

01:20:35,270 --> 01:20:33,780

detection in various regions of space so

1503

01:20:37,070 --> 01:20:35,280

let's first take a step back and ask the

1504

01:20:39,649 --> 01:20:37,080

question why do we even care about

1505

01:20:41,270 --> 01:20:39,659

Interstellar molecules so because we're

1506

01:20:42,950 --> 01:20:41,280

looking all the way out in space we're

1507

01:20:45,229 --> 01:20:42,960

not fortunate to be able to throw a

1508

01:20:46,790 --> 01:20:45,239

thermometer and a reaction Beaker easily

1509

01:20:49,430 --> 01:20:46,800

observe some sort of physical change

1510

01:20:50,990 --> 01:20:49,440

during a reaction instead in order to

1511

01:20:52,729 --> 01:20:51,000

trace the physical properties and

1512

01:20:54,770 --> 01:20:52,739

evolutionary history of interstellar

1513

01:20:57,290 --> 01:20:54,780

sources we oftentimes rely on the

1514

01:20:59,270 --> 01:20:57,300

molecules that we detect along with the

1515

01:21:02,030 --> 01:20:59,280

properties of said molecules and just a

1516

01:21:04,209 --> 01:21:02,040

couple of examples D to H ratios provide

1517

01:21:06,830 --> 01:21:04,219

information about the temperatures

1518

01:21:09,410 --> 01:21:06,840

of the environments during molecular

1519

01:21:11,810 --> 01:21:09,420

formation and the detection of sio can

1520

01:21:14,090 --> 01:21:11,820

trace things like Stellar outflows or

1521

01:21:16,189 --> 01:21:14,100

shocks so in the past

1522

01:21:17,810 --> 01:21:16,199

if we wanted to model molecular

1523

01:21:19,250 --> 01:21:17,820

abundances and use us to predict new

1524

01:21:21,530 --> 01:21:19,260

molecules for detection we relied

1525

01:21:23,390 --> 01:21:21,540

heavily on astrochemical models and

1526

01:21:25,070 --> 01:21:23,400

these as can be seen on the screen are

1527

01:21:27,410 --> 01:21:25,080

vast networks of interconnected

1528

01:21:29,630 --> 01:21:27,420

reactions each reaction having its own

1529

01:21:32,330 --> 01:21:29,640

rate constant and ultimately they can be

1530

01:21:35,450 --> 01:21:32,340

used to derive the time-dependent

1531

01:21:37,550 --> 01:21:35,460

molecular abundances of these species

1532

01:21:39,169 --> 01:21:37,560

and while these are excellent tools to

1533

01:21:40,910 --> 01:21:39,179

gauge our current understanding of the

1534

01:21:43,729 --> 01:21:40,920

specific chemical processes in space

1535

01:21:46,370 --> 01:21:43,739

there's a couple of drawbacks first of

1536

01:21:47,990 --> 01:21:46,380

all in order to add a new molecule or

1537

01:21:50,390 --> 01:21:48,000

reaction to the network we oftentimes

1538

01:21:52,030 --> 01:21:50,400

rely very heavily on chemical intuition

1539

01:21:54,709 --> 01:21:52,040

additionally the

1540

01:21:56,810 --> 01:21:54,719

rate constants that are inputted into

1541

01:21:59,510 --> 01:21:56,820

the networks are oftentimes either

1542

01:22:00,950 --> 01:21:59,520

extrapolated or approximated and the

1543

01:22:02,630 --> 01:22:00,960

uncertainty that comes along with this

1544

01:22:03,950 --> 01:22:02,640

when you propagate it through the whole

1545

01:22:06,290 --> 01:22:03,960

network can result in some very

1546

01:22:08,149 --> 01:22:06,300

uncertain or inaccurate modeled

1547

01:22:10,430 --> 01:22:08,159

abundances and finally it's just

1548

01:22:11,810 --> 01:22:10,440

difficult to include new molecules in

1549

01:22:13,729 --> 01:22:11,820

order to add a new molecule to the

1550

01:22:15,830 --> 01:22:13,739

network you have to include every single

1551  
01:22:17,330 --> 01:22:15,840  
reaction and I could create the molecule

1552  
01:22:19,070 --> 01:22:17,340  
as well as everyone that could

1553  
01:22:22,250 --> 01:22:19,080  
subsequently destroy it so that's a

1554  
01:22:24,770 --> 01:22:22,260  
difficult and often times inefficient

1555  
01:22:26,390 --> 01:22:24,780  
process so in response to these

1556  
01:22:28,370 --> 01:22:26,400  
predictive shortcomings uh previous

1557  
01:22:30,290 --> 01:22:28,380  
postdoc in our group Dr Kelvin Lee

1558  
01:22:32,030 --> 01:22:30,300  
developed a machine learning method

1559  
01:22:34,130 --> 01:22:32,040  
that's able to predict and model

1560  
01:22:36,709 --> 01:22:34,140  
molecular abundances in space without

1561  
01:22:38,450 --> 01:22:36,719  
requiring these complete networks and

1562  
01:22:40,430 --> 01:22:38,460  
instead molecular abundances are

1563  
01:22:43,430 --> 01:22:40,440

expressed purely in terms of a chemical

1564

01:22:45,950 --> 01:22:43,440

Vector space so in this process the

1565

01:22:47,990 --> 01:22:45,960

first step is you need to collect

1566

01:22:50,750 --> 01:22:48,000

telescope data toward a specific

1567

01:22:53,149 --> 01:22:50,760

Interstellar source from this line

1568

01:22:55,729 --> 01:22:53,159

survey you'll be able to decipher which

1569

01:22:58,189 --> 01:22:55,739

molecules are present along with the

1570

01:23:02,030 --> 01:22:58,199

abundances or column densities of said

1571

01:23:03,830 --> 01:23:02,040

molecules following this for any machine

1572

01:23:05,630 --> 01:23:03,840

learning application you need to

1573

01:23:07,910 --> 01:23:05,640

vectorize your input so we have to make

1574

01:23:11,090 --> 01:23:07,920

molecular feature vectors out of the

1575

01:23:13,490 --> 01:23:11,100

molecules we're detecting to do this we

1576

01:23:15,530 --> 01:23:13,500

utilize the multivac algorithm which is

1577

01:23:17,750 --> 01:23:15,540

an unsupervised algorithm that creates

1578

01:23:19,850 --> 01:23:17,760

context aware substructure Vector

1579

01:23:22,490 --> 01:23:19,860

representations that can be subsequently

1580

01:23:24,950 --> 01:23:22,500

summed to form molecular feature vectors

1581

01:23:27,590 --> 01:23:24,960

so at this point we have our molecular

1582

01:23:29,450 --> 01:23:27,600

feature vectors our inputs as well as

1583

01:23:31,430 --> 01:23:29,460

our relevant column densities our

1584

01:23:34,610 --> 01:23:31,440

outputs and what we do as mentioned

1585

01:23:36,770 --> 01:23:34,620

previously we input this into a machine

1586

01:23:39,470 --> 01:23:36,780

learning model that learns the best way

1587

01:23:41,270 --> 01:23:39,480

the model parameters to map those

1588

01:23:43,850 --> 01:23:41,280

molecular features to the relevant

1589

01:23:46,610 --> 01:23:43,860

column densities and this is just a

1590

01:23:49,430 --> 01:23:46,620

figure from the initial paper and what

1591

01:23:51,649 --> 01:23:49,440

it shows is that a very simple right

1592

01:23:53,689 --> 01:23:51,659

regularize linear regression machine

1593

01:23:56,149 --> 01:23:53,699

learning method a ridge regression model

1594

01:23:57,709 --> 01:23:56,159

is able to far out compete even the

1595

01:24:01,310 --> 01:23:57,719

state-of-the-art Gotham Nautilus

1596

01:24:04,310 --> 01:24:01,320

astrochemical model in reproducing and

1597

01:24:07,850 --> 01:24:04,320

predicting the chemical abundances in

1598

01:24:09,709 --> 01:24:07,860

the tmc-1 dark molecular cloud so while

1599

01:24:12,290 --> 01:24:09,719

kelvin's initial work was a fantastic

1600

01:24:14,149 --> 01:24:12,300

proof of concept that this method can in

1601  
01:24:16,490 --> 01:24:14,159  
fact effectively model and predict

1602  
01:24:18,530 --> 01:24:16,500  
molecular abundances in space there's a

1603  
01:24:21,350 --> 01:24:18,540  
number of things that just remain simply

1604  
01:24:23,810 --> 01:24:21,360  
untested first of all untested outside

1605  
01:24:25,910 --> 01:24:23,820  
of dark molecular cloud so the initial

1606  
01:24:27,950 --> 01:24:25,920  
work was focused on the tmc1 dark

1607  
01:24:30,709 --> 01:24:27,960  
molecular cloud chemical inventory and

1608  
01:24:33,110 --> 01:24:30,719  
this is a very cold and quiescent region

1609  
01:24:34,669 --> 01:24:33,120  
of interstellar space so we also want to

1610  
01:24:37,729 --> 01:24:34,679  
ensure that these same methods can also

1611  
01:24:39,950 --> 01:24:37,739  
apply to warmer more turbulent protostar

1612  
01:24:43,010 --> 01:24:39,960  
sources

1613  
01:24:46,790 --> 01:24:43,020

and for this we looked at the class 0

1614

01:24:48,229 --> 01:24:46,800

protostar binary IRAs 16293 B this is an

1615

01:24:50,330 --> 01:24:48,239

especially attractive Source because it

1616

01:24:51,770 --> 01:24:50,340

has a very dense molecular line survey

1617

01:24:54,290 --> 01:24:51,780

and it's been studied extensively with

1618

01:24:56,390 --> 01:24:54,300

interferometric data it's also vital

1619

01:24:58,370 --> 01:24:56,400

that we can model the abundances in both

1620

01:25:00,169 --> 01:24:58,380

these cold dark clouds and the warmer

1621

01:25:02,330 --> 01:25:00,179

protostellar sources because

1622

01:25:04,430 --> 01:25:02,340

understanding the chemical inventories

1623

01:25:05,810 --> 01:25:04,440

of these two different sources allows us

1624

01:25:08,689 --> 01:25:05,820

to investigate how the chemistry

1625

01:25:11,090 --> 01:25:08,699

actually evolves as a star is forming

1626

01:25:12,950 --> 01:25:11,100

additionally in part due to the

1627

01:25:15,470 --> 01:25:12,960

shortcomings of the multivac algorithm

1628

01:25:18,590 --> 01:25:15,480

there were initially no isotopologues

1629

01:25:22,070 --> 01:25:18,600

included in the data set however ira6

1630

01:25:24,470 --> 01:25:22,080

and 293b consistently shows very high

1631

01:25:26,090 --> 01:25:24,480

levels of isotopic substitution as a

1632

01:25:28,130 --> 01:25:26,100

result in order to fill out the data set

1633

01:25:30,470 --> 01:25:28,140

we felt the need to include these

1634

01:25:32,810 --> 01:25:30,480

molecules additionally as mentioned

1635

01:25:35,330 --> 01:25:32,820

previously isotopologues provide

1636

01:25:37,070 --> 01:25:35,340

information about the temperatures and

1637

01:25:39,110 --> 01:25:37,080

time scales of molecular formation in

1638

01:25:41,570 --> 01:25:39,120

space and therefore being able to model

1639

01:25:43,250 --> 01:25:41,580

these ratios effectively with this

1640

01:25:44,930 --> 01:25:43,260

machine learning method would provide a

1641

01:25:48,169 --> 01:25:44,940

straightforward and efficient way to

1642

01:25:50,810 --> 01:25:48,179

gain additional astrochemical insight so

1643

01:25:53,510 --> 01:25:50,820

in order to include these isotopologues

1644

01:25:55,030 --> 01:25:53,520

we added hand-picked isotope descriptors

1645

01:25:57,410 --> 01:25:55,040

at the end of our multivac

1646

01:25:59,870 --> 01:25:57,420

representations and more specifically we

1647

01:26:02,870 --> 01:25:59,880

added 19 extra Vector Dimensions that

1648

01:26:05,390 --> 01:26:02,880

denoted which specific minor isotopes

1649

01:26:07,250 --> 01:26:05,400

are substituted into the molecule along

1650

01:26:10,010 --> 01:26:07,260

with the chemical environment of said

1651

01:26:11,930 --> 01:26:10,020

isotopic substitution so just as an

1652

01:26:14,689 --> 01:26:11,940

example three of the vector Dimensions

1653

01:26:17,270 --> 01:26:14,699

denote whether the 13 carbon is sp sb2

1654

01:26:19,129 --> 01:26:17,280

or sp3 hybridized and we chose this

1655

01:26:21,649 --> 01:26:19,139

feature because as you can see it has a

1656

01:26:25,250 --> 01:26:21,659

notable impact on the mean 12C to 13c

1657

01:26:27,110 --> 01:26:25,260

ratio of the molecules in this source so

1658

01:26:28,669 --> 01:26:27,120

now getting into some results we train

1659

01:26:31,070 --> 01:26:28,679

both a gaussian process regression and

1660

01:26:32,510 --> 01:26:31,080

Bayesian Ridge regression model to map

1661

01:26:34,970 --> 01:26:32,520

the molecular features of the column

1662

01:26:37,550 --> 01:26:34,980

densities and what we're ultimately able

1663

01:26:40,910 --> 01:26:37,560

to see is that the models are able to

1664

01:26:43,370 --> 01:26:40,920

both effectively model the molecules

1665

01:26:45,709 --> 01:26:43,380

provided to it in the training set but

1666

01:26:48,770 --> 01:26:45,719

also extrapolate quite well to yet

1667

01:26:51,350 --> 01:26:48,780

unseen molecules in the testing set

1668

01:26:52,910 --> 01:26:51,360

additionally because we included isotope

1669

01:26:55,270 --> 01:26:52,920

logs in our data set we wanted to see

1670

01:26:57,530 --> 01:26:55,280

how well these models were able to

1671

01:26:59,689 --> 01:26:57,540

reproduce the column densities and

1672

01:27:02,149 --> 01:26:59,699

isotopic ratios of the molecules in the

1673

01:27:05,209 --> 01:27:02,159

source so what you can see on the top

1674

01:27:07,610 --> 01:27:05,219

row of the deuterium and  $^{13}\text{C}$  substituted

1675

01:27:09,410 --> 01:27:07,620

isotopolog the using five-fold

1676  
01:27:12,470 --> 01:27:09,420  
cross-validation the column band these

1677  
01:27:14,810 --> 01:27:12,480  
are very accurately modeled once you

1678  
01:27:16,490 --> 01:27:14,820  
extrapolate this out to actual isotopic

1679  
01:27:18,709 --> 01:27:16,500  
ratio predictions these are much more

1680  
01:27:22,370 --> 01:27:18,719  
sensitive to small changes in column

1681  
01:27:23,990 --> 01:27:22,380  
densities as a result a small error in

1682  
01:27:26,750 --> 01:27:24,000  
the column density prediction can result

1683  
01:27:29,750 --> 01:27:26,760  
in a large isotopic ratio error so the

1684  
01:27:32,450 --> 01:27:29,760  
bottom row of actual isotopic ratios is

1685  
01:27:34,970 --> 01:27:32,460  
slightly less precise however just

1686  
01:27:36,890 --> 01:27:34,980  
because of how nuanced the process of

1687  
01:27:39,229 --> 01:27:36,900  
isotopic fractionation is in space and

1688  
01:27:40,910 --> 01:27:39,239

how simple our encoding is we're very

1689

01:27:43,370 --> 01:27:40,920

encouraged by these results that we're

1690

01:27:44,870 --> 01:27:43,380

able to very accurately model the column

1691

01:27:47,330 --> 01:27:44,880

densities of these isotopically

1692

01:27:49,729 --> 01:27:47,340

substituted species

1693

01:27:51,890 --> 01:27:49,739

so as mentioned previously due to the

1694

01:27:53,390 --> 01:27:51,900

strong performance on the testing set we

1695

01:27:55,750 --> 01:27:53,400

have some sort of confidence that these

1696

01:27:59,390 --> 01:27:55,760

models can extrapolate to yet unseen

1697

01:28:01,729 --> 01:27:59,400

species and as a result we proceeded to

1698

01:28:03,770 --> 01:28:01,739

input about 90 000 astrochemically

1699

01:28:06,050 --> 01:28:03,780

relevant molecules into the train models

1700

01:28:07,910 --> 01:28:06,060

to see which undetected species are

1701

01:28:09,590 --> 01:28:07,920

likely the most abundant in this source

1702

01:28:12,350 --> 01:28:09,600

and on the bar chart on the screen you

1703

01:28:15,709 --> 01:28:12,360

can see the top 10 predicted abundance

1704

01:28:17,030 --> 01:28:15,719

molecules toward IRS 6 and 293 B and

1705

01:28:18,890 --> 01:28:17,040

there's two things to point out here

1706

01:28:21,110 --> 01:28:18,900

first of all three of these molecules

1707

01:28:22,790 --> 01:28:21,120

namely hydrogen peroxide ethane and

1708

01:28:24,490 --> 01:28:22,800

carbon dioxide have all been previously

1709

01:28:27,649 --> 01:28:24,500

detected in different regions of space

1710

01:28:29,330 --> 01:28:27,659

additionally something you may notice in

1711

01:28:32,689 --> 01:28:29,340

the bar chart is that many of these

1712

01:28:35,450 --> 01:28:32,699

molecules are very oxygenated and fairly

1713

01:28:37,910 --> 01:28:35,460

saturated hydrocarbons and this is also

1714

01:28:39,410 --> 01:28:37,920

a good sign because when looking at the

1715

01:28:41,629 --> 01:28:39,420

actual chemical inventory of these

1716

01:28:44,450 --> 01:28:41,639

sources or this specific Source sorry

1717

01:28:46,910 --> 01:28:44,460

the most abundant detected molecules are

1718

01:28:50,090 --> 01:28:46,920

also these very oxygenated hydrocarbons

1719

01:28:52,430 --> 01:28:50,100

so not only is it learning to predict

1720

01:28:54,169 --> 01:28:52,440

known Interstellar molecules but at the

1721

01:28:55,550 --> 01:28:54,179

same time it's narrowing down to the

1722

01:28:57,770 --> 01:28:55,560

correct region of chemical space

1723

01:29:00,410 --> 01:28:57,780

relevant to this source

1724

01:29:02,450 --> 01:29:00,420

so as I mentioned these 10 molecules

1725

01:29:04,490 --> 01:29:02,460

have not been previously detected in

1726

01:29:06,590 --> 01:29:04,500

this source and the reason for that in

1727

01:29:08,510 --> 01:29:06,600

many cases is just simply a lack of

1728

01:29:12,290 --> 01:29:08,520

rotational Spectra being taken in the

1729

01:29:13,910 --> 01:29:12,300

lab so now next steps is we want to take

1730

01:29:16,189 --> 01:29:13,920

that next step forward and collect the

1731

01:29:17,990 --> 01:29:16,199

rotational Spectra of some of these

1732

01:29:19,129 --> 01:29:18,000

predicted high abundance molecules that

1733

01:29:20,870 --> 01:29:19,139

they can be searched for in these

1734

01:29:22,910 --> 01:29:20,880

protestalar sources one of particular

1735

01:29:25,970 --> 01:29:22,920

interest is circled on the screen

1736

01:29:27,830 --> 01:29:25,980

methoxy ethanol and methoxyethanol is in

1737

01:29:29,810 --> 01:29:27,840

the same chemical family as both methoxy

1738

01:29:31,729 --> 01:29:29,820

methanol and methoxyethane which have

1739

01:29:34,610 --> 01:29:31,739

been detected in high abundance toward

1740

01:29:36,649 --> 01:29:34,620

IRS 16 293 B

1741

01:29:38,450 --> 01:29:36,659

but not only is this molecule chemically

1742

01:29:39,770 --> 01:29:38,460

similar to several that have been seen

1743

01:29:41,330 --> 01:29:39,780

before but we also have some sort of

1744

01:29:44,149 --> 01:29:41,340

mechanistic reason to believe it may be

1745

01:29:46,970 --> 01:29:44,159

present so methoxy methanol has been

1746

01:29:50,990 --> 01:29:46,980

shown to form via reaction of the  $\text{CH}_3\text{O}$

1747

01:29:53,590 --> 01:29:51,000

the methoxy radical with  $\text{CH}_2\text{OH}$  on grain

1748

01:29:56,390 --> 01:29:53,600

services so the high abundance of

1749

01:29:58,430 --> 01:29:56,400

methoxymethanol also suggests that in

1750

01:30:00,470 --> 01:29:58,440

the pre-stellar phase of the source that

1751

01:30:02,750 --> 01:30:00,480

the methoxy radical was highly abundant

1752

01:30:05,330 --> 01:30:02,760

on these grain services as a result it

1753

01:30:07,370 --> 01:30:05,340

could feasibly react with the other high

1754

01:30:08,930 --> 01:30:07,380

abundance organic radicals in this

1755

01:30:10,790 --> 01:30:08,940

source and we therefore believe that the

1756

01:30:12,590 --> 01:30:10,800

methoxylated versions of these high

1757

01:30:15,590 --> 01:30:12,600

abundance Organics in this Source may be

1758

01:30:17,990 --> 01:30:15,600

strong targets for astrochemical study

1759

01:30:19,729 --> 01:30:18,000

so next step is to use chirp pulse

1760

01:30:21,410 --> 01:30:19,739

Fourier transform microwave spectroscopy

1761

01:30:23,810 --> 01:30:21,420

to study the rotational spectrum of this

1762

01:30:26,330 --> 01:30:23,820

molecule subsequently use the laboratory

1763

01:30:28,490 --> 01:30:26,340

Spectrum to search for this molecule in

1764

01:30:30,790 --> 01:30:28,500

various protostellar sources and upon its

1765

01:30:35,930 --> 01:30:30,800

detection learn more about the chemistry

1766

01:30:37,610 --> 01:30:35,940

of this highly abundant maser radical

1767

01:30:39,050 --> 01:30:37,620

so that's all the work I've done so far

1768

01:30:41,390 --> 01:30:39,060

as well as what I'm working towards I'd

1769

01:30:42,830 --> 01:30:41,400

like to say a big thank you to my group

1770

01:30:43,729 --> 01:30:42,840

shown on the screen the picture on the

1771

01:30:45,470 --> 01:30:43,739

right is just in the green Bank

1772

01:30:47,750 --> 01:30:45,480

telescope which is a very cool

1773

01:30:49,430 --> 01:30:47,760

experience I definitely recommend if you

1774

01:30:51,229 --> 01:30:49,440

have the opportunity to travel there but

1775

01:30:59,450 --> 01:30:51,239

thank you for listening and I'd be happy

1776

01:31:04,550 --> 01:31:02,330

thank you Zachary so we are running a

1777

01:31:06,410 --> 01:31:04,560

little behind so I suggest we use the

1778

01:31:08,330 --> 01:31:06,420

brake and you can find sakuri entering

1779

01:31:10,490 --> 01:31:08,340

in the break room to ask questions and

1780

01:31:39,290 --> 01:31:10,500

we'll meet again at 10 30 for the icy

1781

01:31:39,300 --> 01:31:45,370

foreign

1782

01:32:48,050 --> 01:31:58,760

[Music]

1783

01:32:56,370 --> 01:32:48,060

thank you

1784

01:33:49,530 --> 01:33:22,070

[Music]

1785

01:33:54,720 --> 01:33:49,540

thank you

1786

01:33:54,730 --> 01:34:00,050

[Music]

1787

01:34:00,060 --> 01:34:03,810

foreign

1788

01:34:59,629 --> 01:34:17,200

[Music]

1789

01:34:59,639 --> 01:35:03,060

foreign

1790

01:35:03,070 --> 01:35:11,990

[Music]

1791

01:35:26,890 --> 01:35:14,370

foreign

1792

01:36:22,729 --> 01:35:44,350

[Music]

1793

01:36:22,739 --> 01:36:28,670

foreign

1794

01:37:56,350 --> 01:37:05,420

[Music]

1795

01:38:24,830 --> 01:37:57,980

thank you

1796

01:38:58,810 --> 01:38:24,840

[Music]

1797

01:39:02,020 --> 01:39:00,770

thank you

1798

01:39:19,460 --> 01:39:02,030

foreign

1799

01:39:37,390 --> 01:39:30,850

[Music]

1800

01:39:37,400 --> 01:39:40,830

thank you

1801  
01:40:08,400 --> 01:39:45,950  
[Music]

1802  
01:40:45,950 --> 01:40:08,410  
foreign

1803  
01:41:15,950 --> 01:41:01,730  
[Music]

1804  
01:41:15,960 --> 01:41:19,460  
foreign

1805  
01:41:25,810 --> 01:41:23,450  
[Music]

1806  
01:41:40,830 --> 01:41:25,820  
foreign

1807  
01:41:55,820 --> 01:41:45,940  
[Music]

1808  
01:42:15,920 --> 01:41:55,830  
foreign

1809  
01:42:15,930 --> 01:42:26,450  
[Music]

1810  
01:42:45,920 --> 01:42:28,250  
foreign

1811  
01:43:51,950 --> 01:43:19,450  
[Music]

1812  
01:43:53,070 --> 01:43:51,960  
thank you

1813  
01:44:15,970 --> 01:43:53,080

foreign

1814

01:44:19,470 --> 01:44:18,470

[Music]

1815

01:44:47,510 --> 01:44:19,480

foreign

1816

01:44:49,460 --> 01:44:47,520

[Music]

1817

01:45:15,900 --> 01:44:49,470

foreign

1818

01:46:19,480 --> 01:45:43,550

[Music]

1819

01:46:23,570 --> 01:46:19,490

foreign

1820

01:46:25,830 --> 01:46:23,580

[Music]

1821

01:46:41,660 --> 01:46:25,840

foreign

1822

01:46:55,830 --> 01:46:53,629

[Music]

1823

01:47:48,020 --> 01:46:55,840

foreign

1824

01:48:43,490 --> 01:47:57,580

[Music]

1825

01:48:56,470 --> 01:48:45,960

foreign

1826  
01:49:10,800 --> 01:48:58,690  
thank you

1827  
01:49:19,450 --> 01:49:17,330  
[Music]

1828  
01:49:31,740 --> 01:49:19,460  
foreign

1829  
01:52:09,390 --> 01:49:40,800  
[Music]

1830  
01:52:16,630 --> 01:52:09,400  
thank you

1831  
01:52:40,129 --> 01:52:31,690  
[Music]

1832  
01:52:40,139 --> 01:52:43,710  
foreign

1833  
01:53:12,890 --> 01:53:03,780  
[Music]

1834  
01:53:23,960 --> 01:53:14,650  
thank you

1835  
01:53:23,970 --> 01:53:43,450  
[Music]

1836  
01:53:51,129 --> 01:53:46,490  
our first speaker will be Sarah Miller

1837  
01:53:54,430 --> 01:53:52,280  
all right

1838  
01:53:57,350 --> 01:53:54,440

[Music]

1839

01:53:59,090 --> 01:53:57,360

thank you uh so yeah I'm Sarah Miller

1840

01:54:01,729 --> 01:53:59,100

I'm working with Professor Brittany

1841

01:54:03,890 --> 01:54:01,739

Schmidt at Cornell University and I am

1842

01:54:06,770 --> 01:54:03,900

working to build a global circulation

1843

01:54:08,510 --> 01:54:06,780

model for the ocean at Europa

1844

01:54:10,070 --> 01:54:08,520

um so before we move on I wanted to kind

1845

01:54:12,290 --> 01:54:10,080

of point out the cover image I chose

1846

01:54:13,790 --> 01:54:12,300

which is primarily because I thought the

1847

01:54:16,370 --> 01:54:13,800

colors made for a pretty PowerPoint

1848

01:54:18,770 --> 01:54:16,380

theme and secondarily because it shows

1849

01:54:20,870 --> 01:54:18,780

some interesting kind of structures that

1850

01:54:22,490 --> 01:54:20,880

exist on the ice crust on Europa so as

1851  
01:54:24,890 --> 01:54:22,500  
you can see it's not a smooth ice

1852  
01:54:27,770 --> 01:54:24,900  
skating rink it's a very interesting and

1853  
01:54:30,050 --> 01:54:27,780  
geologically active Zone which hints

1854  
01:54:31,490 --> 01:54:30,060  
that probably the interior is a dynamic

1855  
01:54:33,830 --> 01:54:31,500  
and very interesting place to study

1856  
01:54:36,470 --> 01:54:33,840  
which is what I'm going to talk about

1857  
01:54:38,149 --> 01:54:36,480  
next before I dive into the science I do

1858  
01:54:39,590 --> 01:54:38,159  
want to take a moment to thank my team

1859  
01:54:41,870 --> 01:54:39,600  
and kind of the people who have helped

1860  
01:54:43,430 --> 01:54:41,880  
me bring my understanding

1861  
01:54:44,750 --> 01:54:43,440  
um in this field up so I have a

1862  
01:54:46,370 --> 01:54:44,760  
background in fluid dynamics and

1863  
01:54:47,629 --> 01:54:46,380

aerospace engineering which I'll talk a

1864

01:54:49,129 --> 01:54:47,639

little bit about throughout this talk

1865

01:54:51,410 --> 01:54:49,139

but these people have been really

1866

01:54:53,209 --> 01:54:51,420

instrumental in kind of working with me

1867

01:54:56,209 --> 01:54:53,219

on the planetary aspect as well as my

1868

01:54:58,129 --> 01:54:56,219

funding sources through an NSF grfp and

1869

01:55:00,350 --> 01:54:58,139

a NASA finest and an Amelia Earhart

1870

01:55:01,729 --> 01:55:00,360

fellowship and some wonderful people who

1871

01:55:04,250 --> 01:55:01,739

support this work

1872

01:55:05,930 --> 01:55:04,260

okay so as I mentioned uh Europa has a

1873

01:55:09,950 --> 01:55:05,940

very interesting surface and it hints

1874

01:55:12,050 --> 01:55:09,960

that there is a dynamic ocean interior

1875

01:55:13,910 --> 01:55:12,060

and I think that the ocean circulation

1876  
01:55:15,709 --> 01:55:13,920  
the physical oceanography piece of this

1877  
01:55:17,390 --> 01:55:15,719  
puzzle is a really interesting one in

1878  
01:55:18,950 --> 01:55:17,400  
terms of habitability because when we

1879  
01:55:20,870 --> 01:55:18,960  
look at Earth's ocean

1880  
01:55:22,970 --> 01:55:20,880  
um the transport of heat and salt and

1881  
01:55:24,890 --> 01:55:22,980  
nutrients throughout the ocean column is

1882  
01:55:25,850 --> 01:55:24,900  
really what sustains our biosphere so I

1883  
01:55:27,410 --> 01:55:25,860  
think it has really interesting

1884  
01:55:30,410 --> 01:55:27,420  
habitability implications on other

1885  
01:55:31,970 --> 01:55:30,420  
planets as well and specifically I want

1886  
01:55:35,090 --> 01:55:31,980  
to narrow this down even further the

1887  
01:55:37,609 --> 01:55:35,100  
region of our ocean that separates the

1888  
01:55:40,250 --> 01:55:37,619

glacial glacially covered parts of our

1889

01:55:42,169 --> 01:55:40,260

ocean from the liquid layer that ice

1890

01:55:44,330 --> 01:55:42,179

ocean boundary layer is really

1891

01:55:46,609 --> 01:55:44,340

instrumental in setting far-field ocean

1892

01:55:47,990 --> 01:55:46,619

properties so that tiny boundary layer

1893

01:55:50,570 --> 01:55:48,000

region between the ice and the ocean

1894

01:55:52,910 --> 01:55:50,580

actually has an outsized effect on

1895

01:55:55,609 --> 01:55:52,920

affecting Global Mass Water mass

1896

01:55:57,950 --> 01:55:55,619

transport and so I think that's very

1897

01:56:00,350 --> 01:55:57,960

much worthy of intense study in the

1898

01:56:02,390 --> 01:56:00,360

modeling realm for Europa

1899

01:56:04,490 --> 01:56:02,400

so I'm not the first person to attempt

1900

01:56:05,750 --> 01:56:04,500

to build a global circulation model for

1901

01:56:07,490 --> 01:56:05,760

Europa

1902

01:56:10,669 --> 01:56:07,500

um but the the state of the field is

1903

01:56:12,410 --> 01:56:10,679

really kind of Divergent so um models of

1904

01:56:14,930 --> 01:56:12,420

Europa generally fall into one of two

1905

01:56:16,550 --> 01:56:14,940

categories depending on kind of how you

1906

01:56:18,609 --> 01:56:16,560

set your boundary conditions and really

1907

01:56:21,229 --> 01:56:18,619

how you set up this ice ocean interface

1908

01:56:22,850 --> 01:56:21,239

mathematically so usually there's kind

1909

01:56:26,030 --> 01:56:22,860

of an outsized effect of either the

1910

01:56:27,709 --> 01:56:26,040

rotation driven or buoyancy driven so

1911

01:56:30,890 --> 01:56:27,719

kind of temperature salinity gradients

1912

01:56:33,530 --> 01:56:30,900

in the model and the results are very

1913

01:56:35,149 --> 01:56:33,540

different so Global circulation models

1914

01:56:36,649 --> 01:56:35,159

exist they usually fall into one of

1915

01:56:38,870 --> 01:56:36,659

these two categories and they do not

1916

01:56:40,430 --> 01:56:38,880

agree with each other now if we look at

1917

01:56:42,470 --> 01:56:40,440

terrestrial Ocean Models on the other

1918

01:56:43,609 --> 01:56:42,480

hand they look very different and that's

1919

01:56:46,250 --> 01:56:43,619

because they've had a lot more

1920

01:56:49,490 --> 01:56:46,260

scientific Manpower in years of study

1921

01:56:52,430 --> 01:56:49,500

and actual data so how nice for them so

1922

01:56:54,169 --> 01:56:52,440

their models are very sophisticated

1923

01:56:55,850 --> 01:56:54,179

compared to what we see in planetary

1924

01:56:57,770 --> 01:56:55,860

Ocean Models

1925

01:56:59,090 --> 01:56:57,780

that being said there are still kind of

1926

01:57:01,729 --> 01:56:59,100

parts of Earth's ocean that we don't

1927

01:57:03,530 --> 01:57:01,739

understand so it's very much ocean

1928

01:57:05,450 --> 01:57:03,540

modeling is an active area of research

1929

01:57:07,129 --> 01:57:05,460

and there's still some mechanisms that

1930

01:57:09,050 --> 01:57:07,139

remain poorly constrained which is

1931

01:57:11,510 --> 01:57:09,060

really humbling to think about doing

1932

01:57:14,510 --> 01:57:11,520

this on a body that we have zero data

1933

01:57:17,209 --> 01:57:14,520

for and know a lot less about

1934

01:57:18,470 --> 01:57:17,219

but I'm going to try anyway

1935

01:57:20,089 --> 01:57:18,480

um so let me introduce you to the tool

1936

01:57:23,169 --> 01:57:20,099

that I'm using so I'm using the MIT

1937

01:57:26,709 --> 01:57:23,179

General circulation model so it's a 3D

1938

01:57:29,089 --> 01:57:26,719

circulation model that employs the full

1939

01:57:30,830 --> 01:57:29,099

non-hydrostatic incompressible navier

1940

01:57:32,570 --> 01:57:30,840

Stokes equations

1941

01:57:34,910 --> 01:57:32,580

it also has some really interesting and

1942

01:57:36,649 --> 01:57:34,920

very useful packages for Europa so an

1943

01:57:37,250 --> 01:57:36,659

ice shelf package

1944

01:57:39,290 --> 01:57:37,260

um

1945

01:57:41,510 --> 01:57:39,300

a deep convection package which is

1946

01:57:43,609 --> 01:57:41,520

really helpful because Europa unlike

1947

01:57:46,430 --> 01:57:43,619

Earth has a really deep ocean compared

1948

01:57:47,629 --> 01:57:46,440

to its planetary radius and that is

1949

01:57:50,570 --> 01:57:47,639

important when you're talking about

1950

01:57:52,310 --> 01:57:50,580

large scale flow features so I won't

1951

01:57:55,070 --> 01:57:52,320

kind of dive into the nitty-gritty it's

1952

01:57:57,350 --> 01:57:55,080

written in Fortran so if you're a

1953

01:57:59,450 --> 01:57:57,360

modeler you're probably just cringed uh

1954

01:58:01,729 --> 01:57:59,460

but yeah it's a it's a very powerful

1955

01:58:03,290 --> 01:58:01,739

very useful tool

1956

01:58:05,209 --> 01:58:03,300

so there's lots of knobs that you can

1957

01:58:06,890 --> 01:58:05,219

turn within this model and I'm working

1958

01:58:08,689 --> 01:58:06,900

on turning kind of all of these through

1959

01:58:10,609 --> 01:58:08,699

sensitivity studies throughout my PhD

1960

01:58:13,010 --> 01:58:10,619

but what I want to focus on in this talk

1961

01:58:15,410 --> 01:58:13,020

is the role of topography underneath the

1962

01:58:17,750 --> 01:58:15,420

ice shelf so in this case I'm talking

1963

01:58:19,910 --> 01:58:17,760

about both the small scale topography so

1964

01:58:22,310 --> 01:58:19,920

surfiness roughness surface roughness of

1965

01:58:25,370 --> 01:58:22,320

the ice which affects things like

1966

01:58:28,250 --> 01:58:25,380

turbulence in the boundary layer as well

1967

01:58:30,530 --> 01:58:28,260

as large scale features on the ice that

1968

01:58:32,030 --> 01:58:30,540

can form large scale flow features now

1969

01:58:34,310 --> 01:58:32,040

you might be thinking like why would a

1970

01:58:35,870 --> 01:58:34,320

turbulent boundary layer affect global

1971

01:58:39,169 --> 01:58:35,880

ocean circulation

1972

01:58:41,570 --> 01:58:39,179

and specifically habitability for this

1973

01:58:43,430 --> 01:58:41,580

interest and I want you to remember that

1974

01:58:46,490 --> 01:58:43,440

the ocean time scales operate a lot

1975

01:58:48,229 --> 01:58:46,500

faster than planetary time scales and

1976

01:58:50,629 --> 01:58:48,239

that could be an important link for a

1977

01:58:52,550 --> 01:58:50,639

habitability argument

1978

01:58:54,530 --> 01:58:52,560

so a quick review of kind of boundary

1979

01:58:56,030 --> 01:58:54,540

layer of physics

1980

01:58:57,410 --> 01:58:56,040

um I took out the full equations because

1981

01:58:59,649 --> 01:58:57,420

they're pretty ugly and I just have

1982

01:59:02,270 --> 01:58:59,659

these like nice kind of simplified

1983

01:59:04,089 --> 01:59:02,280

relationships that I want to discuss

1984

01:59:05,810 --> 01:59:04,099

um so I'm using kind of a widely adopted

1985

01:59:08,030 --> 01:59:05,820

parameterization called the three

1986

01:59:10,490 --> 01:59:08,040

equation parameterization it's very

1987

01:59:12,410 --> 01:59:10,500

creatively named and essentially it's

1988

01:59:15,589 --> 01:59:12,420

just looking at this fluxes those are

1989

01:59:19,010 --> 01:59:15,599

those Q values between a solid ice shelf

1990

01:59:21,589 --> 01:59:19,020

which is fresh water or fresh ice a

1991

01:59:23,870 --> 01:59:21,599

mixed boundary layer region and then the

1992

01:59:25,490 --> 01:59:23,880

mixed layer the liquid ocean

1993

01:59:27,470 --> 01:59:25,500

so we're looking at kind of the three

1994

01:59:28,790 --> 01:59:27,480

unknowns in these equations are the

1995

01:59:31,910 --> 01:59:28,800

temperature and salinity of the boundary

1996

01:59:33,530 --> 01:59:31,920

layer as well as a melt rate or MDOT

1997

01:59:36,530 --> 01:59:33,540

which is negative if it's melting

1998

01:59:38,570 --> 01:59:36,540

positive if it's freezing and that's

1999

01:59:41,990 --> 01:59:38,580

kind of how we're constraining the phase

2000

01:59:44,510 --> 01:59:42,000

change that's happening at this region

2001

01:59:47,030 --> 01:59:44,520

so I'm using a model that's um

2002

01:59:51,229 --> 01:59:47,040

kind of an ongoing International effort

2003

01:59:54,109 --> 01:59:51,239

within the MIT GCM Community to uh

2004

01:59:56,149 --> 01:59:54,119

model this kind of physics

2005

01:59:58,550 --> 01:59:56,159

um for Earth's ocean and so this is a

2006

02:00:00,589 --> 01:59:58,560

simplified version of that map so it's a

2007

02:00:02,570 --> 02:00:00,599

two equation parameterization that's

2008

02:00:05,330 --> 02:00:02,580

assuming the salinity of the boundary

2009

02:00:07,189 --> 02:00:05,340

layer and the mixed layer is the same

2010

02:00:09,169 --> 02:00:07,199

um current research and kind of more

2011

02:00:11,089 --> 02:00:09,179

recent results since submitting this

2012

02:00:12,830 --> 02:00:11,099

abstract I've been able to like use the

2013

02:00:15,350 --> 02:00:12,840

three equation parameterization but

2014

02:00:17,570 --> 02:00:15,360

those graphs are still pretty ugly so

2015

02:00:18,890 --> 02:00:17,580

maybe next at gradcon

2016

02:00:20,810 --> 02:00:18,900

um

2017

02:00:22,609 --> 02:00:20,820

yeah and kind of one other thing that's

2018

02:00:25,070 --> 02:00:22,619

very common on Earth but not a great

2019

02:00:28,330 --> 02:00:25,080

approximation for Europa is that often

2020

02:00:31,010 --> 02:00:28,340

in Ocean Models the pressure dependence

2021

02:00:33,109 --> 02:00:31,020

of density is approximated by depth

2022

02:00:35,689 --> 02:00:33,119

dependence I mentioned that europa's

2023

02:00:37,070 --> 02:00:35,699

ocean is a lot deeper than Earth's so

2024

02:00:38,330 --> 02:00:37,080

this is something that I've removed as

2025

02:00:41,750 --> 02:00:38,340

well because I think

2026

02:00:44,089 --> 02:00:41,760

no longer holds for europa's ocean

2027

02:00:46,669 --> 02:00:44,099

um so I mentioned it's probably not like

2028

02:00:47,870 --> 02:00:46,679

a flat ice skating rink under europa's

2029

02:00:49,609 --> 02:00:47,880

eye shell we don't know what it looks

2030

02:00:51,050 --> 02:00:49,619

like but it's probably not that

2031

02:00:52,669 --> 02:00:51,060

beautiful and simple

2032

02:00:54,410 --> 02:00:52,679

um it's probably not this beautiful and

2033

02:00:56,390 --> 02:00:54,420

simple either but to start with to kind

2034

02:00:57,589 --> 02:00:56,400

of demonstrate some of the flow features

2035

02:00:59,629 --> 02:00:57,599

that might develop with ice shelf

2036

02:01:03,109 --> 02:00:59,639

topography here's like a very simple

2037

02:01:05,530 --> 02:01:03,119

ramp that I'm introducing so it's not a

2038

02:01:08,390 --> 02:01:05,540

global model quite yet it's just a

2039

02:01:09,350 --> 02:01:08,400

rectangular domain starting at a fixed

2040

02:01:10,910 --> 02:01:09,360

initial

2041

02:01:11,570 --> 02:01:10,920

temperature

2042

02:01:13,910 --> 02:01:11,580

um

2043

02:01:17,089 --> 02:01:13,920

and we're going to introduce a heat

2044

02:01:19,850 --> 02:01:17,099

gradient and a flow through ice melting

2045

02:01:21,890 --> 02:01:19,860

and see what develops

2046

02:01:24,229 --> 02:01:21,900

so we're seeing some already just with

2047

02:01:26,089 --> 02:01:24,239

very simple geometry interesting and

2048

02:01:28,070 --> 02:01:26,099

kind of recognizable flow features so we

2049

02:01:29,510 --> 02:01:28,080

see the development of what looks kind

2050

02:01:31,550 --> 02:01:29,520

of like a western boundary current on

2051  
02:01:33,290 --> 02:01:31,560  
the left and an ocean gyre on the right

2052  
02:01:36,589 --> 02:01:33,300  
and these are happening because there is

2053  
02:01:37,970 --> 02:01:36,599  
melting happening at depth so if you

2054  
02:01:39,589 --> 02:01:37,980  
remember the phase diagram of water

2055  
02:01:42,410 --> 02:01:39,599  
there is a pressure dependence on the

2056  
02:01:44,149 --> 02:01:42,420  
melting point of ice and so we see

2057  
02:01:46,550 --> 02:01:44,159  
melting happening on the bottom of this

2058  
02:01:49,490 --> 02:01:46,560  
ramp and then as the fresh waters Rising

2059  
02:01:51,169 --> 02:01:49,500  
along the Melt water the ramp it's

2060  
02:01:54,770 --> 02:01:51,179  
circulating and that's creating a

2061  
02:01:57,290 --> 02:01:54,780  
circular flow feature this dryer

2062  
02:01:59,510 --> 02:01:57,300  
so we have on the left these are just

2063  
02:02:01,550 --> 02:01:59,520

stream functions the barotropic stream

2064

02:02:03,290 --> 02:02:01,560

function and then the right and

2065

02:02:04,970 --> 02:02:03,300

overturning stream function just in a

2066

02:02:07,370 --> 02:02:04,980

couple different directions

2067

02:02:09,770 --> 02:02:07,380

so maybe more importantly uh

2068

02:02:11,450 --> 02:02:09,780

the Melt rate what's happening so we're

2069

02:02:13,550 --> 02:02:11,460

seeing both regions of melting and

2070

02:02:14,990 --> 02:02:13,560

freezing The Contours got a little dense

2071

02:02:16,910 --> 02:02:15,000

for the melting so I just kind of

2072

02:02:20,209 --> 02:02:16,920

outlined that where that's happening

2073

02:02:22,310 --> 02:02:20,219

there but that's happening um kind of as

2074

02:02:25,729 --> 02:02:22,320

the warmer Ocean mixed layer water is

2075

02:02:28,129 --> 02:02:25,739

interacting with this Frozen ramp

2076

02:02:30,350 --> 02:02:28,139

and so we see that kind of

2077

02:02:32,030 --> 02:02:30,360

um already just very simple geometry

2078

02:02:33,950 --> 02:02:32,040

there's lots of Dynamics happening

2079

02:02:35,689 --> 02:02:33,960

there's freezing there's melting there's

2080

02:02:36,530 --> 02:02:35,699

flow features

2081

02:02:39,770 --> 02:02:36,540

um

2082

02:02:41,570 --> 02:02:39,780

but this is probably not very realistic

2083

02:02:44,450 --> 02:02:41,580

maybe more realistic is something like

2084

02:02:47,510 --> 02:02:44,460

this so

2085

02:02:48,109 --> 02:02:47,520

this is a almost Global

2086

02:02:50,750 --> 02:02:48,119

um

2087

02:02:52,910 --> 02:02:50,760

topography that I stole from what

2088

02:02:54,410 --> 02:02:52,920

Earth's ice shelves look like I could

2089

02:02:56,629 --> 02:02:54,420

have the poles because of convergence

2090

02:02:58,669 --> 02:02:56,639

issues and it's a pretty coarse

2091

02:03:00,290 --> 02:02:58,679

resolution but it still captures a lot

2092

02:03:03,109 --> 02:03:00,300

of the large-scale flow features that we

2093

02:03:05,450 --> 02:03:03,119

see on Earth as well as some turbulence

2094

02:03:09,229 --> 02:03:05,460

and mixing events effects from small

2095

02:03:10,669 --> 02:03:09,239

scale features that are missing and so

2096

02:03:12,770 --> 02:03:10,679

I think it's really important to think

2097

02:03:13,550 --> 02:03:12,780

that like when you're modeling

2098

02:03:16,070 --> 02:03:13,560

um

2099

02:03:18,830 --> 02:03:16,080

heat transfer like your grid resolution

2100

02:03:21,290 --> 02:03:18,840

is really important so the size of your

2101  
02:03:23,149 --> 02:03:21,300  
grid cell in your model affects kind of

2102  
02:03:25,070 --> 02:03:23,159  
how quickly heat is transferred through

2103  
02:03:26,750 --> 02:03:25,080  
your ocean and so this is really too

2104  
02:03:27,530 --> 02:03:26,760  
course to understand

2105  
02:03:29,270 --> 02:03:27,540  
um

2106  
02:03:32,270 --> 02:03:29,280  
what's happening in turbulence and

2107  
02:03:33,830 --> 02:03:32,280  
Boundary layer effects so I'm

2108  
02:03:36,050 --> 02:03:33,840  
kind of

2109  
02:03:39,169 --> 02:03:36,060  
accommodating that in the model by

2110  
02:03:41,689 --> 02:03:39,179  
modifying the MIT GCM to have like

2111  
02:03:43,310 --> 02:03:41,699  
spatial grid remeshing so I'm slicing up

2112  
02:03:45,290 --> 02:03:43,320  
the grid cells

2113  
02:03:47,209 --> 02:03:45,300

so that I can have melting and freezing

2114

02:03:48,770 --> 02:03:47,219

happening within a single model run

2115

02:03:50,050 --> 02:03:48,780

which is not kind of the standard

2116

02:03:52,669 --> 02:03:50,060

configuration

2117

02:03:54,530 --> 02:03:52,679

within the boundary layer so this has

2118

02:03:55,729 --> 02:03:54,540

been kind of very helpful in

2119

02:03:56,510 --> 02:03:55,739

understanding

2120

02:03:58,729 --> 02:03:56,520

um

2121

02:04:03,410 --> 02:03:58,739

turbulence and more quick time scale

2122

02:04:06,709 --> 02:04:05,270

now this is kind of one of several

2123

02:04:08,870 --> 02:04:06,719

things that needs to happen to have a

2124

02:04:10,729 --> 02:04:08,880

more realistic ice shells like greater

2125

02:04:11,930 --> 02:04:10,739

spatial grid density in the boundary

2126

02:04:12,589 --> 02:04:11,940

layer

2127

02:04:14,990 --> 02:04:12,599

um

2128

02:04:17,089 --> 02:04:15,000

there's also but even so you know it's

2129

02:04:17,750 --> 02:04:17,099

not going to be a simple ramp

2130

02:04:19,669 --> 02:04:17,760

um

2131

02:04:21,830 --> 02:04:19,679

there's other things to introduce like

2132

02:04:23,629 --> 02:04:21,840

salt different heat and salt transfer

2133

02:04:25,129 --> 02:04:23,639

coefficients

2134

02:04:26,930 --> 02:04:25,139

um

2135

02:04:29,030 --> 02:04:26,940

a mushy layer there's interesting work

2136

02:04:30,649 --> 02:04:29,040

that's being done by this on this by

2137

02:04:31,850 --> 02:04:30,659

Jacob buffo if you want to look at his

2138

02:04:32,450 --> 02:04:31,860

work

2139

02:04:34,669 --> 02:04:32,460

um

2140

02:04:36,109 --> 02:04:34,679

so in my model currently the ice is

2141

02:04:38,689 --> 02:04:36,119

assumed as a completely fresh water

2142

02:04:41,209 --> 02:04:38,699

layer that's probably not the case there

2143

02:04:44,750 --> 02:04:41,219

might be zones of brines and interesting

2144

02:04:48,410 --> 02:04:44,760

kind of pockets of heterogeneities that

2145

02:04:50,209 --> 02:04:48,420

will affect these processes but this is

2146

02:04:52,910 --> 02:04:50,219

kind of all just taking steps to like

2147

02:04:55,310 --> 02:04:52,920

introduce more realistic features into

2148

02:04:57,649 --> 02:04:55,320

an ice shell model and then look at the

2149

02:04:59,689 --> 02:04:57,659

global circulation effects of those

2150

02:05:01,430 --> 02:04:59,699

features

2151

02:05:04,189 --> 02:05:01,440

so kind of to kind of wrap up this

2152

02:05:05,990 --> 02:05:04,199

little bit that I've discussed um

2153

02:05:08,350 --> 02:05:06,000

terrestrial models I think can be very

2154

02:05:10,970 --> 02:05:08,360

valuable in the planetary Community

2155

02:05:12,169 --> 02:05:10,980

within those models specifically I think

2156

02:05:14,149 --> 02:05:12,179

there still needs to be a lot of work

2157

02:05:16,310 --> 02:05:14,159

done on the ice ocean boundary layer

2158

02:05:18,050 --> 02:05:16,320

which is what I've been focusing on this

2159

02:05:19,970 --> 02:05:18,060

past year of my PhD

2160

02:05:22,689 --> 02:05:19,980

and the potential impacts for

2161

02:05:25,189 --> 02:05:22,699

habitability of this kind of great

2162

02:05:27,290 --> 02:05:25,199

resolution on an ISO student boundary

2163

02:05:30,109 --> 02:05:27,300

layer could be very important for

2164

02:05:32,970 --> 02:05:31,729

all right and I'm happy to take

2165

02:05:44,089 --> 02:05:32,980

questions

2166

02:05:51,709 --> 02:05:48,890

so if you are assuming uh so with the

2167

02:05:55,010 --> 02:05:51,719

mushy layer you know like a slurry for

2168

02:05:58,550 --> 02:05:55,020

instance is the Assumption of uh

2169

02:06:01,430 --> 02:05:58,560

incompressible fluid still valid and

2170

02:06:04,129 --> 02:06:01,440

does that change that makes never Stokes

2171

02:06:07,189 --> 02:06:04,139

much more complicated right so how would

2172

02:06:09,350 --> 02:06:07,199

that really affect the your modeling

2173

02:06:12,109 --> 02:06:09,360

would you have to change some things or

2174

02:06:15,169 --> 02:06:12,119

yeah no that's a really good question so

2175

02:06:17,390 --> 02:06:15,179

um realistically yes you would change uh

2176  
02:06:19,550 --> 02:06:17,400  
the kind of forcing equations so the

2177  
02:06:21,050 --> 02:06:19,560  
model as it currently runs it assumes

2178  
02:06:22,609 --> 02:06:21,060  
that um

2179  
02:06:24,169 --> 02:06:22,619  
kind of backing up a little bit the

2180  
02:06:25,790 --> 02:06:24,179  
equation of state of seawater is a

2181  
02:06:27,910 --> 02:06:25,800  
linear function of salinity so if you

2182  
02:06:30,350 --> 02:06:27,920  
introduce something like a brine

2183  
02:06:32,510 --> 02:06:30,360  
it's removing that kind of linear

2184  
02:06:34,430 --> 02:06:32,520  
assumption that said like the model as

2185  
02:06:36,050 --> 02:06:34,440  
it currently stands it does have a solid

2186  
02:06:38,689 --> 02:06:36,060  
ice layer so it doesn't look at brine

2187  
02:06:41,570 --> 02:06:38,699  
Pockets or mushy layers yet

2188  
02:06:44,390 --> 02:06:41,580

um if you wanted to do that I do think

2189

02:06:46,729 --> 02:06:44,400

that yeah you'd need to change the

2190

02:06:49,070 --> 02:06:46,739

equation of State at seawater locally

2191

02:06:51,589 --> 02:06:49,080

yeah to accommodate those and what about

2192

02:06:53,450 --> 02:06:51,599

the incompressibility assumption

2193

02:06:55,129 --> 02:06:53,460

I think that's a small enough one where

2194

02:06:57,350 --> 02:06:55,139

if you're looking at the effects on

2195

02:06:58,490 --> 02:06:57,360

overturning in flow it wouldn't have an

2196

02:07:00,229 --> 02:06:58,500

effect but it would be a very cool

2197

02:07:09,109 --> 02:07:00,239

sensitivity study so it's a good

2198

02:07:14,689 --> 02:07:12,589

sorry a really ignorant question so

2199

02:07:16,370 --> 02:07:14,699

Europa it seems like there's a

2200

02:07:20,450 --> 02:07:16,380

very kind of noticeable temperature

2201

02:07:22,970 --> 02:07:20,460

gradient is that just due to pressure

2202

02:07:26,149 --> 02:07:22,980

like what's the middle of Europa oh

2203

02:07:28,490 --> 02:07:26,159

interesting question okay I think I have

2204

02:07:30,649 --> 02:07:28,500

um a backup slide that might help

2205

02:07:33,290 --> 02:07:30,659

so yeah so the mechanisms that are kind

2206

02:07:35,089 --> 02:07:33,300

of important for Europa Heating and

2207

02:07:37,729 --> 02:07:35,099

what's sustaining the ocean are like

2208

02:07:39,350 --> 02:07:37,739

tidal heating that it have bottom

2209

02:07:42,410 --> 02:07:39,360

heating from residual heat of formation

2210

02:07:44,089 --> 02:07:42,420

internal heat if there is this Dynamic

2211

02:07:46,550 --> 02:07:44,099

eye shell that's freezing and melting

2212

02:07:49,189 --> 02:07:46,560

like I think it is then you have heat

2213

02:07:49,850 --> 02:07:49,199

fluxes from freezing and melting

2214

02:07:52,070 --> 02:07:49,860

um

2215

02:07:53,870 --> 02:07:52,080

yeah so there's a lot going on

2216

02:07:56,270 --> 02:07:53,880

um the kind of Weights of these effects

2217

02:07:57,350 --> 02:07:56,280

is still very much unknown and so that's

2218

02:07:59,990 --> 02:07:57,360

why I'm really trying to use

2219

02:08:01,850 --> 02:08:00,000

observations from Earth so for instance

2220

02:08:03,709 --> 02:08:01,860

I'm using like turbulent turbulent

2221

02:08:05,750 --> 02:08:03,719

transfer coefficients of freezing and

2222

02:08:08,450 --> 02:08:05,760

melting from Antarctic field studies to

2223

02:08:10,129 --> 02:08:08,460

kind of influence this model but yeah

2224

02:08:12,109 --> 02:08:10,139

it's really like there's a lot going on

2225

02:08:13,370 --> 02:08:12,119

so it's really kind of the challenge is

2226

02:08:14,930 --> 02:08:13,380

trying to figure out which one is

2227

02:08:17,990 --> 02:08:14,940

driving

2228

02:08:22,250 --> 02:08:18,000

um yeah the thermal gradient

2229

02:08:22,260 --> 02:08:30,530

yeah we have time for one more question

2230

02:08:33,950 --> 02:08:32,689

Taylor planner at Georgia Tech great

2231

02:08:35,990 --> 02:08:33,960

talk Sarah

2232

02:08:38,530 --> 02:08:36,000

um you were talking about Brian Pockets

2233

02:08:41,990 --> 02:08:38,540

to like make it the model more realistic

2234

02:08:45,109 --> 02:08:42,000

did you have do you plan on doing that

2235

02:08:47,390 --> 02:08:45,119

with your model and have they done it on

2236

02:08:49,970 --> 02:08:47,400

earth like with like Earth models have

2237

02:08:51,709 --> 02:08:49,980

they even thought of like incorporating

2238

02:08:53,510 --> 02:08:51,719

bride pockets

2239

02:08:55,370 --> 02:08:53,520

yeah it's a good question so the answer

2240

02:08:57,109 --> 02:08:55,380

is like no most

2241

02:08:59,870 --> 02:08:57,119

um like

2242

02:09:01,970 --> 02:08:59,880

glacial models and Earth Global ocean

2243

02:09:03,649 --> 02:09:01,980

circulation models don't include brine

2244

02:09:05,870 --> 02:09:03,659

Pockets because on Earth those are more

2245

02:09:08,689 --> 02:09:05,880

seen in like Lake environments or kind

2246

02:09:10,189 --> 02:09:08,699

of like the like hyper saline lakes and

2247

02:09:11,930 --> 02:09:10,199

Flash bows and lakes that like Jacob

2248

02:09:14,149 --> 02:09:11,940

works on um

2249

02:09:15,530 --> 02:09:14,159

they might Europe as a yeah different

2250

02:09:16,250 --> 02:09:15,540

conditions though

2251

02:09:18,290 --> 02:09:16,260

um

2252

02:09:20,990 --> 02:09:18,300

and so they could exist there so at most

2253

02:09:22,910 --> 02:09:21,000

I think I would do a like a case study

2254

02:09:24,589 --> 02:09:22,920

on what would happen if Brian pocket

2255

02:09:25,910 --> 02:09:24,599

Pockets exist so it's something I'm

2256

02:09:27,290 --> 02:09:25,920

working on now

2257

02:09:28,910 --> 02:09:27,300

um but it's not something I'd include in

2258

02:09:31,430 --> 02:09:28,920

every run because it's just still very

2259

02:09:32,570 --> 02:09:31,440

much an unknown yeah I was going to say

2260

02:09:34,669 --> 02:09:32,580

that was kind of like a loaded question

2261

02:09:38,689 --> 02:09:34,679

but I was curious no it's a good

2262

02:09:49,850 --> 02:09:40,850

thank you so much for the toxic thank

2263

02:09:59,030 --> 02:09:52,550

okay our next speaker is Sam nesraldine

2264

02:10:02,870 --> 02:10:01,129

hello

2265

02:10:06,050 --> 02:10:02,880

pleasure to be here

2266

02:10:08,390 --> 02:10:06,060

uh so I'm in the program in Applied

2267

02:10:10,250 --> 02:10:08,400

Mathematics at the University of Arizona

2268

02:10:13,669 --> 02:10:10,260

um but I work with Professor Regis

2269

02:10:16,550 --> 02:10:13,679

farrier who's an ecologist and uh

2270

02:10:19,370 --> 02:10:16,560

postdoc antenna affolder who is also an

2271

02:10:22,669 --> 02:10:19,380

ecologist and a planetary scientist

2272

02:10:25,129 --> 02:10:22,679

um so we developed these Global models

2273

02:10:27,830 --> 02:10:25,139

of Europa and so what you see right here

2274

02:10:29,689 --> 02:10:27,840

is the Euro Europa Clipper Mission which

2275

02:10:32,209 --> 02:10:29,699

is going to launch next year in October

2276

02:10:35,930 --> 02:10:32,219

hopefully and I believe it's the largest

2277

02:10:37,729 --> 02:10:35,940

in terms of size spacecraft that NASA's

2278

02:10:39,470 --> 02:10:37,739

ever built because of those massive

2279

02:10:41,330 --> 02:10:39,480

solar panels

2280

02:10:45,350 --> 02:10:41,340

um because we're when we're five times

2281

02:10:47,750 --> 02:10:45,360

away from the Sun at Jupiter I think the

2282

02:10:54,530 --> 02:10:47,760

brightness scales like inverse Square

2283

02:11:00,350 --> 02:10:57,290

so why do we care about Europa

2284

02:11:02,510 --> 02:11:00,360

so beneath the ice crust we have an

2285

02:11:04,550 --> 02:11:02,520

ocean which potentially contains two to

2286

02:11:07,370 --> 02:11:04,560

three times the amount of water as on

2287

02:11:09,709 --> 02:11:07,380

Earth which is when I first discovered

2288

02:11:11,089 --> 02:11:09,719

that fact I was just so blown away by

2289

02:11:13,250 --> 02:11:11,099

that

2290

02:11:16,370 --> 02:11:13,260

um and we have an energy source from

2291

02:11:18,589 --> 02:11:16,380

tidal heating namely we may have

2292

02:11:21,050 --> 02:11:18,599

hydrothermal venting as a result of that

2293

02:11:23,570 --> 02:11:21,060

we saw that on Enceladus because we saw

2294

02:11:25,250 --> 02:11:23,580

silicates in the plumes we haven't

2295

02:11:27,770 --> 02:11:25,260

confirmed that yet in Europa but it's

2296

02:11:30,229 --> 02:11:27,780

very likely based on the amount of tidal

2297

02:11:32,950 --> 02:11:30,239

energy that we expect

2298

02:11:36,830 --> 02:11:32,960

um and we also have a rock ocean

2299

02:11:38,570 --> 02:11:36,840

interface so that's very essential for

2300

02:11:39,470 --> 02:11:38,580

you know cycling chemicals needed for

2301

02:11:42,410 --> 02:11:39,480

life

2302

02:11:44,390 --> 02:11:42,420

uh and we have a lot of convection as

2303

02:11:46,669 --> 02:11:44,400

Sarah talked about

2304

02:11:49,850 --> 02:11:46,679

um which is very essential also for

2305

02:11:54,649 --> 02:11:52,850

so as a result we need these models to

2306

02:11:57,410 --> 02:11:54,659

constrain what we're going to see from

2307

02:11:59,570 --> 02:11:57,420

the mission so we had juice also the esa

2308

02:12:00,470 --> 02:11:59,580

Mission let's not forget about that

2309

02:12:02,390 --> 02:12:00,480

um

2310

02:12:03,649 --> 02:12:02,400

uh so we need to model all these

2311

02:12:04,310 --> 02:12:03,659

different layers

2312

02:12:06,589 --> 02:12:04,320

um

2313

02:12:09,530 --> 02:12:06,599

so working off what we did for install

2314

02:12:11,570 --> 02:12:09,540

it is to analyze the Cassini data we're

2315

02:12:15,530 --> 02:12:11,580

going to do that here specifically

2316

02:12:18,109 --> 02:12:15,540

focusing on the ecosystem aspect

2317

02:12:19,910 --> 02:12:18,119

and so what we want to do with that is

2318

02:12:21,169 --> 02:12:19,920

provide clear constraints on what kind

2319

02:12:22,970 --> 02:12:21,179

of biosyntheries we're going to expect

2320

02:12:27,229 --> 02:12:22,980

based on a number of different

2321

02:12:30,169 --> 02:12:27,239

hypotheses of abiotic

2322

02:12:35,629 --> 02:12:30,179

possibilities biotic possibilities and

2323

02:12:41,149 --> 02:12:38,030

so as I said our approach is very

2324

02:12:43,189 --> 02:12:41,159

multi-level uh we are going to first

2325

02:12:46,609 --> 02:12:43,199

look at the bottom layer which is the

2326

02:12:48,169 --> 02:12:46,619

mixing of the core in the ocean uh to

2327

02:12:49,669 --> 02:12:48,179

assess you know the chemical structure

2328

02:12:52,550 --> 02:12:49,679

coming out of you know coming out

2329

02:12:54,290 --> 02:12:52,560

through through the water passing

2330

02:12:56,149 --> 02:12:54,300

through the core

2331

02:12:57,950 --> 02:12:56,159

uh and what chemicals are going to come

2332

02:12:59,870 --> 02:12:57,960

through that we're going to have to

2333

02:13:02,450 --> 02:12:59,880

assess what how that mixes in the water

2334

02:13:04,790 --> 02:13:02,460

to assess how much uh chemicals we're

2335

02:13:07,370 --> 02:13:04,800

going to see coming out of the plumes

2336

02:13:10,129 --> 02:13:07,380

and then we also need to take some model

2337

02:13:12,550 --> 02:13:10,139

organisms from Earth to understand the

2338

02:13:15,350 --> 02:13:12,560

metabolisms that we might expect

2339

02:13:18,050 --> 02:13:15,360

along with the ecological and possible

2340

02:13:20,510 --> 02:13:18,060

evolutionary dynamics of the life that

2341

02:13:22,790 --> 02:13:20,520

we're modeling

2342

02:13:25,310 --> 02:13:22,800

so with this framework we're going to

2343

02:13:27,649 --> 02:13:25,320

estimate the likelihoods of certain data

2344

02:13:31,609 --> 02:13:27,659

sets that we're going to see via a

2345

02:13:36,410 --> 02:13:33,649

so to intimidate you a little bit we're

2346

02:13:38,209 --> 02:13:36,420

going to have some math

2347

02:13:41,270 --> 02:13:38,219

um so let's talk about the mixing we

2348

02:13:43,430 --> 02:13:41,280

look at the dimensionless mixing ratio  $X$

2349

02:13:45,470 --> 02:13:43,440

and the temperature  $T$  so we have a

2350

02:13:47,689 --> 02:13:45,480

partial differential equation which with

2351

02:13:49,490 --> 02:13:47,699

spatial and time variables

2352

02:13:52,310 --> 02:13:49,500

solving this partial differential

2353

02:13:53,930 --> 02:13:52,320

equation gives us this steady state

2354

02:13:56,870 --> 02:13:53,940

composition

2355

02:13:59,930 --> 02:13:56,880

and temperature of the mixing layer with

2356

02:14:03,770 --> 02:13:59,940

the mass flux density

2357

02:14:08,930 --> 02:14:06,229

we can compute what we're going to see

2358

02:14:12,109 --> 02:14:08,940

coming out of the plumes by integrating

2359

02:14:14,629 --> 02:14:12,119

over the entire space uh so we we

2360

02:14:17,390 --> 02:14:14,639

integrate the integrand contains this

2361

02:14:19,729 --> 02:14:17,400

Mass flux density and the concentration

2362

02:14:22,189 --> 02:14:19,739

of a specific chemical component that

2363

02:14:26,089 --> 02:14:22,199

we're looking at so whether that be a

2364

02:14:28,129 --> 02:14:26,099

glycine or other amino acids or you know

2365

02:14:31,850 --> 02:14:28,139

cells potentially

2366

02:14:34,370 --> 02:14:31,860

so the concentration of this compound at

2367

02:14:37,189 --> 02:14:34,380

the base of the ocean plume assuming

2368

02:14:38,810 --> 02:14:37,199

that the buoyant mixing layer mixes

2369

02:14:40,370 --> 02:14:38,820

together as we described from the

2370

02:14:42,950 --> 02:14:40,380

previous model

2371

02:14:46,430 --> 02:14:42,960

is given by this quotient of these

2372

02:14:51,229 --> 02:14:48,350

so then we want to look at the cell

2373

02:14:53,030 --> 02:14:51,239

metabolism and output and there's a very

2374

02:14:56,209 --> 02:14:53,040

large variety of possibilities we could

2375

02:14:58,129 --> 02:14:56,219

be working with here so we kind of run

2376

02:15:01,270 --> 02:14:58,139

the model for tons and tons of

2377

02:15:03,169 --> 02:15:01,280

possibilities of Earth analogs

2378

02:15:06,050 --> 02:15:03,179

depending on these environmental

2379

02:15:09,050 --> 02:15:06,060

conditions so we model this catabolic

2380

02:15:12,410 --> 02:15:09,060

reaction rate of a specific organism

2381

02:15:14,390 --> 02:15:12,420

using the Arrhenius law I know that came

2382

02:15:16,250 --> 02:15:14,400

up yesterday Arrhenius in one of the

2383

02:15:16,990 --> 02:15:16,260

trivia questions

2384

02:15:19,069 --> 02:15:17,000

um

2385

02:15:21,310 --> 02:15:19,079

uh so

2386

02:15:25,729 --> 02:15:21,320

and that's so the Arrhenius lie is

2387

02:15:28,189 --> 02:15:25,739

specifically this quotient here and we

2388

02:15:31,850 --> 02:15:28,199

use the catabolic energy constant for

2389

02:15:34,550 --> 02:15:31,860

given by this term and it goes in here

2390

02:15:39,649 --> 02:15:34,560

to understand the ratio of inactivated

2391

02:15:42,050 --> 02:15:39,659

to activated enzymes for the reaction

2392

02:15:45,050 --> 02:15:42,060

now critically we assess the ecological

2393

02:15:47,510 --> 02:15:45,060

dynamics of the system so

2394

02:15:49,430 --> 02:15:47,520

in this case we are dealing with one

2395

02:15:53,689 --> 02:15:49,440

population

2396

02:15:58,430 --> 02:15:55,310

ode model

2397

02:15:59,770 --> 02:15:58,440

describing the Dynamics but we've been

2398

02:16:02,270 --> 02:15:59,780

thinking about incorporating

2399

02:16:04,189 --> 02:16:02,280

multi-species into this because there's

2400

02:16:05,750 --> 02:16:04,199

actually a significant dynamical

2401  
02:16:09,169 --> 02:16:05,760  
difference when you have competition

2402  
02:16:10,910 --> 02:16:09,179  
between species in the environment and

2403  
02:16:14,209 --> 02:16:10,920  
that would seriously affect what we'll

2404  
02:16:15,050 --> 02:16:14,219  
see when we go there so we have to we

2405  
02:16:17,410 --> 02:16:15,060  
have to

2406  
02:16:19,490 --> 02:16:17,420  
have multiple different ecosystem

2407  
02:16:21,169 --> 02:16:19,500  
Dynamics models

2408  
02:16:24,729 --> 02:16:21,179  
and so we solve this and get a steady

2409  
02:16:29,030 --> 02:16:24,739  
state concentration of a specific uh

2410  
02:16:33,830 --> 02:16:31,250  
so what can we learn from specifically

2411  
02:16:35,690 --> 02:16:33,840  
the Europa Clipper Mission uh so the

2412  
02:16:38,209 --> 02:16:35,700  
Europa Clipper Mission has some very

2413  
02:16:41,030 --> 02:16:38,219

interesting instruments we have a

2414

02:16:43,190 --> 02:16:41,040

mapping Imaging spectrometer so it will

2415

02:16:45,589 --> 02:16:43,200

map the surface and conduct the

2416

02:16:47,750 --> 02:16:45,599

spectroscopy of the surface and the

2417

02:16:49,610 --> 02:16:47,760

distribution of the Organics so as

2418

02:16:52,310 --> 02:16:49,620

things come out of the plumes they'll

2419

02:16:54,110 --> 02:16:52,320

they fall onto the surface and we should

2420

02:16:55,669 --> 02:16:54,120

expect to see an interesting chemical

2421

02:16:58,790 --> 02:16:55,679

composition I know they're already doing

2422

02:17:01,370 --> 02:16:58,800

this with jwst from the from a distance

2423

02:17:03,049 --> 02:17:01,380

they haven't analyzed that data yet but

2424

02:17:07,089 --> 02:17:03,059

uh should be interesting

2425

02:17:10,549 --> 02:17:07,099

and then to sort of sniff the exosphere

2426

02:17:13,790 --> 02:17:10,559

of Europa we have a mass spectrometer

2427

02:17:16,190 --> 02:17:13,800

Mass specs it'll determine the the

2428

02:17:18,589 --> 02:17:16,200

composition of the of the ocean beneath

2429

02:17:20,810 --> 02:17:18,599

by sniffing that exosphere

2430

02:17:23,330 --> 02:17:20,820

and then we have a surface dust analyzer

2431

02:17:27,950 --> 02:17:23,340

uh it'll have it'll measure like the

2432

02:17:31,629 --> 02:17:30,349

and so in this image you can see kind of

2433

02:17:38,150 --> 02:17:31,639

a remote

2434

02:17:43,190 --> 02:17:40,610

so let's focus on this slide a little

2435

02:17:46,190 --> 02:17:43,200

bit so this is the overall framework so

2436

02:17:47,929 --> 02:17:46,200

at the top we have those mechanistic

2437

02:17:50,509 --> 02:17:47,939

models for the geochemistry and the

2438

02:17:52,910 --> 02:17:50,519

biology that we discussed earlier

2439

02:17:56,509 --> 02:17:52,920

and so the flow of information goes from

2440

02:17:58,190 --> 02:17:56,519

the top as prior probability probability

2441

02:18:02,150 --> 02:17:58,200

densities

2442

02:18:03,469 --> 02:18:02,160

that flow into s-parameters into the

2443

02:18:06,349 --> 02:18:03,479

general model

2444

02:18:08,690 --> 02:18:06,359

then we pass those parameters into the

2445

02:18:10,250 --> 02:18:08,700

biological model for physiology and

2446

02:18:12,230 --> 02:18:10,260

evolution

2447

02:18:14,810 --> 02:18:12,240

which then goes to our habitability

2448

02:18:17,690 --> 02:18:14,820

Criterion so the habitability Criterion

2449

02:18:19,490 --> 02:18:17,700

that we generally use here is it's a

2450

02:18:21,169 --> 02:18:19,500

differential equation describing the

2451

02:18:23,330 --> 02:18:21,179

population so essentially if I were to

2452

02:18:25,610 --> 02:18:23,340

take an Earth-like organism drop it onto

2453

02:18:27,410 --> 02:18:25,620

Europa would the change in the

2454

02:18:29,450 --> 02:18:27,420

population be positive or would it be

2455

02:18:31,549 --> 02:18:29,460

zero so the derivative of population

2456

02:18:34,250 --> 02:18:31,559

growth essentially

2457

02:18:37,009 --> 02:18:34,260

and so we pass that into Bayes theorem

2458

02:18:40,910 --> 02:18:37,019

as prior distributions the posterior

2459

02:18:44,990 --> 02:18:40,920

distributions uh come from these uh so

2460

02:18:47,870 --> 02:18:45,000

we okay actually to be more specific

2461

02:18:49,610 --> 02:18:47,880

we simulate all of these models with

2462

02:18:52,549 --> 02:18:49,620

thousands of data points

2463

02:18:54,230 --> 02:18:52,559

to get what we call pseudo data uh in

2464

02:18:57,169 --> 02:18:54,240

what's called an approximate Bayesian

2465

02:18:59,810 --> 02:18:57,179

computation and so we pass that into the

2466

02:19:02,389 --> 02:18:59,820

model and we take the observational data

2467

02:19:04,429 --> 02:19:02,399

and we put that into base theorem so if

2468

02:19:06,830 --> 02:19:04,439

any of you are aware of Bayes theorem

2469

02:19:09,049 --> 02:19:06,840

that is a way of assessing the

2470

02:19:10,730 --> 02:19:09,059

probability of a certain event given

2471

02:19:12,650 --> 02:19:10,740

prior information given posterior

2472

02:19:14,570 --> 02:19:12,660

information

2473

02:19:16,429 --> 02:19:14,580

um and so now we have this cycle of

2474

02:19:17,870 --> 02:19:16,439

information so after we get a

2475

02:19:19,549 --> 02:19:17,880

probability from base theorem we can

2476

02:19:21,410 --> 02:19:19,559

pass it back into the geophysical

2477

02:19:23,629 --> 02:19:21,420

parameters model and then continue to

2478

02:19:26,330 --> 02:19:23,639

constrain as we get more observational

2479

02:19:32,330 --> 02:19:28,490

so here's an example of how we did that

2480

02:19:35,089 --> 02:19:32,340

with Enceladus for Cassini

2481

02:19:37,549 --> 02:19:35,099

so in this graph here you can see the

2482

02:19:38,990 --> 02:19:37,559

blue dots are simulations for

2483

02:19:40,910 --> 02:19:39,000

uninhabitable

2484

02:19:43,389 --> 02:19:40,920

parameter space

2485

02:19:46,669 --> 02:19:43,399

the orange dots are

2486

02:19:49,190 --> 02:19:46,679

uninhabited but habitable

2487

02:19:50,750 --> 02:19:49,200

and the green dots are habitable and

2488

02:19:53,630 --> 02:19:50,760

habited

2489

02:19:55,849 --> 02:19:53,640

so what you can see from analyzing the

2490

02:19:58,070 --> 02:19:55,859

methane content of the plume and Cassini

2491

02:20:00,410 --> 02:19:58,080

using this framework was that the vast

2492

02:20:02,570 --> 02:20:00,420

majority of simulations for all the

2493

02:20:06,410 --> 02:20:02,580

possibilities we assessed

2494

02:20:07,370 --> 02:20:06,420

fall under the biotic category

2495

02:20:11,630 --> 02:20:07,380

um

2496

02:20:17,450 --> 02:20:15,050

I mean that speaks for itself right

2497

02:20:19,849 --> 02:20:17,460

so um but there's a very important

2498

02:20:22,070 --> 02:20:19,859

constraint on this namely the

2499

02:20:24,710 --> 02:20:22,080

probability of a by Genesis

2500

02:20:26,450 --> 02:20:24,720

so what we do in this model is assess

2501

02:20:29,650 --> 02:20:26,460

all the possibilities from probability

2502

02:20:32,690 --> 02:20:29,660

zero to probability one of abiogenesis

2503

02:20:36,590 --> 02:20:32,700

and so what we found was at a pretty low

2504

02:20:39,349 --> 02:20:36,600

probability of abiogenesis uh the from

2505

02:20:40,849 --> 02:20:39,359

the previous slide

2506

02:20:43,370 --> 02:20:40,859

um

2507

02:20:45,710 --> 02:20:43,380

with a low probability of a biogenesis

2508

02:20:47,630 --> 02:20:45,720

you see that biotic explanations are the

2509

02:20:49,309 --> 02:20:47,640

most probable for what we're seeing the

2510

02:20:51,710 --> 02:20:49,319

in the methane content

2511

02:20:54,950 --> 02:20:51,720

so we really need to develop our models

2512

02:20:56,750 --> 02:20:54,960

of abiogenesis to really limit limit

2513

02:20:59,750 --> 02:20:56,760

this variable and constrain this

2514

02:21:05,990 --> 02:21:03,170

so the conclusion is in order to find

2515

02:21:08,270 --> 02:21:06,000

life we really have to model these

2516

02:21:09,830 --> 02:21:08,280

planetary systems with the assumption

2517

02:21:11,870 --> 02:21:09,840

that there could be life there already

2518

02:21:13,250 --> 02:21:11,880

because if we don't we're going to show

2519

02:21:15,650 --> 02:21:13,260

up there and we're going to think okay

2520

02:21:17,809 --> 02:21:15,660

it's habitable but why because

2521

02:21:19,490 --> 02:21:17,819

potentially the habitability of a planet

2522

02:21:21,530 --> 02:21:19,500

is actually coming from the life is

2523

02:21:24,170 --> 02:21:21,540

already there so we have to incorporate

2524

02:21:27,190 --> 02:21:24,180

that into our into our potential models

2525

02:21:30,730 --> 02:21:27,200

so this will allow us to really enhance

2526

02:21:33,770 --> 02:21:30,740

Mission data analysis

2527

02:21:36,170 --> 02:21:33,780

beforehand uh so you know with when we

2528

02:21:37,910 --> 02:21:36,180

had Cassini we showed up there and we

2529

02:21:40,490 --> 02:21:37,920

had no idea what was going on we're like

2530

02:21:43,130 --> 02:21:40,500

wild plumes this is amazing

2531

02:21:45,469 --> 02:21:43,140

um but it took many many years to really

2532

02:21:47,450 --> 02:21:45,479

assess this so hopefully with Europa

2533

02:21:50,630 --> 02:21:47,460

Clipper we have this framework in hand

2534

02:21:53,929 --> 02:21:50,640

as a software package so the data can be

2535

02:21:56,750 --> 02:21:53,939

fed through real time and the benefit of

2536

02:21:58,550 --> 02:21:56,760

this is then we can narrow down in on

2537

02:22:01,010 --> 02:21:58,560

specific areas of Europa that are of

2538

02:22:04,250 --> 02:22:01,020

interest to us and really maximize the

2539

02:22:17,510 --> 02:22:04,260

scientific yield of these missions

2540

02:22:24,530 --> 02:22:21,349

uh nice talk uh two questions maybe the

2541

02:22:25,969 --> 02:22:24,540

first did you choose a prior for a

2542

02:22:28,250 --> 02:22:25,979

biogenesis

2543

02:22:30,050 --> 02:22:28,260

yeah so we sampled the entire space from

2544

02:22:32,450 --> 02:22:30,060

zero to one probability

2545

02:22:34,610 --> 02:22:32,460

in that in those 10 000 or so

2546

02:22:36,650 --> 02:22:34,620

simulations

2547

02:22:39,050 --> 02:22:36,660

so basically

2548

02:22:41,230 --> 02:22:39,060

um we can't pick a prior for abiogenesis

2549

02:22:43,610 --> 02:22:41,240

there's no constraint on that variable

2550

02:22:47,090 --> 02:22:43,620

so essentially we have to run the model

2551  
02:22:49,610 --> 02:22:47,100  
for all possibilities of abiogenesis so

2552  
02:22:52,490 --> 02:22:49,620  
so like I said specifically with the

2553  
02:22:55,250 --> 02:22:52,500  
Enceladus data we found that uh much

2554  
02:22:57,410 --> 02:22:55,260  
less than 50 chance abiogenesis ensures

2555  
02:22:59,030 --> 02:22:57,420  
that the biotic explanation is the most

2556  
02:23:02,750 --> 02:22:59,040  
probable explanation I believe is around

2557  
02:23:05,450 --> 02:23:02,760  
30 or less probability but if you're

2558  
02:23:07,309 --> 02:23:05,460  
beneath that threshold then really the

2559  
02:23:10,670 --> 02:23:07,319  
abiotic explanations are way more

2560  
02:23:13,250 --> 02:23:10,680  
probable even though the samples from

2561  
02:23:15,230 --> 02:23:13,260  
the abiotic simulations are much smaller

2562  
02:23:17,510 --> 02:23:15,240  
but you know when the probability of

2563  
02:23:20,510 --> 02:23:17,520

evangelists is really low

2564

02:23:22,550 --> 02:23:20,520

it's just not going to happen right so

2565

02:23:35,389 --> 02:23:22,560

I've got that answered my second

2566

02:23:41,090 --> 02:23:38,570

hey thank you for your talk so for

2567

02:23:42,610 --> 02:23:41,100

Europa are you also in terms of

2568

02:23:45,889 --> 02:23:42,620

metabolism are you thinking about

2569

02:23:48,230 --> 02:23:45,899

methanogenesis or yeah okay so that was

2570

02:23:51,110 --> 02:23:48,240

the first step to consider um in for

2571

02:23:52,910 --> 02:23:51,120

Enceladus it was kind of a the most

2572

02:23:54,830 --> 02:23:52,920

obvious thing to look at because of the

2573

02:23:58,610 --> 02:23:54,840

methane content

2574

02:24:00,950 --> 02:23:58,620

um with Europa it's more complex uh

2575

02:24:03,050 --> 02:24:00,960

because we don't have any real data from

2576

02:24:04,910 --> 02:24:03,060

Europa and also the environments on

2577

02:24:06,950 --> 02:24:04,920

Europa are much more varied you have

2578

02:24:08,990 --> 02:24:06,960

subsurface pockets of water along with

2579

02:24:11,030 --> 02:24:09,000

the ocean and maybe you have like

2580

02:24:14,090 --> 02:24:11,040

biofilms on the bottom of the eye so

2581

02:24:17,030 --> 02:24:14,100

it's it's a much more complex thing

2582

02:24:18,530 --> 02:24:17,040

um so my hope is to uh run all the

2583

02:24:21,830 --> 02:24:18,540

simulations for all the possible

2584

02:24:23,990 --> 02:24:21,840

hypotheses that exist currently okay and

2585

02:24:26,330 --> 02:24:24,000

I have one little follow-up question so

2586

02:24:27,590 --> 02:24:26,340

you very briefly talked about Dynamic

2587

02:24:29,570 --> 02:24:27,600

communities and you mentioned

2588

02:24:32,210 --> 02:24:29,580

competition are you just looking at

2589

02:24:34,670 --> 02:24:32,220

competition or are you looking at other

2590

02:24:36,469 --> 02:24:34,680

sorts of consortiums like in a biofilm

2591

02:24:40,610 --> 02:24:36,479

there's competition but there's also

2592

02:24:42,950 --> 02:24:40,620

lots of sharing going on right so um if

2593

02:24:44,809 --> 02:24:42,960

we're including multi-species in our

2594

02:24:47,450 --> 02:24:44,819

models we're hoping to incorporate all

2595

02:24:48,590 --> 02:24:47,460

the possible interactions between these

2596

02:24:49,309 --> 02:24:48,600

species

2597

02:24:53,090 --> 02:24:49,319

um

2598

02:24:55,790 --> 02:24:53,100

which is really critical I want to re re

2599

02:24:58,070 --> 02:24:55,800

uh iterate because you know the

2600

02:25:00,650 --> 02:24:58,080

competition can kill off like all of the

2601  
02:25:03,290 --> 02:25:00,660  
life you know so we need to sort of have

2602  
02:25:05,389 --> 02:25:03,300  
an evolutionary perspective also and not

2603  
02:25:08,510 --> 02:25:05,399  
just like a real-time ecological

2604  
02:25:10,790 --> 02:25:08,520  
perspective to assess these things

2605  
02:25:13,330 --> 02:25:10,800  
um so really good question

2606  
02:25:16,010 --> 02:25:13,340  
thank you

2607  
02:25:18,290 --> 02:25:16,020  
very quick questions

2608  
02:25:19,969 --> 02:25:18,300  
hi Emily bear Stanford University I was

2609  
02:25:22,370 --> 02:25:19,979  
wondering so in the biological part of

2610  
02:25:23,929 --> 02:25:22,380  
the model what kind of data goes into

2611  
02:25:26,510 --> 02:25:23,939  
that and how can environmental

2612  
02:25:27,889 --> 02:25:26,520  
microbiologists help modelers improve

2613  
02:25:30,950 --> 02:25:27,899

their models what kind of data do you

2614

02:25:33,770 --> 02:25:30,960

need for that right so we need Earth

2615

02:25:35,990 --> 02:25:33,780

analogs primarily we need the you know

2616

02:25:39,290 --> 02:25:36,000

catabolic reaction parameters

2617

02:25:40,969 --> 02:25:39,300

for specific Earth analog so you know we

2618

02:25:43,130 --> 02:25:40,979

might want to go to Antarctica and see

2619

02:25:45,170 --> 02:25:43,140

what's going on there

2620

02:25:47,570 --> 02:25:45,180

um and that's our best that's our best

2621

02:25:49,910 --> 02:25:47,580

way to constrain it at the moment

2622

02:25:54,050 --> 02:25:49,920

so that's how I think biologists really

2623

02:25:57,110 --> 02:25:54,060

should really help us in that way

2624

02:25:58,550 --> 02:25:57,120

yeah exactly

2625

02:26:11,469 --> 02:25:58,560

thank you so much for your thoughts

2626

02:26:22,670 --> 02:26:15,290

our next Pico speaker is Pavel Clair

2627

02:26:25,969 --> 02:26:24,469

hi everyone

2628

02:26:27,650 --> 02:26:25,979

um I'm just going to make a quick note

2629

02:26:29,570 --> 02:26:27,660

before we start that it's great to be an

2630

02:26:30,950 --> 02:26:29,580

astrobiology conference because the

2631

02:26:32,510 --> 02:26:30,960

background slides are going to go much

2632

02:26:34,250 --> 02:26:32,520

more smoothly

2633

02:26:35,870 --> 02:26:34,260

um I presented this in a microscopy

2634

02:26:38,090 --> 02:26:35,880

conference a few months back and it was

2635

02:26:40,610 --> 02:26:38,100

a different experience

2636

02:26:42,110 --> 02:26:40,620

um so thank you all for being here

2637

02:26:43,610 --> 02:26:42,120

um and being you

2638

02:26:45,710 --> 02:26:43,620

um so

2639

02:26:47,090 --> 02:26:45,720

um I'm gonna talk uh this is going to be

2640

02:26:49,190 --> 02:26:47,100

a little bit of a pivot from some of the

2641

02:26:51,770 --> 02:26:49,200

previous talks but I'm going to talk

2642

02:26:55,670 --> 02:26:51,780

um about uh some of the methods that

2643

02:26:59,270 --> 02:26:55,680

I've been working on to actually detect

2644

02:27:02,389 --> 02:26:59,280

life on a mission a life detection

2645

02:27:03,530 --> 02:27:02,399

mission to Europa or Enceladus I'm also

2646

02:27:07,190 --> 02:27:03,540

going to make a note so I'm going to be

2647

02:27:08,990 --> 02:27:07,200

talking about uh a life life detection

2648

02:27:10,610 --> 02:27:09,000

missions to Europa and Enceladus as a

2649

02:27:13,490 --> 02:27:10,620

target for this but

2650

02:27:14,750 --> 02:27:13,500

um once you have a space capable

2651  
02:27:16,070 --> 02:27:14,760  
microscope this could potentially be

2652  
02:27:17,330 --> 02:27:16,080  
applied to like all sorts of

2653  
02:27:19,429 --> 02:27:17,340  
destinations there's lots of fun

2654  
02:27:22,250 --> 02:27:19,439  
possibilities here

2655  
02:27:24,710 --> 02:27:22,260  
the aforementioned background slides so

2656  
02:27:26,090 --> 02:27:24,720  
um when we're picking destinations to

2657  
02:27:26,870 --> 02:27:26,100  
look for life

2658  
02:27:29,389 --> 02:27:26,880  
um

2659  
02:27:31,070 --> 02:27:29,399  
there's uh we like to look for places

2660  
02:27:33,710 --> 02:27:31,080  
that have habitable conditions things

2661  
02:27:37,670 --> 02:27:33,720  
that have liquid water abundant energy

2662  
02:27:40,309 --> 02:27:37,680  
sources and conditions that are suitable

2663  
02:27:42,830 --> 02:27:40,319

for uh Life as we know it or as we might

2664

02:27:44,929 --> 02:27:42,840

predict it may exist and

2665

02:27:46,190 --> 02:27:44,939

um I'm just going to let Enceladus and

2666

02:27:47,690 --> 02:27:46,200

Europa sit up there because we've

2667

02:27:49,910 --> 02:27:47,700

already heard a lot of justifications as

2668

02:27:51,469 --> 02:27:49,920

to why those are promising targets to

2669

02:27:52,969 --> 02:27:51,479

find those conditions and why we might

2670

02:27:56,510 --> 02:27:52,979

have had

2671

02:27:59,030 --> 02:27:56,520

um an uh origin of life or living

2672

02:28:01,670 --> 02:27:59,040

organisms currently there

2673

02:28:02,929 --> 02:28:01,680

um but when we're searching for life we

2674

02:28:05,150 --> 02:28:02,939

also have to think about how we're

2675

02:28:06,889 --> 02:28:05,160

actually going to look for it and so

2676

02:28:09,590 --> 02:28:06,899

um we can kind of break down life into

2677

02:28:13,610 --> 02:28:09,600

some of the key components that make it

2678

02:28:16,309 --> 02:28:13,620

up things like uh catalysts that help it

2679

02:28:17,929 --> 02:28:16,319

uh metabolize

2680

02:28:20,270 --> 02:28:17,939

um things like information storage

2681

02:28:21,590 --> 02:28:20,280

polymers so DNA or RNA and earth-based

2682

02:28:23,510 --> 02:28:21,600

life of them look very different for

2683

02:28:27,349 --> 02:28:23,520

extraterrestrial life

2684

02:28:29,809 --> 02:28:27,359

um and also compartments life on on

2685

02:28:32,330 --> 02:28:29,819

Earth Life as we know it loves to put

2686

02:28:34,490 --> 02:28:32,340

things inside of membranes and then

2687

02:28:36,710 --> 02:28:34,500

sometimes they put those membranes

2688

02:28:39,590 --> 02:28:36,720

inside other membranes and have them

2689

02:28:41,870 --> 02:28:39,600

connect to other even more membranes but

2690

02:28:44,809 --> 02:28:41,880

those that packaging really helps it do

2691

02:28:48,290 --> 02:28:44,819

some interesting chemistry

2692

02:28:51,110 --> 02:28:48,300

um and so when we're then thinking about

2693

02:28:53,929 --> 02:28:51,120

this in the context of a mission

2694

02:28:55,849 --> 02:28:53,939

um we can start to think about how we

2695

02:28:57,830 --> 02:28:55,859

might actually observe that and what

2696

02:28:59,510 --> 02:28:57,840

analytical approaches we need to take to

2697

02:29:02,570 --> 02:28:59,520

try and get at that

2698

02:29:03,590 --> 02:29:02,580

um and so I put the like giant table up

2699

02:29:06,290 --> 02:29:03,600

here

2700

02:29:08,030 --> 02:29:06,300

um because uh these are all things that

2701

02:29:10,309 --> 02:29:08,040

people are working on

2702

02:29:12,590 --> 02:29:10,319

um for Life detection instrumentation

2703

02:29:14,690 --> 02:29:12,600

but we're going to be focusing for this

2704

02:29:16,190 --> 02:29:14,700

talk on containers

2705

02:29:18,950 --> 02:29:16,200

um and so

2706

02:29:21,770 --> 02:29:18,960

um the reason for that is

2707

02:29:24,170 --> 02:29:21,780

um that again as mentioned life loves to

2708

02:29:25,670 --> 02:29:24,180

package things into compartments and

2709

02:29:29,030 --> 02:29:25,680

those compartments can be directly

2710

02:29:31,849 --> 02:29:29,040

observable by using a microscope to look

2711

02:29:34,550 --> 02:29:31,859

for morphology and also for the

2712

02:29:36,590 --> 02:29:34,560

colocalization of certain key chemical

2713

02:29:39,889 --> 02:29:36,600

biomarkers

2714

02:29:42,950 --> 02:29:39,899

um so in

2715

02:29:44,630 --> 02:29:42,960

um our team we're working on um a

2716

02:29:46,670 --> 02:29:44,640

microscopy system that we call a

2717

02:29:47,929 --> 02:29:46,680

luminescence imager for exploration or

2718

02:29:50,210 --> 02:29:47,939

life

2719

02:29:53,690 --> 02:29:50,220

um and there is uh two key hardware

2720

02:29:55,849 --> 02:29:53,700

components of this system one is the

2721

02:29:57,110 --> 02:29:55,859

fluidic subsystem and this is to deal

2722

02:29:59,330 --> 02:29:57,120

with

2723

02:30:02,690 --> 02:29:59,340

um the actual sample processing and

2724

02:30:04,429 --> 02:30:02,700

preparation for imaging something so um

2725

02:30:06,110 --> 02:30:04,439

my background full disclosure is

2726

02:30:09,050 --> 02:30:06,120

actually not an astrobiology it's in

2727

02:30:11,330 --> 02:30:09,060

fluorescence microscopy and

2728

02:30:13,550 --> 02:30:11,340

um you know I spent like five or six

2729

02:30:15,950 --> 02:30:13,560

years in grad school just moving fluids

2730

02:30:17,750 --> 02:30:15,960

around in tubes and like preparing

2731

02:30:20,389 --> 02:30:17,760

things on slides before they actually

2732

02:30:21,770 --> 02:30:20,399

get to the microscope I've been told it

2733

02:30:25,010 --> 02:30:21,780

would be expensive to send me to

2734

02:30:26,389 --> 02:30:25,020

Enceladus so uh this is this is my

2735

02:30:29,030 --> 02:30:26,399

replacement

2736

02:30:31,130 --> 02:30:29,040

um and then the other end is the actual

2737

02:30:32,690 --> 02:30:31,140

microscope itself so the optic system

2738

02:30:33,830 --> 02:30:32,700

which is going to have all of the things

2739

02:30:35,929 --> 02:30:33,840

that you need to actually take your

2740

02:30:38,330 --> 02:30:35,939

pretty pictures

2741

02:30:40,550 --> 02:30:38,340

um so I'm gonna break down what goes

2742

02:30:44,030 --> 02:30:40,560

into these systems a little bit so the

2743

02:30:45,950 --> 02:30:44,040

fluidic subsystem that uh like uh silver

2744

02:30:49,969 --> 02:30:45,960

plate on top

2745

02:30:53,450 --> 02:30:49,979

um is the rotary filter stage and so the

2746

02:30:55,849 --> 02:30:53,460

um the stage can do seven individual

2747

02:30:57,770 --> 02:30:55,859

experiments um and so that accounts for

2748

02:30:59,870 --> 02:30:57,780

originally this was designed with the

2749

02:31:01,730 --> 02:30:59,880

Europa Lander Mission Concept in mind

2750

02:31:04,849 --> 02:31:01,740

where there would be three separate

2751  
02:31:07,670 --> 02:31:04,859  
samples each with a replicate and then a

2752  
02:31:10,010 --> 02:31:07,680  
procedural blank and then each of those

2753  
02:31:10,690 --> 02:31:10,020  
individually has

2754  
02:31:15,650 --> 02:31:10,700  
um

2755  
02:31:18,650 --> 02:31:15,660  
three uh filters of different sizes

2756  
02:31:20,929 --> 02:31:18,660  
um and so uh that basically will let you

2757  
02:31:24,110 --> 02:31:20,939  
sort out particles so the filters are 10

2758  
02:31:26,929 --> 02:31:24,120  
microns 1.2 microns and uh 0.2 microns

2759  
02:31:29,570 --> 02:31:26,939  
in size and that's just so you don't end

2760  
02:31:30,770 --> 02:31:29,580  
up with larger particles obscuring any

2761  
02:31:32,809 --> 02:31:30,780  
of the smaller particles that you're

2762  
02:31:35,870 --> 02:31:32,819  
trying to image in your sample

2763  
02:31:38,750 --> 02:31:35,880

um and that way you're not missing any

2764

02:31:39,710 --> 02:31:38,760

of the like good stuff that might be

2765

02:31:40,490 --> 02:31:39,720

there

2766

02:31:42,650 --> 02:31:40,500

um

2767

02:31:44,210 --> 02:31:42,660

there you use all it's also attached to

2768

02:31:45,770 --> 02:31:44,220

the fluidix manifold which is the part

2769

02:31:48,530 --> 02:31:45,780

that actually moves all of the liquids

2770

02:31:51,670 --> 02:31:48,540

and fluids around and it also has a lot

2771

02:31:55,550 --> 02:31:51,680

of sensors for pressure pH conductivity

2772

02:31:57,530 --> 02:31:55,560

and also crucially some storage for the

2773

02:31:58,910 --> 02:31:57,540

fluorescent stains that I'm going to be

2774

02:32:00,410 --> 02:31:58,920

talking about a little bit later in the

2775

02:32:01,429 --> 02:32:00,420

talk

2776

02:32:03,770 --> 02:32:01,439

um

2777

02:32:05,630 --> 02:32:03,780

and then these were the filters that I

2778

02:32:08,030 --> 02:32:05,640

mentioned earlier and so uh this is

2779

02:32:10,490 --> 02:32:08,040

again for sample size sorting but

2780

02:32:12,050 --> 02:32:10,500

they're also made of a silicon nitrate

2781

02:32:13,550 --> 02:32:12,060

substrate that has a low fluorescence

2782

02:32:14,210 --> 02:32:13,560

background

2783

02:32:17,270 --> 02:32:14,220

um

2784

02:32:19,849 --> 02:32:17,280

and this whole system has passed

2785

02:32:23,270 --> 02:32:19,859

Environmental Testing so um one thing

2786

02:32:26,210 --> 02:32:23,280

about microscopes and also uh you know

2787

02:32:28,450 --> 02:32:26,220

fluid fluidix has a fair bit of space

2788

02:32:31,370 --> 02:32:28,460

flight Heritage but in general Hardware

2789

02:32:33,469 --> 02:32:31,380

uh can break and I'm sure everyone who's

2790

02:32:35,570 --> 02:32:33,479

worked in the lab is dealt with a lot of

2791

02:32:37,130 --> 02:32:35,580

like issues before so you want to make

2792

02:32:38,510 --> 02:32:37,140

sure these things are robust and you can

2793

02:32:40,610 --> 02:32:38,520

actually get it to where you want to

2794

02:32:43,150 --> 02:32:40,620

launch it to

2795

02:32:46,910 --> 02:32:43,160

um the optic subsystem

2796

02:32:49,969 --> 02:32:46,920

is a nice small compact box and so um

2797

02:32:54,650 --> 02:32:49,979

this is a 10 centimeter by 10 centimeter

2798

02:32:56,510 --> 02:32:54,660

by 13 centimeter Cube I have an image on

2799

02:32:58,250 --> 02:32:56,520

my phone that I didn't upload to the

2800

02:33:00,770 --> 02:32:58,260

presentation because the image quality

2801  
02:33:04,429 --> 02:33:00,780  
is not that good but for context that's

2802  
02:33:06,530 --> 02:33:04,439  
uh about as tall as a banana which is

2803  
02:33:08,210 --> 02:33:06,540  
very small for like a benchtop

2804  
02:33:11,150 --> 02:33:08,220  
fluorescence microscope

2805  
02:33:14,210 --> 02:33:11,160  
um there is like fancier microscopes can

2806  
02:33:15,889 --> 02:33:14,220  
sometimes be like the size of of a

2807  
02:33:17,510 --> 02:33:15,899  
person if you're trying to do crazy like

2808  
02:33:19,730 --> 02:33:17,520  
two Photon lifetime Imaging or something

2809  
02:33:21,650 --> 02:33:19,740  
but even an Epi fluorescent scope would

2810  
02:33:23,450 --> 02:33:21,660  
probably occupy like this Podium

2811  
02:33:25,610 --> 02:33:23,460  
normally and there'd be a lot of like

2812  
02:33:29,330 --> 02:33:25,620  
miscellaneous kind of assorted parts so

2813  
02:33:31,429 --> 02:33:29,340

it's a really nice little system

2814

02:33:34,309 --> 02:33:31,439

and so that contains all of the

2815

02:33:35,809 --> 02:33:34,319

excitation LEDs emission filters all the

2816

02:33:38,630 --> 02:33:35,819

Optics

2817

02:33:41,330 --> 02:33:38,640

um and so uh this table is just kind of

2818

02:33:44,090 --> 02:33:41,340

going through what the different uh bits

2819

02:33:47,510 --> 02:33:44,100

of Hardware that we have are and

2820

02:33:49,790 --> 02:33:47,520

um to kind of like give the the the high

2821

02:33:53,330 --> 02:33:49,800

level Summary of why this is relevant

2822

02:33:55,130 --> 02:33:53,340

um basically we have three LEDs that are

2823

02:33:57,590 --> 02:33:55,140

common excitation wavelengths for

2824

02:33:59,090 --> 02:33:57,600

different fluorescent stains that can

2825

02:34:01,670 --> 02:33:59,100

also excite different types of

2826

02:34:03,830 --> 02:34:01,680

autofluorescence and then

2827

02:34:06,590 --> 02:34:03,840

um one thing that's actually relatively

2828

02:34:07,849 --> 02:34:06,600

unique to this microscope certainly no

2829

02:34:10,550 --> 02:34:07,859

microscopes I've worked with previously

2830

02:34:12,530 --> 02:34:10,560

I've had this is the 275 nanometer LED

2831

02:34:14,330 --> 02:34:12,540

so that's actually fairly far in the

2832

02:34:16,910 --> 02:34:14,340

ultraviolet range

2833

02:34:19,450 --> 02:34:16,920

um and that's really good at exciting uh

2834

02:34:22,790 --> 02:34:19,460

protein fluorescence so uh tryptophan

2835

02:34:25,010 --> 02:34:22,800

phenylalanine the various aromatic amino

2836

02:34:27,650 --> 02:34:25,020

acid side chains actually fluoresce

2837

02:34:29,330 --> 02:34:27,660

quite brightly in the ultraviolet and so

2838

02:34:32,389 --> 02:34:29,340

that can help image native fluorescent

2839

02:34:34,969 --> 02:34:32,399

of samples and also excite the

2840

02:34:36,290 --> 02:34:34,979

fluorescence of many different kinds of

2841

02:34:37,969 --> 02:34:36,300

minerals

2842

02:34:42,230 --> 02:34:37,979

um

2843

02:34:43,550 --> 02:34:42,240

the objective is also set up to help uh

2844

02:34:46,190 --> 02:34:43,560

well it's

2845

02:34:48,230 --> 02:34:46,200

robust to space flight but also the part

2846

02:34:50,389 --> 02:34:48,240

that I think is super fun is that it

2847

02:34:52,429 --> 02:34:50,399

most objectives actually can't collect

2848

02:34:53,990 --> 02:34:52,439

light in that ultraviolet range

2849

02:34:57,230 --> 02:34:54,000

um so it is a custom objective that's

2850

02:34:59,510 --> 02:34:57,240

built for those sorts of experiments

2851  
02:35:01,670 --> 02:34:59,520  
um it has a Piezo stage that lets us do

2852  
02:35:04,250 --> 02:35:01,680  
automated Z stacking

2853  
02:35:06,230 --> 02:35:04,260  
um and this is also been subjected to

2854  
02:35:09,710 --> 02:35:06,240  
environmental and shock and vibrational

2855  
02:35:11,570 --> 02:35:09,720  
testing and also radiation testing

2856  
02:35:13,969 --> 02:35:11,580  
um to the specifications of the Europa

2857  
02:35:19,250 --> 02:35:13,979  
Lander mission

2858  
02:35:20,990 --> 02:35:19,260  
so um we're now on our ongoing work is

2859  
02:35:24,170 --> 02:35:21,000  
actually characterizing this microscope

2860  
02:35:27,170 --> 02:35:24,180  
by Imaging different types of samples to

2861  
02:35:29,870 --> 02:35:27,180  
see what the the the limits are of what

2862  
02:35:31,670 --> 02:35:29,880  
we can detect so um this sample is just

2863  
02:35:33,950 --> 02:35:31,680

kind of showing uh some of the bright

2864

02:35:35,450 --> 02:35:33,960

some bright field images from a sample

2865

02:35:38,690 --> 02:35:35,460

that was collected from Lake undersea in

2866

02:35:41,389 --> 02:35:38,700

Antarctica and so um I'm showing here

2867

02:35:44,510 --> 02:35:41,399

the 10 Micron and 1.2 Micron filters to

2868

02:35:47,389 --> 02:35:44,520

kind of highlight that um we can image

2869

02:35:49,670 --> 02:35:47,399

the the objects at

2870

02:35:52,969 --> 02:35:49,680

um of very different sizes and you can

2871

02:35:55,190 --> 02:35:52,979

see the the physical uh size of the

2872

02:35:59,150 --> 02:35:55,200

little uh holes there

2873

02:36:02,570 --> 02:35:59,160

um and so if we were to just put this

2874

02:36:04,849 --> 02:36:02,580

all onto one filter that microbial matte

2875

02:36:06,469 --> 02:36:04,859

looking thing on the the

2876

02:36:08,210 --> 02:36:06,479

year left

2877

02:36:10,130 --> 02:36:08,220

um would probably obscure some of the

2878

02:36:12,349 --> 02:36:10,140

smaller objects that we're seeing in the

2879

02:36:14,270 --> 02:36:12,359

other filter sizes

2880

02:36:15,830 --> 02:36:14,280

um and so

2881

02:36:18,170 --> 02:36:15,840

um as I mentioned earlier we can also

2882

02:36:19,429 --> 02:36:18,180

excite native fluorescence and so we can

2883

02:36:21,590 --> 02:36:19,439

correlate this as well with the bright

2884

02:36:23,210 --> 02:36:21,600

field images so we can take an image of

2885

02:36:26,270 --> 02:36:23,220

an object say oh hey that looks

2886

02:36:28,429 --> 02:36:26,280

interesting I wonder what that is look

2887

02:36:29,750 --> 02:36:28,439

at the you know native fluorescence in

2888

02:36:31,969 --> 02:36:29,760

different ranges and get a sense of okay

2889

02:36:34,250 --> 02:36:31,979

wait we've got a bunch of like

2890

02:36:35,990 --> 02:36:34,260

Organics that are fluorescent in the UV

2891

02:36:38,990 --> 02:36:36,000

range that are all localized on this

2892

02:36:42,770 --> 02:36:39,000

object that's pretty exciting

2893

02:36:44,929 --> 02:36:42,780

um and then we can also then stain the

2894

02:36:47,389 --> 02:36:44,939

sample with fluorescent stains to look

2895

02:36:50,110 --> 02:36:47,399

for more specific chemical signatures um

2896

02:36:52,969 --> 02:36:50,120

and so in this case I'm showing the same

2897

02:36:55,790 --> 02:36:52,979

sample after it's been treated with a

2898

02:36:58,910 --> 02:36:55,800

stain for primary amines and another one

2899

02:37:01,670 --> 02:36:58,920

that stains lipids and so we can look

2900

02:37:04,570 --> 02:37:01,680

for both the presence of those molecules

2901

02:37:07,610 --> 02:37:04,580

but also their co-localization in space

2902

02:37:09,170 --> 02:37:07,620

and this is a really like unique and

2903

02:37:11,570 --> 02:37:09,180

Powerful kind of data that you can get

2904

02:37:13,670 --> 02:37:11,580

from the microscope is not just like

2905

02:37:15,590 --> 02:37:13,680

what compounds are there but seeing that

2906

02:37:17,929 --> 02:37:15,600

they're associating with each other kind

2907

02:37:21,010 --> 02:37:17,939

of gives you a good piece of evidence

2908

02:37:23,090 --> 02:37:21,020

that you might be seeing some

2909

02:37:26,150 --> 02:37:23,100

disequilibrium and some living

2910

02:37:30,770 --> 02:37:29,270

um microscopy data is also

2911

02:37:35,510 --> 02:37:30,780

large

2912

02:37:37,670 --> 02:37:35,520

types of data that we've talked about in

2913

02:37:40,070 --> 02:37:37,680

this conference so far but certainly

2914

02:37:42,650 --> 02:37:40,080

large enough that if you were trying to

2915

02:37:45,290 --> 02:37:42,660

send all of this data back from Europa

2916

02:37:49,309 --> 02:37:45,300

or Enceladus it would be more

2917

02:37:50,990 --> 02:37:49,319

complicated to handle and so one of the

2918

02:37:55,730 --> 02:37:51,000

things that we're able to do on this

2919

02:37:59,750 --> 02:37:55,740

microscope is actually take a z-stack of

2920

02:38:02,150 --> 02:37:59,760

of images and compress it down to a

2921

02:38:04,910 --> 02:38:02,160

single image that's much less in data

2922

02:38:07,130 --> 02:38:04,920

volume and so the image I'm showing

2923

02:38:09,950 --> 02:38:07,140

right now is

2924

02:38:11,270 --> 02:38:09,960

um an image set of images that were

2925

02:38:13,790 --> 02:38:11,280

automatically collected at different

2926

02:38:15,170 --> 02:38:13,800

focal planes in the sample

2927

02:38:17,210 --> 02:38:15,180

um and then after it's run through the

2928

02:38:19,610 --> 02:38:17,220

compression routine you end up with a

2929

02:38:22,670 --> 02:38:19,620

single in Focus image and you're now

2930

02:38:24,590 --> 02:38:22,680

suddenly gone from megabytes of data to

2931

02:38:26,389 --> 02:38:24,600

kilobytes of data

2932

02:38:29,630 --> 02:38:26,399

um and then

2933

02:38:33,469 --> 02:38:29,640

um you can even go further with that and

2934

02:38:35,270 --> 02:38:33,479

you'll notice that this sample has uh

2935

02:38:37,670 --> 02:38:35,280

bright objects against a dark background

2936

02:38:39,889 --> 02:38:37,680

we don't actually care what the like

2937

02:38:41,750 --> 02:38:39,899

Photon shot noise is on the background

2938

02:38:44,210 --> 02:38:41,760

for our purposes that might as well just

2939

02:38:46,250 --> 02:38:44,220

all be zero and so the final compression

2940

02:38:48,830 --> 02:38:46,260

step is actually taking that and setting

2941

02:38:51,110 --> 02:38:48,840

it to zero and so we're just recording

2942

02:38:53,570 --> 02:38:51,120

um the actual bright objects that are

2943

02:38:55,010 --> 02:38:53,580

detected in the image and so that all

2944

02:38:56,389 --> 02:38:55,020

reduces the data size quite

2945

02:38:58,490 --> 02:38:56,399

substantially

2946

02:39:00,050 --> 02:38:58,500

um without really getting rid of any of

2947

02:39:03,110 --> 02:39:00,060

the information that we actually want to

2948

02:39:06,230 --> 02:39:03,650

um

2949

02:39:07,250 --> 02:39:06,240

so how would this work in in a mission I

2950

02:39:08,690 --> 02:39:07,260

just talked about a lot of different

2951

02:39:10,969 --> 02:39:08,700

parts and now I'm going to bring it all

2952

02:39:12,590 --> 02:39:10,979

back together into how this system could

2953

02:39:16,550 --> 02:39:12,600

be implemented

2954

02:39:18,110 --> 02:39:16,560

um so and I have the little Europa

2955

02:39:21,110 --> 02:39:18,120

Lander picture there

2956

02:39:23,150 --> 02:39:21,120

um but basically uh we pretend that the

2957

02:39:25,849 --> 02:39:23,160

microscope is somewhere in that Lander

2958

02:39:28,370 --> 02:39:25,859

um you would take your sample process it

2959

02:39:30,410 --> 02:39:28,380

pump it through the fluidic system you

2960

02:39:32,210 --> 02:39:30,420

can image it on the microscope

2961

02:39:35,870 --> 02:39:32,220

um you're going to end up with megabytes

2962

02:39:37,910 --> 02:39:35,880

of data that you can then compress back

2963

02:39:40,910 --> 02:39:37,920

down to your kilobytes of data send it

2964

02:39:43,309 --> 02:39:40,920

back to your ground-based Observer that

2965

02:39:45,349 --> 02:39:43,319

will then be able to say oh okay cool we

2966

02:39:46,910 --> 02:39:45,359

got a microbial mat on Europa time to

2967

02:39:49,130 --> 02:39:46,920

hit the Press

2968

02:39:53,270 --> 02:39:51,830

and so uh yeah just briefly

2969

02:39:55,969 --> 02:39:53,280

acknowledgments there's been a lot of

2970

02:39:58,250 --> 02:39:55,979

funding that's gone into this

2971

02:39:59,430 --> 02:39:58,260

um and um I'll be happy to take any

2972

02:40:13,070 --> 02:39:59,440

questions

2973

02:40:17,630 --> 02:40:15,590

great talk uh this is Chad pazoriski at

2974

02:40:19,490 --> 02:40:17,640

Georgia Tech so

2975

02:40:21,530 --> 02:40:19,500

um I'm really happy that you touched on

2976

02:40:23,270 --> 02:40:21,540

uh compression first of all uh of the

2977

02:40:24,770 --> 02:40:23,280

data because that's incredibly important

2978

02:40:26,929 --> 02:40:24,780

and

2979

02:40:28,969 --> 02:40:26,939

um I was also really thrilled that you

2980

02:40:30,230 --> 02:40:28,979

talked about the um sample prep and

2981

02:40:31,429 --> 02:40:30,240

fluidics because I think that's

2982

02:40:34,790 --> 02:40:31,439

something that a lot of people don't

2983

02:40:37,250 --> 02:40:34,800

consider for these NCG missions uh my

2984

02:40:40,370 --> 02:40:37,260

question has to do with

2985

02:40:43,910 --> 02:40:40,380

um comparing uh microscopy and staining

2986

02:40:46,309 --> 02:40:43,920

with uh perhaps something like Raman or

2987

02:40:47,929 --> 02:40:46,319

IR where you could get information about

2988

02:40:49,790 --> 02:40:47,939

at least functional groups of the

2989

02:40:52,490 --> 02:40:49,800

Organics present and co-locate things

2990

02:40:54,889 --> 02:40:52,500

that I imagine similar resolution

2991

02:40:57,530 --> 02:40:54,899

spatially but you wouldn't need to

2992

02:41:00,110 --> 02:40:57,540

include those processing steps so would

2993

02:41:02,330 --> 02:41:00,120

you advocate for a system that's I guess

2994

02:41:03,830 --> 02:41:02,340

maybe not redundant but but has both of

2995

02:41:05,750 --> 02:41:03,840

those features or do you think one is

2996

02:41:07,130 --> 02:41:05,760

better than the other yes this is

2997

02:41:08,750 --> 02:41:07,140

actually a super interesting discussion

2998

02:41:10,910 --> 02:41:08,760

and we can definitely also talk more

2999

02:41:12,770 --> 02:41:10,920

about it at lunch but the the high level

3000

02:41:14,590 --> 02:41:12,780

thing that I'm going to say is that um

3001

02:41:17,990 --> 02:41:14,600

you you get

3002

02:41:19,370 --> 02:41:18,000

you're going to have different pros and

3003

02:41:20,889 --> 02:41:19,380

cons and get different types of data

3004

02:41:23,809 --> 02:41:20,899

those techniques so if you're doing

3005

02:41:26,929 --> 02:41:23,819

let's if you want to get spatially

3006

02:41:28,250 --> 02:41:26,939

correlated Ramen data when you're

3007

02:41:31,429 --> 02:41:28,260

building a microscope and you're trying

3008

02:41:32,809 --> 02:41:31,439

to image something unless you're using a

3009

02:41:36,170 --> 02:41:32,819

super resolution technique you're

3010

02:41:39,290 --> 02:41:36,180

limited by diffraction in terms of like

3011

02:41:40,849 --> 02:41:39,300

the the resolution that you can get and

3012

02:41:42,469 --> 02:41:40,859

that is proportional to the wavelength

3013

02:41:45,770 --> 02:41:42,479

that you're using so when you start to

3014

02:41:47,469 --> 02:41:45,780

get into like the IR you know range and

3015

02:41:50,570 --> 02:41:47,479

things like that

3016

02:41:52,910 --> 02:41:50,580

your spatial resolution starts to be

3017

02:41:55,910 --> 02:41:52,920

more limited than it is in the optical

3018

02:41:58,070 --> 02:41:55,920

range the flip side is you're right you

3019

02:41:59,210 --> 02:41:58,080

can get precise chemical information out

3020

02:42:02,570 --> 02:41:59,220

without

3021

02:42:06,650 --> 02:42:02,580

um you know adding labels and so I think

3022

02:42:08,570 --> 02:42:06,660

that definitely those are like

3023

02:42:10,910 --> 02:42:08,580

in in in in the perfect mission

3024

02:42:12,050 --> 02:42:10,920

architecture I think you do both

3025

02:42:16,849 --> 02:42:12,060

um

3026

02:42:18,349 --> 02:42:16,859

it's it's it's unfortunate that we can't

3027

02:42:20,570 --> 02:42:18,359

send all the instruments that we want

3028

02:42:22,490 --> 02:42:20,580

out there but like in my ideal world I

3029

02:42:25,070 --> 02:42:22,500

think those that would be a powerful

3030

02:42:28,070 --> 02:42:25,080

like correlative technique there

3031

02:42:30,230 --> 02:42:28,080

um to kind of get a a strong sense of

3032

02:42:38,330 --> 02:42:30,240

what you're seeing in your sample

3033

02:42:38,340 --> 02:42:44,590

foreign

3034

02:42:49,849 --> 02:42:48,050

again thanks for an awesome talk this is

3035

02:42:51,770 --> 02:42:49,859

really exciting so I was wondering what

3036

02:42:55,429 --> 02:42:51,780

sample prep looks like

3037

02:42:57,290 --> 02:42:55,439

um in the Rover or whatever and

3038

02:42:58,730 --> 02:42:57,300

um what the capabilities are for that so

3039

02:43:00,230 --> 02:42:58,740

could you actually do like incubation

3040

02:43:01,790 --> 02:43:00,240

experiments and then look at it with

3041

02:43:02,990 --> 02:43:01,800

microscopy or is it coming straight from

3042

02:43:04,130 --> 02:43:03,000

the environment going straight to the

3043

02:43:07,790 --> 02:43:04,140

microscope

3044

02:43:10,849 --> 02:43:07,800

yeah so um it's the

3045

02:43:13,010 --> 02:43:10,859

the the design that we had in mind for

3046

02:43:14,809 --> 02:43:13,020

for sample prep here and when I said I

3047

02:43:17,150 --> 02:43:14,819

say we it's not

3048

02:43:19,010 --> 02:43:17,160

um us this was kind of the built around

3049

02:43:21,290 --> 02:43:19,020

the Europa Lander specifications but

3050

02:43:23,150 --> 02:43:21,300

essentially you'd have a sample cup that

3051  
02:43:26,389 --> 02:43:23,160  
would collect an ice sample and melt it

3052  
02:43:29,570 --> 02:43:26,399  
down and so that was kind of the um

3053  
02:43:32,090 --> 02:43:29,580  
initial like thoughts behind the design

3054  
02:43:33,770 --> 02:43:32,100  
here but the fluidics processing system

3055  
02:43:35,270 --> 02:43:33,780  
can basically handle anything that's in

3056  
02:43:37,570 --> 02:43:35,280  
a liquid state but the assumption would

3057  
02:43:39,889 --> 02:43:37,580  
be that it's a relatively unprocessed

3058  
02:43:41,510 --> 02:43:39,899  
field sample

3059  
02:43:44,090 --> 02:43:41,520  
um

3060  
02:43:45,650 --> 02:43:44,100  
relatively unprocessed because obviously

3061  
02:43:47,030 --> 02:43:45,660  
if it's like ice or something and you're

3062  
02:43:49,010 --> 02:43:47,040  
melting it down you are still doing

3063  
02:43:50,510 --> 02:43:49,020

something to that sample

3064

02:43:53,929 --> 02:43:50,520

um

3065

02:43:53,939 --> 02:43:57,650

okay we have time for one more question

3066

02:44:02,030 --> 02:44:00,710

I thank you for the great talk

3067

02:44:04,910 --> 02:44:02,040

um

3068

02:44:08,090 --> 02:44:04,920

my question is uh maybe I missed that

3069

02:44:11,990 --> 02:44:08,100

you mentioned how

3070

02:44:15,170 --> 02:44:12,000

are you going to differentiate uh

3071

02:44:15,889 --> 02:44:15,180

any other particles

3072

02:44:19,910 --> 02:44:15,899

um

3073

02:44:24,130 --> 02:44:19,920

from the living materials like can you

3074

02:44:26,929 --> 02:44:24,140

specifically staying genetic material or

3075

02:44:28,730 --> 02:44:26,939

anything biological

3076

02:44:30,170 --> 02:44:28,740

yeah so that's actually that's a great

3077

02:44:34,010 --> 02:44:30,180

question and

3078

02:44:35,150 --> 02:44:34,020

um so the the the the goal here is to

3079

02:44:38,030 --> 02:44:35,160

kind of pick up as many different

3080

02:44:40,610 --> 02:44:38,040

breadcrumbs as you as as we can to try

3081

02:44:41,990 --> 02:44:40,620

and uh differentiate and so you

3082

02:44:43,550 --> 02:44:42,000

mentioned stains for genetic material

3083

02:44:44,990 --> 02:44:43,560

one of the stains that we would be

3084

02:44:46,969 --> 02:44:45,000

launching with this is a stain for

3085

02:44:51,110 --> 02:44:46,979

nucleic acids

3086

02:44:54,290 --> 02:44:51,120

um now obviously that would be really

3087

02:44:55,790 --> 02:44:54,300

awesome if we found DNA on Europa or

3088

02:44:57,410 --> 02:44:55,800

Enceladus but

3089

02:44:59,210 --> 02:44:57,420

um there's it's kind of an open question

3090

02:45:03,110 --> 02:44:59,220

whether we would

3091

02:45:05,030 --> 02:45:03,120

um and um so the idea behind looking for

3092

02:45:08,030 --> 02:45:05,040

the something like the co-localization

3093

02:45:11,690 --> 02:45:08,040

of amines and lipids is that that gives

3094

02:45:13,010 --> 02:45:11,700

you a more like agnostic idea of like

3095

02:45:14,630 --> 02:45:13,020

hey that might be living material

3096

02:45:17,389 --> 02:45:14,640

because you've got these you know

3097

02:45:20,330 --> 02:45:17,399

chemical signatures that are co-locating

3098

02:45:21,530 --> 02:45:20,340

um the other thing is um so one of our

3099

02:45:23,450 --> 02:45:21,540

um collaborators actually the person who

3100

02:45:25,809 --> 02:45:23,460

helped build the microscope

3101

02:45:28,790 --> 02:45:25,819

um is has some ongoing work

3102

02:45:31,670 --> 02:45:28,800

characterizing the fluorescence of uh

3103

02:45:33,110 --> 02:45:31,680

diff of the wide library of minerals to

3104

02:45:34,849 --> 02:45:33,120

get a sense of like what they would

3105

02:45:37,630 --> 02:45:34,859

potentially look like

3106

02:45:40,550 --> 02:45:37,640

um on the the microscope so we can

3107

02:45:41,750 --> 02:45:40,560

hopefully differentiate between that and

3108

02:45:43,550 --> 02:45:41,760

things that might be a little bit more

3109

02:45:46,610 --> 02:45:43,560

biological but spectroscopically and

3110

02:45:48,050 --> 02:45:46,620

then also you know morphologically

3111

02:45:51,170 --> 02:45:48,060

um

3112

02:45:51,180 --> 02:46:06,710

amazing thank you for the talk

3113

02:46:06,720 --> 02:46:16,730

[Music]

3114

02:46:23,870 --> 02:46:20,330

our next speaker is Kenneth Seton from

3115

02:46:27,170 --> 02:46:25,429

hello

3116

02:46:30,050 --> 02:46:27,180

as Miguel said

3117

02:46:32,929 --> 02:46:30,060

um my name is Marshall and I'm an NPP

3118

02:46:35,929 --> 02:46:32,939

fellow at JPL Caltech and I work with

3119

02:46:37,790 --> 02:46:35,939

Morgan cable and Brianna Henderson and I

3120

02:46:40,910 --> 02:46:37,800

do most of my experimental work at

3121

02:46:44,090 --> 02:46:40,920

Caltech and Paul asimov's lab but

3122

02:46:45,830 --> 02:46:44,100

because this is a conference of

3123

02:46:48,830 --> 02:46:45,840

literally graduate students and

3124

02:46:50,330 --> 02:46:48,840

post-docs I wanted to talk about the

3125

02:46:53,330 --> 02:46:50,340

planetary science summer school program

3126  
02:46:56,570 --> 02:46:53,340  
which is a program for graduate students

3127  
02:46:58,309 --> 02:46:56,580  
and postdocs to teach you all how to

3128  
02:47:00,830 --> 02:46:58,319  
help Mission design for planetary

3129  
02:47:02,690 --> 02:47:00,840  
missions actually happens and to learn

3130  
02:47:04,070 --> 02:47:02,700  
the process and so I'm going to be

3131  
02:47:06,830 --> 02:47:04,080  
presenting

3132  
02:47:09,230 --> 02:47:06,840  
the mission that my team and I developed

3133  
02:47:12,050 --> 02:47:09,240  
during the PSS

3134  
02:47:13,969 --> 02:47:12,060  
in which the majority of the framework

3135  
02:47:16,849 --> 02:47:13,979  
for the mission was developed back in

3136  
02:47:18,950 --> 02:47:16,859  
2021 and that we iterated on since then

3137  
02:47:21,050 --> 02:47:18,960  
the astrobiology exploration at

3138  
02:47:23,809 --> 02:47:21,060

Enceladus or X for short and I'm going

3139

02:47:25,910 --> 02:47:23,819

to preface this by saying that this is

3140

02:47:29,929 --> 02:47:25,920

an Unholy amount of information to

3141

02:47:31,849 --> 02:47:29,939

distill into a dozen slides and so uh I

3142

02:47:33,950 --> 02:47:31,859

did my best unfortunately I can't go

3143

02:47:35,510 --> 02:47:33,960

into a lot of detail with these slides

3144

02:47:37,670 --> 02:47:35,520

but if you have any questions about the

3145

02:47:39,770 --> 02:47:37,680

science and ask a question if you don't

3146

02:47:41,570 --> 02:47:39,780

want to ask a question come find me I'd

3147

02:47:42,889 --> 02:47:41,580

love to be stoked to talk about this

3148

02:47:45,110 --> 02:47:42,899

stuff

3149

02:47:46,490 --> 02:47:45,120

Okay so

3150

02:47:48,469 --> 02:47:46,500

I'm sure you guys are familiar with

3151

02:47:51,110 --> 02:47:48,479

Enceladus at this point

3152

02:47:53,450 --> 02:47:51,120

um but that thing is in solidus it's one

3153

02:47:55,570 --> 02:47:53,460

of uh Saturn's moons and it's it's

3154

02:47:59,150 --> 02:47:55,580

relatively pretty small it's only about

3155

02:48:01,550 --> 02:47:59,160

500 kilometers in diameter but

3156

02:48:03,410 --> 02:48:01,560

there's some super cool stuff going on

3157

02:48:05,929 --> 02:48:03,420

even though it's it's this tiny little

3158

02:48:09,590 --> 02:48:05,939

thing that stuff coming out of the

3159

02:48:11,870 --> 02:48:09,600

bottom of Enceladus is a continuous

3160

02:48:12,950 --> 02:48:11,880

plume that's formed over the South polar

3161

02:48:16,130 --> 02:48:12,960

Terrain

3162

02:48:17,990 --> 02:48:16,140

and so if we zoom in a little bit closer

3163

02:48:19,670 --> 02:48:18,000

these are images from Cassini and though

3164

02:48:21,170 --> 02:48:19,680

it's not actually blue like that that's

3165

02:48:24,170 --> 02:48:21,180

in false color but that's just to show

3166

02:48:26,150 --> 02:48:24,180

you where these um fractures are

3167

02:48:27,710 --> 02:48:26,160

and the plume is sourced from those

3168

02:48:29,990 --> 02:48:27,720

fractures

3169

02:48:32,090 --> 02:48:30,000

um that all combines to form a

3170

02:48:34,190 --> 02:48:32,100

continuous Bloom over the South polar

3171

02:48:37,190 --> 02:48:34,200

terrain and we have really strong

3172

02:48:40,849 --> 02:48:37,200

evidence from some of the measurements

3173

02:48:43,130 --> 02:48:40,859

by Cassini that this plume is directly

3174

02:48:45,230 --> 02:48:43,140

sourced from a subsurface Global liquid

3175

02:48:47,510 --> 02:48:45,240

water ocean

3176

02:48:49,630 --> 02:48:47,520

and so this presents a unique

3177

02:48:53,090 --> 02:48:49,640

opportunity unique in our solar system

3178

02:48:57,410 --> 02:48:53,100

to sample the contents of a subsurface

3179

02:48:59,929 --> 02:48:57,420

ocean in situ using a multi-flyby or an

3180

02:49:01,910 --> 02:48:59,939

Orbiter Mission architecture

3181

02:49:05,630 --> 02:49:01,920

and we have some rough compositional

3182

02:49:08,450 --> 02:49:05,640

information of the plume from Cassini

3183

02:49:09,889 --> 02:49:08,460

using the inms or the ion and neutral

3184

02:49:11,630 --> 02:49:09,899

Mass spectrometer and the cosmic dust

3185

02:49:15,530 --> 02:49:11,640

analyzer and so

3186

02:49:18,530 --> 02:49:15,540

um in the plume gas we see water

3187

02:49:20,990 --> 02:49:18,540

um Hydra small hydrocarbons some simple

3188

02:49:22,490 --> 02:49:21,000

and complex Organics and this is a paper

3189

02:49:24,889 --> 02:49:22,500

from

3190

02:49:27,889 --> 02:49:24,899

the weight at all paper back in 2006

3191

02:49:29,990 --> 02:49:27,899

from the inms data but if we look at

3192

02:49:32,150 --> 02:49:30,000

plume grains we see that they're

3193

02:49:34,070 --> 02:49:32,160

waterized but um we see a lot of

3194

02:49:36,290 --> 02:49:34,080

different salts but in addition to that

3195

02:49:38,030 --> 02:49:36,300

and I I think a previous talk hit on

3196

02:49:39,830 --> 02:49:38,040

this a little bit we see silicon Nano

3197

02:49:42,469 --> 02:49:39,840

grains and that's really important

3198

02:49:44,929 --> 02:49:42,479

because based on what we know the only

3199

02:49:47,270 --> 02:49:44,939

way that these silicon nanoparticles

3200

02:49:49,190 --> 02:49:47,280

could be produced within this size range

3201

02:49:51,349 --> 02:49:49,200

are high temperature hydrothermal

3202

02:49:53,809 --> 02:49:51,359

reactions and that's huge from a

3203

02:49:55,250 --> 02:49:53,819

habitability standpoint and in addition

3204

02:49:58,309 --> 02:49:55,260

to this

3205

02:50:00,889 --> 02:49:58,319

um looking at the CDA data that Cosmic

3206

02:50:03,190 --> 02:50:00,899

dust analyzer we see evidence not direct

3207

02:50:05,630 --> 02:50:03,200

detection because of the the

3208

02:50:07,670 --> 02:50:05,640

instrumental capabilities we had at the

3209

02:50:10,370 --> 02:50:07,680

time this is like 80s technology

3210

02:50:12,889 --> 02:50:10,380

but we see strong evidence for

3211

02:50:15,590 --> 02:50:12,899

macromolecular organic compounds

3212

02:50:17,809 --> 02:50:15,600

and so there's this complex organic

3213

02:50:19,550 --> 02:50:17,819

chemistry going on that we don't really

3214

02:50:21,050 --> 02:50:19,560

understand and we don't know what's

3215

02:50:23,510 --> 02:50:21,060

going on there but like something's

3216

02:50:25,190 --> 02:50:23,520

happening and so we need to figure out

3217

02:50:27,830 --> 02:50:25,200

what's up

3218

02:50:30,290 --> 02:50:27,840

and so with that being said we have

3219

02:50:31,670 --> 02:50:30,300

liquid water we have a geothermal source

3220

02:50:35,030 --> 02:50:31,680

of feed via the high temperature

3221

02:50:38,870 --> 02:50:36,710

essentially all the chemical building

3222

02:50:40,490 --> 02:50:38,880

blocks for Life as we know it they're

3223

02:50:42,530 --> 02:50:40,500

present

3224

02:50:44,809 --> 02:50:42,540

um sulfur hasn't been published yet but

3225

02:50:46,130 --> 02:50:44,819

it has been detected in the greens it

3226  
02:50:48,230 --> 02:50:46,140  
should be published in the next year so

3227  
02:50:52,309 --> 02:50:48,240  
so with all of this

3228  
02:50:54,469 --> 02:50:52,319  
in mind could Enceladus

3229  
02:50:57,530 --> 02:50:54,479  
Harbor life

3230  
02:51:00,230 --> 02:50:57,540  
we thought it would be sick to develop a

3231  
02:51:02,630 --> 02:51:00,240  
mission concept that would be capable of

3232  
02:51:04,670 --> 02:51:02,640  
finding out and so just a brief overview

3233  
02:51:06,230 --> 02:51:04,680  
of our mission architecture it's be it

3234  
02:51:07,429 --> 02:51:06,240  
multiply by missions where you're

3235  
02:51:09,950 --> 02:51:07,439  
orbiting Saturn and do multiple

3236  
02:51:12,050 --> 02:51:09,960  
flybysmen zeldas and we would require 30

3237  
02:51:14,570 --> 02:51:12,060  
flybys for our science and would launch

3238  
02:51:17,210 --> 02:51:14,580

in 2033 and after a nine-year cruise

3239

02:51:18,830 --> 02:51:17,220

phase and a one-year pump down phase we

3240

02:51:20,270 --> 02:51:18,840

would enter four years of science

3241

02:51:22,490 --> 02:51:20,280

operations

3242

02:51:24,830 --> 02:51:22,500

where we would directly search for

3243

02:51:27,530 --> 02:51:24,840

biosignatures through nsitu chemical

3244

02:51:30,250 --> 02:51:27,540

compositional analysis of the plume and

3245

02:51:32,750 --> 02:51:30,260

contextualize these in-situ measurement

3246

02:51:34,910 --> 02:51:32,760

in-situ measurements through a

3247

02:51:36,849 --> 02:51:34,920

synergistic combination of geophysical

3248

02:51:39,770 --> 02:51:36,859

and geomorphological investigations

3249

02:51:42,230 --> 02:51:39,780

aimed at also assessing the habitability

3250

02:51:43,910 --> 02:51:42,240

of Enceladus over geologic time

3251

02:51:45,830 --> 02:51:43,920

and we would do this using a mass

3252

02:51:48,830 --> 02:51:45,840

spectrometer a high resolution camera

3253

02:51:50,750 --> 02:51:48,840

and just a high gain antenna so three it

3254

02:51:51,889 --> 02:51:50,760

well two and a half instruments because

3255

02:51:54,349 --> 02:51:51,899

the antenna you use for radio

3256

02:51:56,630 --> 02:51:54,359

communications

3257

02:51:58,010 --> 02:51:56,640

and so just briefly to talk about how

3258

02:51:59,750 --> 02:51:58,020

before I dive into the science

3259

02:52:02,690 --> 02:51:59,760

objectives how these objectives were

3260

02:52:04,550 --> 02:52:02,700

formulated NASA

3261

02:52:07,790 --> 02:52:04,560

doesn't like

3262

02:52:09,469 --> 02:52:07,800

as much when people just when they're

3263

02:52:10,550 --> 02:52:09,479

developing missions to like take this

3264

02:52:12,110 --> 02:52:10,560

instrument okay we have the sick

3265

02:52:14,210 --> 02:52:12,120

instrument what kind of science can we

3266

02:52:16,490 --> 02:52:14,220

do with it instead

3267

02:52:18,950 --> 02:52:16,500

um we were taught and we were informed

3268

02:52:22,010 --> 02:52:18,960

that NASA prefers that you first start

3269

02:52:25,010 --> 02:52:22,020

by answering or by asking questions like

3270

02:52:27,250 --> 02:52:25,020

what do we not know about Enceladus what

3271

02:52:29,750 --> 02:52:27,260

do we need to know to ask more questions

3272

02:52:32,330 --> 02:52:29,760

and so that's what we started by doing

3273

02:52:33,590 --> 02:52:32,340

and if you do that if you start from the

3274

02:52:35,150 --> 02:52:33,600

science questions and what you're

3275

02:52:37,429 --> 02:52:35,160

interested in and what you want to find

3276

02:52:41,450 --> 02:52:37,439

out the rest of it follows pretty

3277

02:52:43,190 --> 02:52:41,460

logically and so say we want to find out

3278

02:52:45,290 --> 02:52:43,200

this thing okay what do we need to

3279

02:52:46,429 --> 02:52:45,300

measure to figure that thing out okay

3280

02:52:48,469 --> 02:52:46,439

then you have your measurement

3281

02:52:50,210 --> 02:52:48,479

requirements and then at what levels do

3282

02:52:52,010 --> 02:52:50,220

we need to measure this there you have

3283

02:52:53,450 --> 02:52:52,020

like further established measurement

3284

02:52:54,950 --> 02:52:53,460

requirements well how do we make these

3285

02:52:56,450 --> 02:52:54,960

measurements and then you select your

3286

02:52:58,790 --> 02:52:56,460

instruments and then so on and so forth

3287

02:53:00,590 --> 02:52:58,800

and so it just logically flows from it's

3288

02:53:03,349 --> 02:53:00,600

called a left to right approach

3289

02:53:05,510 --> 02:53:03,359

and so I'll talk a little bit about our

3290

02:53:07,429 --> 02:53:05,520

science objectives of course the first

3291

02:53:10,070 --> 02:53:07,439

which is to determine if the molecular

3292

02:53:12,050 --> 02:53:10,080

and isotopic distributions uh within the

3293

02:53:14,929 --> 02:53:12,060

plume are a result of biological

3294

02:53:16,730 --> 02:53:14,939

activity or abiotic chemical processing

3295

02:53:19,550 --> 02:53:16,740

and we would do this just with your

3296

02:53:21,710 --> 02:53:19,560

usual suspects amino acids fatty acids

3297

02:53:24,889 --> 02:53:21,720

and plume grains and um by assessing

3298

02:53:26,690 --> 02:53:24,899

isotopic fractionation in um in the

3299

02:53:28,250 --> 02:53:26,700

plume gas and we would do this just

3300

02:53:29,990 --> 02:53:28,260

using a mass spectrometer and if you

3301

02:53:31,490 --> 02:53:30,000

have any questions about Mass specs or

3302

02:53:33,889 --> 02:53:31,500

instrument selection please ask a

3303

02:53:35,389 --> 02:53:33,899

question or find me later I'd love to

3304

02:53:38,330 --> 02:53:35,399

talk about that

3305

02:53:40,370 --> 02:53:38,340

and the second of our objectives is to

3306

02:53:41,990 --> 02:53:40,380

determine whether Enceladus is in

3307

02:53:44,090 --> 02:53:42,000

thermal equilibrium and is therefore

3308

02:53:46,070 --> 02:53:44,100

capable of sustaining an ocean over

3309

02:53:47,750 --> 02:53:46,080

geologic time scales and this is

3310

02:53:49,969 --> 02:53:47,760

essentially just a heat balance equation

3311

02:53:52,370 --> 02:53:49,979

we want to know how much being how much

3312

02:53:54,590 --> 02:53:52,380

heat is being input to Enceladus through

3313

02:53:56,630 --> 02:53:54,600

tidal dissipation from Saturn and how

3314

02:53:59,990 --> 02:53:56,640

much heat is being emitted by Enceladus

3315

02:54:01,130 --> 02:54:00,000

through like um conductive heat loss and

3316

02:54:03,110 --> 02:54:01,140

you can

3317

02:54:08,809 --> 02:54:03,120

actually determine the heat being

3318

02:54:13,429 --> 02:54:11,630

looking at tidal dissipation from Saturn

3319

02:54:15,349 --> 02:54:13,439

and you can do this using orbital

3320

02:54:18,050 --> 02:54:15,359

migration rates so you could look at

3321

02:54:19,910 --> 02:54:18,060

where Enceladus is at in its orbital

3322

02:54:22,429 --> 02:54:19,920

phase relative to What was seen by

3323

02:54:24,610 --> 02:54:22,439

Cassini to see how the orbital migration

3324

02:54:27,710 --> 02:54:24,620

happens and

3325

02:54:29,870 --> 02:54:27,720

uh from that you could calculate a tidal

3326  
02:54:32,389 --> 02:54:29,880  
dissipation quality factor and you can

3327  
02:54:34,070 --> 02:54:32,399  
determine the heat being emitted by

3328  
02:54:35,929 --> 02:54:34,080  
measuring ice shell thickness which is a

3329  
02:54:39,290 --> 02:54:35,939  
proxy for the heat loss and you can do

3330  
02:54:43,190 --> 02:54:39,300  
that using a gravity signs measurements

3331  
02:54:45,349 --> 02:54:43,200  
the third of our objective objectives

3332  
02:54:46,969 --> 02:54:45,359  
is to looking at plume formation

3333  
02:54:48,650 --> 02:54:46,979  
mechanisms to determine whether the

3334  
02:54:51,590 --> 02:54:48,660  
plume material is being delivered to the

3335  
02:54:52,929 --> 02:54:51,600  
surface via open crevice boiling or

3336  
02:54:55,370 --> 02:54:52,939  
explosive

3337  
02:54:58,670 --> 02:54:55,380  
cryovolcanic-like eruptions

3338  
02:55:00,889 --> 02:54:58,680

and we expect there to be differences in

3339

02:55:02,990 --> 02:55:00,899

the morphology of the vents at the

3340

02:55:04,969 --> 02:55:03,000

surface that are expressed in each

3341

02:55:07,670 --> 02:55:04,979

scenario and you could

3342

02:55:09,830 --> 02:55:07,680

actually sort of tease out how these

3343

02:55:12,469 --> 02:55:09,840

plumes are being formed by high

3344

02:55:14,630 --> 02:55:12,479

resolution imaging of the fence so for

3345

02:55:16,030 --> 02:55:14,640

an open crevice model we expect there to

3346

02:55:19,010 --> 02:55:16,040

be

3347

02:55:20,870 --> 02:55:19,020

vent width variations in response to

3348

02:55:23,630 --> 02:55:20,880

Tidal forcing throughout enceladus's

3349

02:55:25,250 --> 02:55:23,640

orbital phase and for an open crevice

3350

02:55:27,110 --> 02:55:25,260

model we expect these vent width

3351  
02:55:28,550 --> 02:55:27,120  
variations to be consistent along the

3352  
02:55:30,050 --> 02:55:28,560  
strike of the vent

3353  
02:55:32,090 --> 02:55:30,060  
and so by taking multiple high

3354  
02:55:33,710 --> 02:55:32,100  
resolution images of a single vent

3355  
02:55:36,410 --> 02:55:33,720  
throughout in solidus's orbital phase

3356  
02:55:37,610 --> 02:55:36,420  
and looking at vent width variations we

3357  
02:55:39,590 --> 02:55:37,620  
can determine if that were the case

3358  
02:55:41,929 --> 02:55:39,600  
whereas for a purely cryovolcanic

3359  
02:55:44,389 --> 02:55:41,939  
eruptive model we expect these vent

3360  
02:55:46,490 --> 02:55:44,399  
width variations to be restricted to the

3361  
02:55:48,469 --> 02:55:46,500  
immediate vicinity of the vent

3362  
02:55:50,030 --> 02:55:48,479  
and so we could sort of tease out the

3363  
02:55:52,309 --> 02:55:50,040

relative contribution of each of these

3364

02:55:54,230 --> 02:55:52,319

models to plume formation

3365

02:55:55,550 --> 02:55:54,240

and then our fourth and final science

3366

02:55:58,070 --> 02:55:55,560

objective

3367

02:56:00,830 --> 02:55:58,080

is to determine if the geologic activity

3368

02:56:02,510 --> 02:56:00,840

that uh is modifying the South polar

3369

02:56:04,670 --> 02:56:02,520

terrain like we see in all those awesome

3370

02:56:07,969 --> 02:56:04,680

images uh if it's influenced other

3371

02:56:10,130 --> 02:56:07,979

regions in the past over geologic time

3372

02:56:11,990 --> 02:56:10,140

I'm going to do this by uh looking at

3373

02:56:14,750 --> 02:56:12,000

two things both crater infilling and

3374

02:56:17,510 --> 02:56:14,760

elliptical crater orientations because

3375

02:56:19,250 --> 02:56:17,520

if you look at the depth diameter ratios

3376

02:56:21,650 --> 02:56:19,260

of craters around the South polar

3377

02:56:23,570 --> 02:56:21,660

terrain they're pretty shallow compared

3378

02:56:25,790 --> 02:56:23,580

to the rest of the the crater population

3379

02:56:27,710 --> 02:56:25,800

because of all that plume Fallout that's

3380

02:56:29,809 --> 02:56:27,720

infilling the craters and so we see

3381

02:56:31,370 --> 02:56:29,819

really shallow craters around there

3382

02:56:33,349 --> 02:56:31,380

but if you look at the global crater

3383

02:56:35,210 --> 02:56:33,359

population like typically

3384

02:56:36,889 --> 02:56:35,220

um they have a pretty well defined depth

3385

02:56:39,050 --> 02:56:36,899

diameter ratio and so if we were to look

3386

02:56:43,250 --> 02:56:39,060

at survey the global crater population

3387

02:56:45,710 --> 02:56:43,260

and find an area around Enceladus where

3388

02:56:47,150 --> 02:56:45,720

we see anomalously infilled craters that

3389

02:56:49,429 --> 02:56:47,160

could be evidence that there was past

3390

02:56:51,769 --> 02:56:49,439

plume activity and another thing that we

3391

02:56:53,990 --> 02:56:51,779

would look at uh are elliptical crater

3392

02:56:55,790 --> 02:56:54,000

orientations to see if there could have

3393

02:56:58,550 --> 02:56:55,800

been any eye shell reorientation in the

3394

02:57:00,050 --> 02:56:58,560

past because given a preferential

3395

02:57:01,849 --> 02:57:00,060

velocity Vector in the impactor

3396

02:57:04,490 --> 02:57:01,859

population and a small enough impact

3397

02:57:06,889 --> 02:57:04,500

angle below about 15 degrees elliptical

3398

02:57:08,330 --> 02:57:06,899

craters are formed and so like given a

3399

02:57:11,090 --> 02:57:08,340

preferential velocity Vector we expect

3400

02:57:11,750 --> 02:57:11,100

to see mostly East-West

3401

02:57:14,870 --> 02:57:11,760

um

3402

02:57:17,330 --> 02:57:14,880

uh oriented elliptical craters

3403

02:57:21,349 --> 02:57:17,340

and so if we were to survey the crater

3404

02:57:23,150 --> 02:57:21,359

population and see a shift in the

3405

02:57:25,490 --> 02:57:23,160

orientation of these elliptical craters

3406

02:57:27,349 --> 02:57:25,500

that is like relatively consistent we

3407

02:57:30,349 --> 02:57:27,359

could infer past eye shell reorientation

3408

02:57:34,969 --> 02:57:32,990

and so for the mission trajectory

3409

02:57:37,070 --> 02:57:34,979

um briefly we would use a Venus Earth

3410

02:57:43,750 --> 02:57:37,080

Earth

3411

02:57:45,889 --> 02:57:43,760

where we would do we do a a

3412

02:57:47,510 --> 02:57:45,899

slingshot around Venus and then a couple

3413

02:57:49,130 --> 02:57:47,520

orbits around Earth and then slingshot

3414

02:57:50,809 --> 02:57:49,140

out to the Jupiter system and then use

3415

02:57:53,690 --> 02:57:50,819

Jupiter's gravity to slingshot out into

3416

02:57:56,269 --> 02:57:53,700

the Saturn system but

3417

02:57:58,610 --> 02:57:56,279

getting out to Saturn isn't a problem

3418

02:58:00,950 --> 02:57:58,620

it's slowing down that's the problem

3419

02:58:03,889 --> 02:58:00,960

because you're going like 15 20

3420

02:58:05,389 --> 02:58:03,899

kilometers a second and so after Saturn

3421

02:58:08,150 --> 02:58:05,399

orbital insertion

3422

02:58:10,309 --> 02:58:08,160

we do a one-year pump down phase and

3423

02:58:12,769 --> 02:58:10,319

using multiple use multiple flybys of

3424

02:58:16,130 --> 02:58:12,779

Titan using Titan's gravity to reduce

3425

02:58:18,889 --> 02:58:16,140

the spacecraft velocity and tailor the

3426

02:58:20,929 --> 02:58:18,899

inclination and altitude such that we

3427

02:58:23,570 --> 02:58:20,939

could Target and sell at us properly for

3428

02:58:24,889 --> 02:58:23,580

our flybys and then after that enter a

3429

02:58:26,450 --> 02:58:24,899

four year tour phase where we would

3430

02:58:30,349 --> 02:58:26,460

conduct all of our science operations

3431

02:58:33,170 --> 02:58:30,359

that would consist of 30 flybys at least

3432

02:58:35,330 --> 02:58:33,180

and this is this uh requirement is

3433

02:58:38,090 --> 02:58:35,340

driven primarily by our gravity science

3434

02:58:39,889 --> 02:58:38,100

measurements that we need to make and

3435

02:58:43,730 --> 02:58:39,899

the surface mapping would require a

3436

02:58:47,150 --> 02:58:43,740

total of 22 flybys um not necessarily 22

3437

02:58:50,570 --> 02:58:47,160

flybys total dedicated surface mapping

3438

02:58:53,929 --> 02:58:50,580

but the data downlink would require 22

3439

02:58:55,910 --> 02:58:53,939

flybys um and so a minimum of five

3440

02:58:58,010 --> 02:58:55,920

flybys at low altitudes as well for

3441

02:59:00,290 --> 02:58:58,020

event imagery and Institute Bloom

3442

02:59:02,870 --> 02:59:00,300

analyzes

3443

02:59:04,429 --> 02:59:02,880

so keyword to key takeaway uh and

3444

02:59:06,230 --> 02:59:04,439

solidus is sick it's super awesome

3445

02:59:09,590 --> 02:59:06,240

there's a lot of really cool stuff going

3446

02:59:11,750 --> 02:59:09,600

on there and we would

3447

02:59:14,030 --> 02:59:11,760

see what's going on there by looking at

3448

02:59:16,969 --> 02:59:14,040

plume composition heat balance the

3449

02:59:20,630 --> 02:59:16,979

different event formation mechanisms and

3450

02:59:22,550 --> 02:59:20,640

what the surface of Enceladus can tell

3451

02:59:24,290 --> 02:59:22,560

us about its past

3452

02:59:26,349 --> 02:59:24,300

and this is important because in the

3453

02:59:29,090 --> 02:59:26,359

most recent decadal survey

3454

02:59:32,269 --> 02:59:29,100

they specifically call out a New

3455

02:59:34,790 --> 02:59:32,279

Frontiers mission to Enceladus using a

3456

02:59:36,349 --> 02:59:34,800

multi-flyby mission architecture and so

3457

02:59:38,330 --> 02:59:36,359

there's so many outstanding questions

3458

02:59:39,889 --> 02:59:38,340

that we just we just don't know about

3459

02:59:43,010 --> 02:59:39,899

what's going on in Enceladus and we need

3460

02:59:45,550 --> 02:59:43,020

to go back to figure out what's going on

3461

02:59:49,130 --> 02:59:45,560

so as promised a little talk about PSS

3462

02:59:51,070 --> 02:59:49,140

this is my team that I worked with and

3463

02:59:53,510 --> 02:59:51,080

they're the most

3464

02:59:54,769 --> 02:59:53,520

absurdly brilliant group of people that

3465

02:59:56,150 --> 02:59:54,779

I've ever had the pleasure of working

3466

02:59:57,469 --> 02:59:56,160

with

3467

02:59:59,210 --> 02:59:57,479

um they're incredible I'm still friends

3468

03:00:01,490 --> 02:59:59,220

with many of them now

3469

03:00:03,410 --> 03:00:01,500

um and so I I'd like to talk a little

3470

03:00:05,809 --> 03:00:03,420

bit about the PSS

3471

03:00:08,030 --> 03:00:05,819

um it's uh it's not really as much of a

3472

03:00:10,849 --> 03:00:08,040

summer school as it is a rigorous

3473

03:00:14,269 --> 03:00:10,859

Mission design program where they teach

3474

03:00:15,950 --> 03:00:14,279

you how to actually formulate a mission

3475

03:00:18,050 --> 03:00:15,960

um and the deadlines pass for this year

3476

03:00:20,210 --> 03:00:18,060

but it's it's it's competitive you have

3477

03:00:21,950 --> 03:00:20,220

to apply for it and they take 18 people

3478

03:00:23,809 --> 03:00:21,960

per cohort

3479

03:00:25,730 --> 03:00:23,819

um but you get to work with literally

3480

03:00:27,950 --> 03:00:25,740

the best in the business

3481

03:00:30,349 --> 03:00:27,960

um you're mentored by people that are on

3482

03:00:32,330 --> 03:00:30,359

like Europa Clipper Mars sample return

3483

03:00:35,630 --> 03:00:32,340

all that kind of stuff and in the last

3484

03:00:39,410 --> 03:00:35,640

week you get to work one-on-one and are

3485

03:00:43,309 --> 03:00:39,420

mentored by a member of NASA's uh

3486

03:00:45,349 --> 03:00:43,319

Advanced project design team uh TMax

3487

03:00:47,630 --> 03:00:45,359

they're literally the best at what they

3488

03:00:50,090 --> 03:00:47,640

do formulating missions and you've

3489

03:00:50,809 --> 03:00:50,100

learned so much and it's incredible

3490

03:00:53,210 --> 03:00:50,819

um

3491

03:00:55,130 --> 03:00:53,220

if you have any questions please come

3492

03:00:56,570 --> 03:00:55,140

find me ask here or if you don't want to

3493

03:00:59,389 --> 03:00:56,580

ask a question in front of a bunch of

3494

03:01:02,330 --> 03:00:59,399

people come find me talk to me

3495

03:01:03,830 --> 03:01:02,340

um I knew when I first like was thinking

3496

03:01:04,910 --> 03:01:03,840

about doing it I was like oh my God I

3497

03:01:06,950 --> 03:01:04,920

don't know anything about Mission design

3498

03:01:08,809 --> 03:01:06,960

how am I going to do this but everybody

3499

03:01:10,309 --> 03:01:08,819

else in my court thought the exact same

3500

03:01:12,110 --> 03:01:10,319

thing so you don't need to be an expert

3501  
03:01:14,570 --> 03:01:12,120  
in Mission design you just need to be

3502  
03:01:16,190 --> 03:01:14,580  
interested and enthusiastic about doing

3503  
03:01:18,830 --> 03:01:16,200  
this stuff and this is the the most

3504  
03:01:21,170 --> 03:01:18,840  
incredible experience I've had of my

3505  
03:01:24,050 --> 03:01:21,180  
professional career so I would highly

3506  
03:01:34,309 --> 03:01:24,060  
highly recommend this program to anybody

3507  
03:01:43,790 --> 03:01:35,809  
yeah

3508  
03:01:48,290 --> 03:01:47,510  
hi Michael uh I'm from UCSD just up the

3509  
03:01:50,690 --> 03:01:48,300  
hill

3510  
03:01:54,530 --> 03:01:50,700  
um I was wondering

3511  
03:01:55,969 --> 03:01:54,540  
is there like how quickly or is it

3512  
03:02:00,710 --> 03:01:55,979  
plooming like is it going to run out of

3513  
03:02:06,650 --> 03:02:02,630

um well uh

3514

03:02:08,990 --> 03:02:06,660

it's been active for I mean Enceladus is

3515

03:02:11,809 --> 03:02:09,000

anywhere between like 100 million and

3516

03:02:14,570 --> 03:02:11,819

over one two billion years old

3517

03:02:17,990 --> 03:02:14,580

um and it's been like the e-ring around

3518

03:02:19,550 --> 03:02:18,000

Saturn is composed mostly of Enceladus

3519

03:02:21,710 --> 03:02:19,560

plume materials so we know it's been

3520

03:02:24,830 --> 03:02:21,720

around for a very very long time

3521

03:02:26,389 --> 03:02:24,840

and we also know that the ocean is is a

3522

03:02:28,010 --> 03:02:26,399

quite large

3523

03:02:31,309 --> 03:02:28,020

um and makes up a pretty significant

3524

03:02:34,730 --> 03:02:31,319

portion of the the mass of the Moon so I

3525

03:02:37,010 --> 03:02:34,740

I there's a not any evidence as far as

3526

03:02:38,809 --> 03:02:37,020

I'm concerned or as far as I know uh

3527

03:02:50,510 --> 03:02:38,819

that it's running out anytime soon and

3528

03:02:54,530 --> 03:02:52,250

I'm curious

3529

03:02:56,809 --> 03:02:54,540

um does this program kind of have a

3530

03:02:58,429 --> 03:02:56,819

component where you assess the costs of

3531

03:03:03,849 --> 03:02:58,439

certain missions and sort of optimize

3532

03:03:08,570 --> 03:03:06,710

that's the it's like the entire last

3533

03:03:11,150 --> 03:03:08,580

week is like the so the New Frontiers

3534

03:03:13,370 --> 03:03:11,160

five cost cap is 900 million and it

3535

03:03:17,150 --> 03:03:13,380

takes like 700 million to take a piece

3536

03:03:19,790 --> 03:03:17,160

of cardboard to Enceladus and so

3537

03:03:21,349 --> 03:03:19,800

and so yeah that's a huge part of it and

3538

03:03:23,510 --> 03:03:21,359

that's like a huge part of like working

3539

03:03:26,090 --> 03:03:23,520

with TMax is to try and do rapid

3540

03:03:28,849 --> 03:03:26,100

iterations of your your mission concept

3541

03:03:31,130 --> 03:03:28,859

to see what you can do and what trade

3542

03:03:34,490 --> 03:03:31,140

space you can explore to fall with under

3543

03:03:36,290 --> 03:03:34,500

the cost cap because the problem isn't

3544

03:03:38,030 --> 03:03:36,300

like finding all the science to do

3545

03:03:40,269 --> 03:03:38,040

because like there's so much science you

3546

03:03:44,030 --> 03:03:40,279

can do it's finding

3547

03:03:46,849 --> 03:03:44,040

what it's doing the most science for the

3548

03:03:50,269 --> 03:03:46,859

least money and so unfortunately that is

3549

03:03:51,410 --> 03:03:50,279

a massive part of of mission design and

3550

03:04:01,190 --> 03:03:51,420

formulation

3551

03:04:06,950 --> 03:04:04,130

hi uh Colin Robinson uh very man

3552

03:04:08,210 --> 03:04:06,960

University I I was just wondering uh I

3553

03:04:11,150 --> 03:04:08,220

know one of the big

3554

03:04:13,610 --> 03:04:11,160

hindrances to uh sampling Organics from

3555

03:04:16,250 --> 03:04:13,620

blooms and Enceladus is uh destruction

3556

03:04:18,530 --> 03:04:16,260

of Organics because in the sampling

3557

03:04:21,710 --> 03:04:18,540

processes right because of velocity and

3558

03:04:23,150 --> 03:04:21,720

you just go you know at high speeds

3559

03:04:24,769 --> 03:04:23,160

through the bloom with like a cup to

3560

03:04:26,750 --> 03:04:24,779

pick up all that stuff lots of Organics

3561

03:04:28,010 --> 03:04:26,760

are just gonna be obliterated so what

3562

03:04:30,410 --> 03:04:28,020

steps were you guys thinking of taking

3563

03:04:32,510 --> 03:04:30,420

to eliminate destruction of

3564

03:04:34,190 --> 03:04:32,520

biosignatures

3565

03:04:35,090 --> 03:04:34,200

thank you so much for asking that

3566

03:04:35,630 --> 03:04:35,100

question

3567

03:04:38,030 --> 03:04:35,640

um

3568

03:04:39,889 --> 03:04:38,040

I actually that's the research that I'm

3569

03:04:43,130 --> 03:04:39,899

doing at Caltech is we're simulating

3570

03:04:43,910 --> 03:04:43,140

hyper velocity impacts of eye screens

3571

03:04:45,650 --> 03:04:43,920

um

3572

03:04:48,650 --> 03:04:45,660

using impact ionization mass

3573

03:04:50,330 --> 03:04:48,660

spectrometry and we're the only lab in

3574

03:04:52,190 --> 03:04:50,340

the world that can do that at the moment

3575

03:04:54,650 --> 03:04:52,200

that can actually simulate a

3576

03:04:56,809 --> 03:04:54,660

distribution of I well I want to get

3577

03:04:58,670 --> 03:04:56,819

i'll nerd out too much come find me to

3578

03:05:01,670 --> 03:04:58,680

talk about that after after this if you

3579

03:05:04,490 --> 03:05:01,680

want but to answer your question yes

3580

03:05:07,670 --> 03:05:04,500

um there is a velocity regime where you

3581

03:05:09,170 --> 03:05:07,680

have both efficient ionization assuming

3582

03:05:11,389 --> 03:05:09,180

you're using an impact ionization Mass

3583

03:05:13,010 --> 03:05:11,399

spectrometer for analysis of plume

3584

03:05:15,889 --> 03:05:13,020

grains which is pretty necessary at this

3585

03:05:18,830 --> 03:05:15,899

stage yes there is a velocity regime

3586

03:05:21,230 --> 03:05:18,840

that you have efficient ionization and

3587

03:05:23,630 --> 03:05:21,240

molecular survivability for a range of

3588

03:05:27,170 --> 03:05:23,640

of compound classes and the

3589

03:05:29,510 --> 03:05:27,180

survivability velocity range is depends

3590

03:05:30,950 --> 03:05:29,520

on molecular functionality but it's

3591

03:05:32,750 --> 03:05:30,960

somewhere between four and six

3592

03:05:35,210 --> 03:05:32,760

kilometers per second it is like the

3593

03:05:36,950 --> 03:05:35,220

Goldilocks zone that you wanna that you

3594

03:05:39,710 --> 03:05:36,960

want to sample at so yes that's a

3595

03:05:41,330 --> 03:05:39,720

fantastic question and that is a problem

3596

03:05:43,730 --> 03:05:41,340

that a lot of very smart people are

3597

03:05:45,290 --> 03:05:43,740

trying to solve right now in in terms of

3598

03:05:47,630 --> 03:05:45,300

that speed four to six kilometers per

3599

03:05:49,070 --> 03:05:47,640

second uh is that fast enough to be able

3600

03:05:51,889 --> 03:05:49,080

to stay out of the gravitational pull of

3601  
03:05:53,030 --> 03:05:51,899  
Enceladus okay yeah Enceladus does it

3602  
03:05:55,550 --> 03:05:53,040  
there's not very much gravity there

3603  
03:06:00,889 --> 03:05:55,560  
exactly that's tiny yeah thank you no

3604  
03:06:07,150 --> 03:06:03,590  
uh hi I'm a river for paronica from Coco

3605  
03:06:12,110 --> 03:06:08,929  
quick question

3606  
03:06:14,769 --> 03:06:12,120  
um but why there it's like a open for

3607  
03:06:17,750 --> 03:06:14,779  
fracture for purposes uh cryova

3608  
03:06:21,429 --> 03:06:17,760  
volcanism is that going to

3609  
03:06:27,590 --> 03:06:21,439  
um impact the types of uh bio

3610  
03:06:31,429 --> 03:06:30,830  
very much so that's a fantastic question

3611  
03:06:33,349 --> 03:06:31,439  
um

3612  
03:06:36,050 --> 03:06:33,359  
in each case

3613  
03:06:39,650 --> 03:06:36,060

um the mechanism of plume formation

3614

03:06:41,030 --> 03:06:39,660

that's under underlying the surface

3615

03:06:42,590 --> 03:06:41,040

um

3616

03:06:45,950 --> 03:06:42,600

I'm trying to think of the best way to

3617

03:06:49,010 --> 03:06:45,960

say it but the way the grains are formed

3618

03:06:50,809 --> 03:06:49,020

actually strongly influences the

3619

03:06:53,150 --> 03:06:50,819

composition of the grains because you

3620

03:06:55,610 --> 03:06:53,160

have homogeneous nucleation where it's

3621

03:06:58,309 --> 03:06:55,620

you just have like water that just

3622

03:07:00,950 --> 03:06:58,319

freezes and is is shot out and like the

3623

03:07:02,870 --> 03:07:00,960

open crevice boiling situation

3624

03:07:05,090 --> 03:07:02,880

um where you have uh

3625

03:07:06,950 --> 03:07:05,100

a heterogeneous nucleation where you

3626  
03:07:09,710 --> 03:07:06,960  
have well I don't want to get too much

3627  
03:07:12,710 --> 03:07:09,720  
in the weeds but but uh yes

3628  
03:07:14,690 --> 03:07:12,720  
um for a an explosive cryovolcanic

3629  
03:07:17,990 --> 03:07:14,700  
scenario like you mentioned

3630  
03:07:19,969 --> 03:07:18,000  
um we wouldn't see very many

3631  
03:07:22,429 --> 03:07:19,979  
um compositional differences from grain

3632  
03:07:24,530 --> 03:07:22,439  
to grain whereas for the open crevice

3633  
03:07:27,710 --> 03:07:24,540  
boiling scenario due to the different

3634  
03:07:30,170 --> 03:07:27,720  
ice cream nucleation processes that that

3635  
03:07:32,090 --> 03:07:30,180  
could occur you would see very distinct

3636  
03:07:34,790 --> 03:07:32,100  
compositional differences in the grains

3637  
03:07:36,590 --> 03:07:34,800  
and we see that in the CDA data that's

3638  
03:07:38,090 --> 03:07:36,600

where all those the

3639

03:07:40,070 --> 03:07:38,100

um

3640

03:07:41,269 --> 03:07:40,080

evidence for those Organics that I was

3641

03:07:44,090 --> 03:07:41,279

talking about before those complex

3642

03:07:47,269 --> 03:07:44,100

Organics that comes from Ice grains that

3643

03:07:50,690 --> 03:07:47,279

are composed primarily of an organic

3644

03:07:53,750 --> 03:07:50,700

phase that were formed very likely

3645

03:07:55,190 --> 03:07:53,760

through open crevice boiling and so

3646

03:07:58,429 --> 03:07:55,200

um I guess that's a long answer to

3647

03:08:02,150 --> 03:07:58,439

saying yes that it very much matters

3648

03:08:06,230 --> 03:08:04,550

okay our lunch delivery is running a

3649

03:08:13,309 --> 03:08:06,240

little late so we have time for another

3650

03:08:17,210 --> 03:08:15,290

thanks Marshall I've heard this talk

3651  
03:08:19,190 --> 03:08:17,220  
many times you're welcome and every time

3652  
03:08:20,630 --> 03:08:19,200  
and every time it's enjoyable and every

3653  
03:08:23,510 --> 03:08:20,640  
time I feel like I ask the question

3654  
03:08:25,070 --> 03:08:23,520  
about uh what kind of mass spectrometer

3655  
03:08:28,550 --> 03:08:25,080  
are you going to include what kind of

3656  
03:08:31,070 --> 03:08:28,560  
resolution or msms capabilities do you

3657  
03:08:33,050 --> 03:08:31,080  
need to detect biosignatures get

3658  
03:08:35,690 --> 03:08:33,060  
isotopic information

3659  
03:08:38,090 --> 03:08:35,700  
get through matrices of the salt grains

3660  
03:08:40,550 --> 03:08:38,100  
crystals thank you you gave me an excuse

3661  
03:08:42,950 --> 03:08:40,560  
to talk about that now

3662  
03:08:45,290 --> 03:08:42,960  
um so for for the the

3663  
03:08:49,190 --> 03:08:45,300

gas the plume gas

3664

03:08:51,469 --> 03:08:49,200

um you need some sort of like a qitms or

3665

03:08:53,929 --> 03:08:51,479

like Mass specs type instrument that I'm

3666

03:08:57,170 --> 03:08:53,939

sure you're familiar with that stuff

3667

03:08:59,090 --> 03:08:57,180

um but where you need to be able to like

3668

03:09:01,730 --> 03:08:59,100

have a sample Inlet where you take gas

3669

03:09:03,170 --> 03:09:01,740

in and then you you determine the the

3670

03:09:06,530 --> 03:09:03,180

composition of that and that's really

3671

03:09:08,090 --> 03:09:06,540

necessary for uh assessing isotopic

3672

03:09:09,349 --> 03:09:08,100

fractionation

3673

03:09:12,230 --> 03:09:09,359

um because those typically have very

3674

03:09:13,969 --> 03:09:12,240

high mass resolution which you need for

3675

03:09:17,630 --> 03:09:13,979

looking at different isotope logs and

3676

03:09:20,809 --> 03:09:17,640

things whereas for the plume grains

3677

03:09:22,910 --> 03:09:20,819

um a lot of dust detectors don't have

3678

03:09:24,650 --> 03:09:22,920

the same mass resolution

3679

03:09:26,690 --> 03:09:24,660

um just due to the the way the

3680

03:09:28,969 --> 03:09:26,700

instruments are designed and but you

3681

03:09:31,730 --> 03:09:28,979

need information about the ice cream

3682

03:09:34,070 --> 03:09:31,740

composition because of all the cool

3683

03:09:35,809 --> 03:09:34,080

stuff is in the grains and the lower the

3684

03:09:38,750 --> 03:09:35,819

bigger the grains are the lower the

3685

03:09:40,969 --> 03:09:38,760

velocity the or the lower the altitude

3686

03:09:44,030 --> 03:09:40,979

uh the more interesting the grin

3687

03:09:46,969 --> 03:09:44,040

composition is and so you need

3688

03:09:48,769 --> 03:09:46,979

in theory you could just use one to

3689

03:09:50,510 --> 03:09:48,779

answer your question like a mass specs

3690

03:09:52,429 --> 03:09:50,520

type instrument

3691

03:09:54,110 --> 03:09:52,439

um where when I for those people that

3692

03:09:55,670 --> 03:09:54,120

don't know Mass specs is an acronym for

3693

03:09:57,469 --> 03:09:55,680

the mass spectrometer for planetary

3694

03:09:59,389 --> 03:09:57,479

expert well

3695

03:10:00,650 --> 03:09:59,399

enter export yes Mass Spectrum for

3696

03:10:02,630 --> 03:10:00,660

Planetary Exploration that's going to be

3697

03:10:07,250 --> 03:10:02,640

going on Europa clipper

3698

03:10:09,469 --> 03:10:07,260

um but that can do grains but those sort

3699

03:10:12,490 --> 03:10:09,479

of instruments have issues with some of

3700

03:10:15,410 --> 03:10:12,500

the more refractory Organics and some

3701

03:10:17,570 --> 03:10:15,420

inorganic species and so what you really

3702

03:10:19,969 --> 03:10:17,580

need to be able to do this given that

3703

03:10:22,490 --> 03:10:19,979

you have enough cost margin is you need

3704

03:10:23,929 --> 03:10:22,500

a dust detector or a grain like some

3705

03:10:25,610 --> 03:10:23,939

sort of impact ionization Mass

3706

03:10:28,070 --> 03:10:25,620

spectrometer that can utilize these

3707

03:10:29,570 --> 03:10:28,080

hyper velocity impacts as an ionization

3708

03:10:32,030 --> 03:10:29,580

source to determine ice grain

3709

03:10:33,950 --> 03:10:32,040

composition and also something where you

3710

03:10:35,630 --> 03:10:33,960

can assess the composition of the plume

3711

03:10:58,429 --> 03:10:35,640

gas as well

3712

03:11:04,550 --> 03:10:59,410

um

3713

03:11:08,870 --> 03:11:06,650

a couple of slides

3714

03:11:11,750 --> 03:11:08,880

um so it's in eccentric orbit the

3715

03:11:13,910 --> 03:11:11,760

various intric orbit around Saturn and

3716

03:11:15,469 --> 03:11:13,920

so if you look at I don't know can you

3717

03:11:18,530 --> 03:11:15,479

see the the curse okay yeah you can

3718

03:11:21,050 --> 03:11:18,540

right here see that little Green Dot

3719

03:11:23,809 --> 03:11:21,060

um that's where the their every orbit

3720

03:11:25,370 --> 03:11:23,819

you do like a small burn where you use a

3721

03:11:27,889 --> 03:11:25,380

little bit of fuel to make sure that you

3722

03:11:29,809 --> 03:11:27,899

stay uh in the orbit that you need to

3723

03:11:31,610 --> 03:11:29,819

actually do these measurements and so

3724

03:11:33,650 --> 03:11:31,620

it's not as huge of a deal and doesn't

3725

03:11:36,769 --> 03:11:33,660

require like a ton of Delta V or like

3726

03:11:38,269 --> 03:11:36,779

change in velocity of the spacecraft

3727

03:11:39,889 --> 03:11:38,279

um but no that is something to consider

3728

03:11:42,349 --> 03:11:39,899

and though you're right and that is

3729

03:11:43,670 --> 03:11:42,359

something that we took into account when

3730

03:11:50,630 --> 03:11:43,680

doing all these uh the orbital

3731

03:11:55,610 --> 03:11:53,389

uh so the that's before we actually

3732

03:11:57,889 --> 03:11:55,620

start science operations

3733

03:12:00,530 --> 03:11:57,899

um because upon

3734

03:12:02,870 --> 03:12:00,540

Saturn orbital insertion

3735

03:12:05,990 --> 03:12:02,880

um we're going too fast

3736

03:12:08,510 --> 03:12:06,000

um and the the spacecraft the

3737

03:12:09,590 --> 03:12:08,520

inclination altitude geometry things

3738

03:12:11,690 --> 03:12:09,600

like that

3739

03:12:13,550 --> 03:12:11,700

um aren't suitable to immediately enter

3740

03:12:16,429 --> 03:12:13,560

science operations to start doing

3741

03:12:19,010 --> 03:12:16,439

targeted Enceladus flybys and so we need

3742

03:12:21,650 --> 03:12:19,020

to use Titan's gravity to further slow

3743

03:12:23,150 --> 03:12:21,660

down so we can get within that goldilock

3744

03:12:25,070 --> 03:12:23,160

zone that we talked about before for

3745

03:12:27,170 --> 03:12:25,080

sampling

3746

03:12:28,269 --> 03:12:27,180

thank you

3747

03:12:43,190 --> 03:12:28,279

okay

3748

03:13:09,849 --> 03:12:43,200

in Surfside and then we'll reconvene

3749

03:13:09,859 --> 03:13:23,870

all right

3750

03:13:23,880 --> 03:13:38,630

[Music]

3751  
03:13:38,640 --> 03:13:54,070  
foreign

3752  
03:13:54,080 --> 03:14:10,870  
[Music]

3753  
03:14:10,880 --> 03:14:18,510  
thank you

3754  
03:14:18,520 --> 03:14:38,510  
[Music]

3755  
03:14:52,870 --> 03:14:41,200  
foreign

3756  
03:16:01,849 --> 03:15:01,400  
[Music]

3757  
03:16:01,859 --> 03:16:06,590  
foreign

3758  
03:16:06,600 --> 03:16:34,730  
[Music]

3759  
03:16:34,740 --> 03:16:39,840  
foreign

3760  
03:17:21,290 --> 03:17:07,210  
[Music]

3761  
03:17:21,300 --> 03:17:24,150  
foreign

3762  
03:18:06,710 --> 03:17:39,220  
[Music]

3763  
03:18:06,720 --> 03:18:10,650

foreign

3764

03:18:22,969 --> 03:18:16,990

[Music]

3765

03:18:22,979 --> 03:18:27,030

foreign

3766

03:19:41,890 --> 03:18:54,730

[Music]

3767

03:20:05,160 --> 03:19:41,900

foreign

3768

03:20:05,170 --> 03:20:26,330

[Music]

3769

03:20:26,340 --> 03:20:30,320

thank you

3770

03:20:51,530 --> 03:20:46,740

[Music]

3771

03:20:58,010 --> 03:20:52,920

foreign

3772

03:22:08,690 --> 03:21:20,030

[Music]

3773

03:22:08,700 --> 03:22:14,920

foreign

3774

03:22:45,830 --> 03:22:38,640

[Music]

3775

03:23:18,930 --> 03:22:45,840

foreign

3776  
03:23:57,650 --> 03:23:44,080  
[Music]

3777  
03:24:11,770 --> 03:24:00,510  
foreign

3778  
03:25:43,729 --> 03:24:18,220  
[Music]

3779  
03:25:43,739 --> 03:25:48,620  
foreign

3780  
03:26:53,510 --> 03:25:57,470  
[Music]

3781  
03:26:55,610 --> 03:26:53,520  
thank you

3782  
03:27:13,870 --> 03:26:55,620  
foreign

3783  
03:28:14,720 --> 03:27:42,720  
[Music]

3784  
03:29:02,720 --> 03:28:14,730  
foreign

3785  
03:29:26,690 --> 03:29:18,720  
[Music]

3786  
03:29:26,700 --> 03:29:34,720  
foreign

3787  
03:30:31,020 --> 03:29:50,720  
[Music]

3788  
03:30:38,740 --> 03:30:31,030

thank you

3789

03:32:59,510 --> 03:30:45,190

[Music]

3790

03:32:59,520 --> 03:33:02,740

foreign

3791

03:33:43,020 --> 03:33:41,570

[Music]

3792

03:33:50,730 --> 03:33:43,030

thank you

3793

03:34:10,720 --> 03:34:04,080

[Music]

3794

03:34:22,730 --> 03:34:10,730

foreign

3795

03:35:54,590 --> 03:34:38,730

[Music]

3796

03:35:54,600 --> 03:35:59,540

thank you

3797

03:36:37,490 --> 03:36:14,730

[Music]

3798

03:37:03,810 --> 03:36:38,940

foreign

3799

03:37:35,640 --> 03:37:34,269

[Music]

3800

03:37:49,490 --> 03:37:35,650

thank you

3801  
03:38:46,310 --> 03:37:49,500  
[Music]

3802  
03:38:53,170 --> 03:38:46,320  
thank you

3803  
03:38:53,180 --> 03:39:00,110  
[Music]

3804  
03:39:24,460 --> 03:39:02,820  
foreign

3805  
03:39:24,470 --> 03:39:56,030  
[Music]

3806  
03:40:08,090 --> 03:39:58,650  
foreign

3807  
03:40:10,190 --> 03:40:08,100  
[Music]

3808  
03:40:20,970 --> 03:40:10,200  
foreign

3809  
03:41:06,290 --> 03:40:29,970  
[Music]

3810  
03:41:22,490 --> 03:41:06,300  
thank you

3811  
03:41:25,120 --> 03:41:22,500  
[Music]

3812  
03:42:00,090 --> 03:41:25,130  
foreign

3813  
03:42:39,410 --> 03:42:36,769

[Music]

3814

03:43:11,690 --> 03:42:39,420

foreign

3815

03:43:49,790 --> 03:43:26,030

[Music]

3816

03:43:49,800 --> 03:43:53,870

foreign

3817

03:44:59,990 --> 03:44:19,910

[Music]

3818

03:45:55,610 --> 03:45:00,000

foreign

3819

03:46:08,750 --> 03:45:55,620

[Music]

3820

03:46:27,110 --> 03:46:10,540

foreign

3821

03:47:23,870 --> 03:46:55,340

[Music]

3822

03:47:35,370 --> 03:47:26,150

foreign

3823

03:48:22,070 --> 03:48:03,600

[Music]

3824

03:48:33,630 --> 03:48:22,080

foreign

3825

03:49:19,340 --> 03:48:35,630

[Music]

3826  
03:49:50,929 --> 03:49:19,350  
foreign

3827  
03:49:53,110 --> 03:49:50,939  
[Music]

3828  
03:50:03,600 --> 03:49:53,120  
foreign

3829  
03:50:03,610 --> 03:51:00,910  
[Music]

3830  
03:51:05,090 --> 03:51:02,720  
thank you

3831  
03:51:59,090 --> 03:51:05,100  
[Music]

3832  
03:51:59,100 --> 03:52:02,190  
foreign

3833  
03:52:17,390 --> 03:52:15,110  
[Music]

3834  
03:52:45,360 --> 03:52:17,400  
foreign

3835  
03:53:45,220 --> 03:52:50,970  
[Music]

3836  
03:54:04,870 --> 03:53:45,230  
thank you

3837  
03:55:27,189 --> 03:54:17,650  
[Music]

3838  
03:55:47,410 --> 03:55:29,970

thank you

3839

03:56:31,070 --> 03:55:49,370

[Music]

3840

03:56:31,080 --> 03:56:38,750

thank you

3841

03:57:01,560 --> 03:56:56,890

[Music]

3842

03:57:11,410 --> 03:57:01,570

foreign

3843

03:57:39,750 --> 03:57:18,510

[Music]

3844

03:58:11,630 --> 03:57:39,760

thank you

3845

03:58:11,640 --> 03:58:15,040

foreign

3846

03:58:54,050 --> 03:58:22,180

[Music]

3847

03:58:54,060 --> 03:58:59,600

foreign

3848

03:59:24,490 --> 03:59:12,580

[Music]

3849

03:59:38,620 --> 03:59:24,500

foreign

3850

04:00:06,710 --> 03:59:47,500

[Music]

3851  
04:00:26,690 --> 04:00:09,240  
foreign

3852  
04:00:26,700 --> 04:00:39,349  
[Music]

3853  
04:00:39,359 --> 04:00:44,310  
foreign

3854  
04:01:38,290 --> 04:01:05,900  
[Music]

3855  
04:01:51,469 --> 04:01:40,810  
thank you

3856  
04:02:10,340 --> 04:01:53,960  
foreign

3857  
04:02:33,200 --> 04:02:28,870  
[Music]

3858  
04:02:46,280 --> 04:02:33,210  
thank you

3859  
04:03:08,030 --> 04:03:02,740  
[Music]

3860  
04:03:21,230 --> 04:03:08,040  
foreign

3861  
04:03:53,630 --> 04:03:37,650  
[Music]

3862  
04:04:05,330 --> 04:03:56,140  
foreign

3863  
04:04:05,340 --> 04:04:26,710

[Music]

3864

04:05:16,010 --> 04:04:28,090

thank you

3865

04:06:10,550 --> 04:05:29,330

[Music]

3866

04:06:10,560 --> 04:06:13,630

thank you

3867

04:06:47,269 --> 04:06:22,790

[Music]

3868

04:06:47,279 --> 04:06:53,990

foreign

3869

04:07:20,430 --> 04:07:13,430

[Music]

3870

04:07:30,510 --> 04:07:20,440

foreign

3871

04:07:59,330 --> 04:07:46,490

[Music]

3872

04:07:59,340 --> 04:08:03,280

foreign

3873

04:08:28,670 --> 04:08:16,010

[Music]

3874

04:08:30,830 --> 04:08:28,680

hey let's calm down a little bit but get

3875

04:08:32,870 --> 04:08:30,840

excited for Stellar science

3876

04:08:34,610 --> 04:08:32,880

I'd like to go ahead and start our next

3877

04:08:36,830 --> 04:08:34,620

session

3878

04:08:39,349 --> 04:08:36,840

these are short socks all right

3879

04:08:40,910 --> 04:08:39,359

everyone's listening now okay and I want

3880

04:08:42,590 --> 04:08:40,920

to preface this again just like

3881

04:08:44,150 --> 04:08:42,600

yesterday's short talk sessions these

3882

04:08:45,349 --> 04:08:44,160

are going to be short six minute talks

3883

04:08:47,630 --> 04:08:45,359

there will be no time for questions

3884

04:08:50,030 --> 04:08:47,640

after but these presenters will also

3885

04:08:52,130 --> 04:08:50,040

have posters outside at the poster

3886

04:08:54,110 --> 04:08:52,140

session directly afterwards okay so save

3887

04:08:56,150 --> 04:08:54,120

your questions for them

3888

04:09:01,689 --> 04:08:56,160

and without further ado I'd like to

3889

04:09:08,030 --> 04:09:06,349  
from Ohio University Athens

3890

04:09:13,910 --> 04:09:08,040  
thank you

3891

04:09:17,990 --> 04:09:16,790  
from Ohio University I'm a space

3892

04:09:24,889 --> 04:09:18,000  
biologist

3893

04:09:27,110 --> 04:09:24,899  
that we send plant samples to space

3894

04:09:28,969 --> 04:09:27,120  
and I will try to see how those plant

3895

04:09:30,110 --> 04:09:28,979  
samples adapt to the space flight

3896

04:09:32,750 --> 04:09:30,120  
environment

3897

04:09:37,010 --> 04:09:32,760  
and then we use information from these

3898

04:09:39,830 --> 04:09:37,020  
to make them better adapt to a stream

3899

04:09:43,250 --> 04:09:39,840  
environment on earth or to also prepare

3900

04:09:45,070 --> 04:09:43,260  
how we can cultivate plants in space for

3901  
04:09:51,769 --> 04:09:45,080  
future

3902  
04:09:54,650 --> 04:09:51,779  
and so I work on arabidopsis plants

3903  
04:09:58,250 --> 04:09:54,660  
which is a model plant it's what E coli

3904  
04:10:01,070 --> 04:09:58,260  
is to microbiologists and um its model

3905  
04:10:04,010 --> 04:10:01,080  
because it's uh also the genome

3906  
04:10:07,429 --> 04:10:04,020  
sequenced already and so we can easily

3907  
04:10:10,670 --> 04:10:07,439  
trace a particular phenotype to a

3908  
04:10:14,030 --> 04:10:10,680  
particular genotype so to the right up

3909  
04:10:16,969 --> 04:10:14,040  
there is what the arabidosis siblings

3910  
04:10:20,330 --> 04:10:16,979  
look like after we get them back from

3911  
04:10:22,910 --> 04:10:20,340  
the space environment in this case I

3912  
04:10:26,689 --> 04:10:22,920  
mean about the International Space

3913  
04:10:30,170 --> 04:10:26,699

Station at the lower Hutt orbit where we

3914

04:10:32,750 --> 04:10:30,180

have zero gravity microgravity and where

3915

04:10:35,090 --> 04:10:32,760

we have ionizing radiation and altered

3916

04:10:37,849 --> 04:10:35,100

flue gas Dynamics as one of the

3917

04:10:40,969 --> 04:10:37,859

extremities in that environment so

3918

04:10:43,070 --> 04:10:40,979

basically we send seed to space we let

3919

04:10:45,229 --> 04:10:43,080

those seeds germinate in space we let

3920

04:10:47,630 --> 04:10:45,239

them grow for few days we freeze them

3921

04:10:50,590 --> 04:10:47,640

and we return them to Earth and when

3922

04:10:53,929 --> 04:10:50,600

they get part of Hearts I analyze them

3923

04:10:57,229 --> 04:10:53,939

transcriptomics and proteomics to make

3924

04:10:59,830 --> 04:10:57,239

uh to make sense of our such plant

3925

04:11:03,050 --> 04:10:59,840

adapts to the space flight environment

3926

04:11:05,450 --> 04:11:03,060

and for uh us to conduct specified

3927

04:11:09,050 --> 04:11:05,460

environment we use different AdWords as

3928

04:11:11,750 --> 04:11:09,060

you can see on top

3929

04:11:14,150 --> 04:11:11,760

on top Air is the advanced plant habitat

3930

04:11:16,090 --> 04:11:14,160

that's the the most desirable Hardware

3931

04:11:19,849 --> 04:11:16,100

currently for almost everyone

3932

04:11:21,830 --> 04:11:19,859

researching uh space plant biology and

3933

04:11:24,349 --> 04:11:21,840

here we have the brick

3934

04:11:25,910 --> 04:11:24,359

break Hardware I love using the brick

3935

04:11:27,769 --> 04:11:25,920

it's got the name from the fact that

3936

04:11:29,990 --> 04:11:27,779

it's it looks like a brick Block it's

3937

04:11:32,510 --> 04:11:30,000

biological research in canister I work

3938

04:11:35,090 --> 04:11:32,520

with it and this is the European modular

3939

04:11:37,130 --> 04:11:35,100

cultivation system it being retired

3940

04:11:40,130 --> 04:11:37,140

currently and being replaced by the

3941

04:11:43,429 --> 04:11:40,140

multivariable platform so these are just

3942

04:11:45,950 --> 04:11:43,439

a few of the many Hardwares that we used

3943

04:11:49,130 --> 04:11:45,960

to send specimen to space plants micro

3944

04:11:52,849 --> 04:11:49,140

but in this case we we use this to stand

3945

04:11:56,750 --> 04:11:52,859

up plant to space

3946

04:11:59,030 --> 04:11:56,760

uh the first multi-homix are experiments

3947

04:12:01,309 --> 04:11:59,040

conducted on plant Central space was

3948

04:12:04,490 --> 04:12:01,319

conducted by my lab and then we

3949

04:12:07,130 --> 04:12:04,500

discovered that uh comparing the look

3950

04:12:09,410 --> 04:12:07,140

for change of the transcript that's the

3951

04:12:12,229 --> 04:12:09,420

RNA to the look for change of the

3952

04:12:14,689 --> 04:12:12,239

protein while plotting a correlation

3953

04:12:16,969 --> 04:12:14,699

graph of it we discovered very low

3954

04:12:18,950 --> 04:12:16,979

correlation between differentially

3955

04:12:21,650 --> 04:12:18,960

expressed transcripts and differentially

3956

04:12:24,410 --> 04:12:21,660

abundant protein which is uh indicative

3957

04:12:27,830 --> 04:12:24,420

of the fact that post-transcriptional

3958

04:12:30,290 --> 04:12:27,840

modification of transcript is one of the

3959

04:12:33,710 --> 04:12:30,300

Adaptive mechanism of plants to space

3960

04:12:38,030 --> 04:12:33,720

flight environment that means not all

3961

04:12:41,030 --> 04:12:38,040

RNA gets to become protein and that also

3962

04:12:43,370 --> 04:12:41,040

net it's it's underscore the need for us

3963

04:12:45,469 --> 04:12:43,380

to study procurements to conduct

3964

04:12:47,870 --> 04:12:45,479

proteomic studies of these plants that

3965

04:12:50,269 --> 04:12:47,880

we send to space because the proteomies

3966

04:12:52,010 --> 04:12:50,279

will probably give more insight into the

3967

04:12:55,309 --> 04:12:52,020

Adaptive mechanism than the

3968

04:12:58,429 --> 04:12:55,319

transcriptomics unfortunately because

3969

04:13:01,429 --> 04:12:58,439

protonic study uh require large tissue

3970

04:13:03,590 --> 04:13:01,439

Mass which we don't have the luxury of

3971

04:13:06,410 --> 04:13:03,600

having large tissue large plants sent to

3972

04:13:09,590 --> 04:13:06,420

space most people conduct just

3973

04:13:12,349 --> 04:13:09,600

transcriptomic study until date globally

3974

04:13:16,490 --> 04:13:12,359

only for protonic study have been

3975

04:13:19,130 --> 04:13:16,500

conducted on arabidosis and about ISS

3976

04:13:21,590 --> 04:13:19,140

and these are the four protonic studies

3977

04:13:25,010 --> 04:13:21,600

uh different environments are different

3978

04:13:27,410 --> 04:13:25,020

uh conditions different variables uh age

3979

04:13:31,429 --> 04:13:27,420

of the plants out where uh light

3980

04:13:33,830 --> 04:13:31,439

condition seed line used the tissue type

3981

04:13:36,849 --> 04:13:33,840

and the type of protein extracted they

3982

04:13:39,229 --> 04:13:36,859

vary across all those uh four

3983

04:13:41,150 --> 04:13:39,239

experiments two of those experiments

3984

04:13:43,070 --> 04:13:41,160

were conducted on the lab I'm the one in

3985

04:13:47,870 --> 04:13:43,080

charge of the last one in red called The

3986

04:13:51,650 --> 04:13:47,880

Brick LED uh project so to get idea of

3987

04:13:53,750 --> 04:13:51,660

um what's uh the uh to get idea of

3988

04:13:55,550 --> 04:13:53,760

plants response on the the protonic

3989

04:13:58,189 --> 04:13:55,560

level to the space flight environment

3990

04:14:00,710 --> 04:13:58,199

based on these are field data set we

3991

04:14:03,110 --> 04:14:00,720

have to do what we call meta-analysis of

3992

04:14:04,809 --> 04:14:03,120

the protonic data set from this of the

3993

04:14:07,429 --> 04:14:04,819

protonic data sets from these four

3994

04:14:09,969 --> 04:14:07,439

experiment and that's what I do so this

3995

04:14:13,570 --> 04:14:09,979

is the first stage of the metal

3996

04:14:17,689 --> 04:14:13,580

analysis so we start from the left ear

3997

04:14:20,689 --> 04:14:17,699

are we intersected the protein

3998

04:14:23,570 --> 04:14:20,699

um abundance about the detected protein

3999

04:14:25,910 --> 04:14:23,580

across all the four Hardwares and common

4000

04:14:28,910 --> 04:14:25,920

to the protein across all the four

4001

04:14:31,370 --> 04:14:28,920

Hardware these are three proteins

4002

04:14:33,710 --> 04:14:31,380

which are pick up one that's the

4003

04:14:35,809 --> 04:14:33,720

microtubule destabilizing protein which

4004

04:14:38,809 --> 04:14:35,819

is involved in chromosome separation

4005

04:14:41,450 --> 04:14:38,819

during cell division it involves

4006

04:14:43,550 --> 04:14:41,460

information of um cell shape and it's

4007

04:14:46,309 --> 04:14:43,560

also involved in a transport vesicular

4008

04:14:47,990 --> 04:14:46,319

transport implant and also we we

4009

04:14:50,809 --> 04:14:48,000

discovered the comment of these four

4010

04:14:53,030 --> 04:14:50,819

four data sets our protein is that the

4011

04:14:58,130 --> 04:14:53,040

protein involving defense response and

4012

04:15:02,389 --> 04:14:58,140

mRNA binding now I went a step further

4013

04:15:05,150 --> 04:15:02,399

and isolated uh the data set called emcs

4014

04:15:07,849 --> 04:15:05,160

which is a the data set called abrs

4015

04:15:09,349 --> 04:15:07,859

Advanced biological research system I

4016

04:15:11,870 --> 04:15:09,359

isolated it

4017

04:15:14,990 --> 04:15:11,880

from the data from the general data set

4018

04:15:18,349 --> 04:15:15,000

because it uh they use the mutant seed

4019

04:15:21,170 --> 04:15:18,359

line so I I only call I compared those

4020

04:15:24,410 --> 04:15:21,180

seed lines that were the wide type and

4021

04:15:26,570 --> 04:15:24,420

from intersection of the three data set

4022

04:15:28,910 --> 04:15:26,580

that com that you know that use our seed

4023

04:15:32,030 --> 04:15:28,920

lines that are white type we have these

4024

04:15:34,090 --> 04:15:32,040

eight proteins and here are the air the

4025

04:15:37,250 --> 04:15:34,100

proteins so conducting the protein

4026

04:15:40,790 --> 04:15:37,260

protein uh interaction network analysis

4027

04:15:43,429 --> 04:15:40,800

we see that regulation of microtubule

4028

04:15:47,389 --> 04:15:43,439

microtubule destabilization microtubule

4029

04:15:50,330 --> 04:15:47,399

rearrangement is a major adaptation uh

4030

04:15:52,849 --> 04:15:50,340

mechanism of plants to the extreme space

4031

04:15:55,429 --> 04:15:52,859

flight environment and one thing we

4032

04:15:57,530 --> 04:15:55,439

notice in phenotype of plants that we

4033

04:16:01,189 --> 04:15:57,540

grow in space is that they are usually

4034

04:16:03,530 --> 04:16:01,199

uh smaller looking less healthy compared

4035

04:16:05,750 --> 04:16:03,540

to those grown on Earth where we have

4036

04:16:08,990 --> 04:16:05,760

the full gravity and there are no

4037

04:16:10,750 --> 04:16:09,000

ionizing radiation now I went further to

4038

04:16:13,610 --> 04:16:10,760

compare the

4039

04:16:15,590 --> 04:16:13,620

brick data set which are the one that we

4040

04:16:18,050 --> 04:16:15,600

conducted in our lab and we can be so

4041

04:16:20,809 --> 04:16:18,060

sure of so we have two of them we have

4042

04:16:23,210 --> 04:16:20,819

the brick LED which were conducted in

4043

04:16:25,849 --> 04:16:23,220

light you know this brick LED Hardware

4044

04:16:29,330 --> 04:16:25,859

add light in it and we have the brick

4045

04:16:31,610 --> 04:16:29,340

PDF view which had no light so all these

4046

04:16:34,250 --> 04:16:31,620

plants this experiment were both flown

4047

04:16:36,889 --> 04:16:34,260

to space uh weapon were both flew into

4048

04:16:40,130 --> 04:16:36,899

space but won't add light one add more

4049

04:16:43,490 --> 04:16:40,140

light both of them had no gravity are

4050

04:16:46,849 --> 04:16:43,500

they so at The Intercept of them

4051  
04:16:48,290 --> 04:16:46,859  
the protein here 186 of them would

4052  
04:16:50,809 --> 04:16:48,300  
definitely be due to the space flight

4053  
04:16:52,610 --> 04:16:50,819  
environment while the protein here will

4054  
04:16:55,309 --> 04:16:52,620  
be due to photomorphogenesis that is

4055  
04:16:57,590 --> 04:16:55,319  
growth in light cross-interacting

4056  
04:16:59,929 --> 04:16:57,600  
protein maybe between the hardware and

4057  
04:17:01,490 --> 04:16:59,939  
growth and light and Elusive protein due

4058  
04:17:03,530 --> 04:17:01,500  
to the advanced technology that we use

4059  
04:17:06,229 --> 04:17:03,540  
on the brick LED compared to the brick

4060  
04:17:08,689 --> 04:17:06,239  
PDF view why the protein here are those

4061  
04:17:11,210 --> 04:17:08,699  
involved in scotomorphogenesis growth in

4062  
04:17:13,610 --> 04:17:11,220  
darkness and cross-interacting protein

4063  
04:17:15,530 --> 04:17:13,620

now I call this protein due to space

4064

04:17:18,290 --> 04:17:15,540

flight environment I call them the brick

4065

04:17:20,590 --> 04:17:18,300

intercept so comparing the brick

4066

04:17:23,750 --> 04:17:20,600

intercept this is the brick intercept

4067

04:17:25,550 --> 04:17:23,760

comparing it with another data set from

4068

04:17:29,510 --> 04:17:25,560

the European modular cultivation system

4069

04:17:30,710 --> 04:17:29,520

where they add a centrifuge about the

4070

04:17:33,469 --> 04:17:30,720

International Space Station one

4071

04:17:34,610 --> 04:17:33,479

decentric food having the 1G centrifuge

4072

04:17:38,030 --> 04:17:34,620

above International Space Station

4073

04:17:42,650 --> 04:17:38,040

eliminates microgravity so it introduced

4074

04:17:45,769 --> 04:17:42,660

1G gravity so this data set emcs

4075

04:17:47,630 --> 04:17:45,779

as as excluded microgravity and

4076

04:17:50,870 --> 04:17:47,640

everything in this data set is radiation

4077

04:17:53,389 --> 04:17:50,880

so comparing our intersecting this brick

4078

04:17:55,790 --> 04:17:53,399

intercept with this emcs data set

4079

04:17:59,030 --> 04:17:55,800

whatever is in the middle here will

4080

04:18:01,790 --> 04:17:59,040

definitely be due to radiation or

4081

04:18:04,010 --> 04:18:01,800

altered fluid gas Dynamic you know in

4082

04:18:06,530 --> 04:18:04,020

the absence of gravity plants don't pick

4083

04:18:08,990 --> 04:18:06,540

water the same way that we do on Earth

4084

04:18:11,389 --> 04:18:09,000

and whatever we have here is due to

4085

04:18:13,370 --> 04:18:11,399

microgravity definitely and whatever we

4086

04:18:16,729 --> 04:18:13,380

have here proteins here are due to the

4087

04:18:19,130 --> 04:18:16,739

emcs hardware and cross interaction now

4088

04:18:22,189 --> 04:18:19,140

doing a protein protein interaction a

4089

04:18:24,710 --> 04:18:22,199

network of the uh proteins that we

4090

04:18:27,769 --> 04:18:24,720

believe are due to radiation we see that

4091

04:18:30,769 --> 04:18:27,779

ah most of them are involved in ribosome

4092

04:18:33,170 --> 04:18:30,779

assembly ribosome biogenesis and um

4093

04:18:36,229 --> 04:18:33,180

ribosome biogenesis and protein

4094

04:18:38,330 --> 04:18:36,239

translational Machinery so one takeaway

4095

04:18:41,290 --> 04:18:38,340

from this is that arabidosis ribosomal

4096

04:18:45,170 --> 04:18:41,300

activity is altered by space flight

4097

04:18:46,910 --> 04:18:45,180

ionizing radiation So currently I'm I'm

4098

04:18:49,490 --> 04:18:46,920

comparing the transcriptomic data

4099

04:18:51,170 --> 04:18:49,500

between these two data sets and we're

4100

04:18:54,050 --> 04:18:51,180

also trying to do a wet lab

4101

04:18:56,450 --> 04:18:54,060

determination of the specific role of

4102

04:18:59,830 --> 04:18:56,460

this intersecting protein so we're

4103

04:19:02,870 --> 04:18:59,840

hoping to collaboration on our protonic

4104

04:19:04,490 --> 04:19:02,880

meta-analysis of this uh space flight

4105

04:19:07,630 --> 04:19:04,500

stuff there are a lot of things that

4106

04:19:10,010 --> 04:19:07,640

could be done or made so uh my

4107

04:19:13,370 --> 04:19:10,020

acknowledgmental Dr Sarah white that's

4108

04:19:16,790 --> 04:19:13,380

my advisor and then Dr Colin Cruz from

4109

04:19:19,490 --> 04:19:16,800

the National Lab in New Mexico and to

4110

04:19:23,030 --> 04:19:19,500

the NASA analysis working group plant

4111

04:19:30,410 --> 04:19:23,040

homies who sponsored this uh research

4112

04:19:35,630 --> 04:19:32,570

right thank you bolaga our next

4113

04:19:38,510 --> 04:19:35,640

presenter will be Madeline Purnell from

4114

04:19:46,210 --> 04:19:38,520

the University of Utah

4115

04:19:50,750 --> 04:19:49,070

into things because I have a lot to say

4116

04:19:52,010 --> 04:19:50,760

on this topic

4117

04:19:54,349 --> 04:19:52,020

so

4118

04:19:56,689 --> 04:19:54,359

um extremophiles can help us predict the

4119

04:19:59,389 --> 04:19:56,699

boundaries of life here on Earth and the

4120

04:20:01,670 --> 04:19:59,399

possibility of life on other planets yet

4121

04:20:03,969 --> 04:20:01,680

most extreme files that we study are

4122

04:20:05,990 --> 04:20:03,979

typically single cellular organisms

4123

04:20:08,389 --> 04:20:06,000

leaving a gap in knowledge about

4124

04:20:10,849 --> 04:20:08,399

multicellular life and its habitability

4125

04:20:12,830 --> 04:20:10,859

limits and Origins and so that's kind of

4126  
04:20:15,469 --> 04:20:12,840  
where our work comes into play for my

4127  
04:20:16,910 --> 04:20:15,479  
lab so we're a nematode lab

4128  
04:20:19,189 --> 04:20:16,920  
um and nematodes are one of the most

4129  
04:20:21,349 --> 04:20:19,199  
widespread and resilient animal phylums

4130  
04:20:23,150 --> 04:20:21,359  
on earth they make about 80 of all

4131  
04:20:24,790 --> 04:20:23,160  
animal life and are found on every

4132  
04:20:26,929 --> 04:20:24,800  
continent and in every ecosystem

4133  
04:20:28,389 --> 04:20:26,939  
including some found in like South

4134  
04:20:32,530 --> 04:20:28,399  
African gold mines

4135  
04:20:34,849 --> 04:20:32,540  
Antarctica and the dry valleys Etc

4136  
04:20:37,610 --> 04:20:34,859  
so my work is based in the Great Salt

4137  
04:20:41,689 --> 04:20:37,620  
Lake it's an analog Lake for the

4138  
04:20:43,130 --> 04:20:41,699

evaporated saline Lakes on Mars and it

4139

04:20:44,570 --> 04:20:43,140

is also the fourth largest terminal lake

4140

04:20:46,790 --> 04:20:44,580

in the world meaning that it gets a

4141

04:20:49,250 --> 04:20:46,800

large inflow of water

4142

04:20:51,650 --> 04:20:49,260

um but the only source of outflow is via

4143

04:20:54,790 --> 04:20:51,660

evaporation it's also been geologically

4144

04:20:57,889 --> 04:20:54,800

consistent for the last 780 Millennia

4145

04:21:00,429 --> 04:20:57,899

and was only once previously part of

4146

04:21:03,469 --> 04:21:00,439

like a Paleo histeine freshwater lake

4147

04:21:05,150 --> 04:21:03,479

for a really brief period of time

4148

04:21:06,469 --> 04:21:05,160

but one thing that you might notice is

4149

04:21:08,990 --> 04:21:06,479

that it has a really Stark salinity

4150

04:21:10,969 --> 04:21:09,000

gradient that's caused from a railroad

4151  
04:21:12,410 --> 04:21:10,979  
construction that cut the Great Salt

4152  
04:21:14,870 --> 04:21:12,420  
Lake in half creating the North and

4153  
04:21:17,210 --> 04:21:14,880  
South arms so the South arm is about at

4154  
04:21:19,070 --> 04:21:17,220  
15 salinity due to the inflow of water

4155  
04:21:20,689 --> 04:21:19,080  
and the north arm doesn't get any inflow

4156  
04:21:22,610 --> 04:21:20,699  
of water and so stays at about 27

4157  
04:21:25,130 --> 04:21:22,620  
salinity

4158  
04:21:27,889 --> 04:21:25,140  
um 15 solidity adjusts so you are aware

4159  
04:21:30,110 --> 04:21:27,899  
is about three times more saline than

4160  
04:21:32,330 --> 04:21:30,120  
the ocean and is well beyond the

4161  
04:21:34,070 --> 04:21:32,340  
previous maximum recorded salinity

4162  
04:21:36,229 --> 04:21:34,080  
gradient that nematodes have been found

4163  
04:21:38,510 --> 04:21:36,239

to live in and so my lab went searching

4164

04:21:40,250 --> 04:21:38,520

for nematodes in the Great Salt Lake and

4165

04:21:42,830 --> 04:21:40,260

so we chose four different six different

4166

04:21:45,349 --> 04:21:42,840

sites sorry to look at three which were

4167

04:21:47,630 --> 04:21:45,359

from an inflow river that

4168

04:21:49,550 --> 04:21:47,640

um was between like fresh water to hypo

4169

04:21:50,870 --> 04:21:49,560

saline conditions and then three from

4170

04:21:53,929 --> 04:21:50,880

inside the Great Salt Lake which were

4171

04:21:56,750 --> 04:21:53,939

well into the hyper saline conditions

4172

04:21:59,809 --> 04:21:56,760

and it is here that we found some

4173

04:22:04,010 --> 04:22:01,670

so one unique structure in the Great

4174

04:22:05,870 --> 04:22:04,020

Salt Lake are these microbialites

4175

04:22:08,269 --> 04:22:05,880

um they're Organo sedimentary structures

4176  
04:22:10,130 --> 04:22:08,279  
and they're built by file photosynthetic

4177  
04:22:12,229 --> 04:22:10,140  
microbes and so our host to complex

4178  
04:22:14,210 --> 04:22:12,239  
microbial communities as well as our

4179  
04:22:16,429 --> 04:22:14,220  
nematodes they're also in the oldest

4180  
04:22:18,349 --> 04:22:16,439  
known evidence of life on Earth some

4181  
04:22:19,610 --> 04:22:18,359  
dating back to about 3.4 billion years

4182  
04:22:22,070 --> 04:22:19,620  
ago

4183  
04:22:23,830 --> 04:22:22,080  
um and so they can kind of offer us a

4184  
04:22:27,050 --> 04:22:23,840  
glimpse of life before

4185  
04:22:28,790 --> 04:22:27,060  
more complex life forms and they range

4186  
04:22:31,849 --> 04:22:28,800  
about 20 to 30 percent of the Great Salt

4187  
04:22:36,229 --> 04:22:33,769  
so we've found that these nematodes

4188  
04:22:38,809 --> 04:22:36,239

through 18s sequencing are novel

4189

04:22:40,610 --> 04:22:38,819

hysterity species Monastery are

4190

04:22:42,889 --> 04:22:40,620

typically a freshwater nematode though

4191

04:22:45,769 --> 04:22:42,899

some are also found in marine ecosystems

4192

04:22:47,689 --> 04:22:45,779

and so our goal now is to look at their

4193

04:22:49,490 --> 04:22:47,699

genome and transcriptome in order to be

4194

04:22:51,710 --> 04:22:49,500

able to tell the presence and absence of

4195

04:22:53,750 --> 04:22:51,720

Gene families and see what genes are

4196

04:22:56,689 --> 04:22:53,760

being functionally used here in the

4197

04:22:58,790 --> 04:22:56,699

Great Salt Lake to potentially like help

4198

04:23:01,309 --> 04:22:58,800

with saline UV and temperature

4199

04:23:04,010 --> 04:23:01,319

tolerances and we're also looking at

4200

04:23:06,910 --> 04:23:04,020

co-evolution with other microbiota so by

4201  
04:23:09,889 --> 04:23:06,920  
isolating single worms we can look at

4202  
04:23:13,070 --> 04:23:09,899  
Presence of microbiota in or on the worm

4203  
04:23:15,590 --> 04:23:13,080  
so we want to be able to look at diatoms

4204  
04:23:19,490 --> 04:23:15,600  
fungus and bacteria and so far we've

4205  
04:23:22,849 --> 04:23:19,500  
been able to do V4 region of 16sr RNA

4206  
04:23:24,349 --> 04:23:22,859  
sequencing of bacteria and we found a

4207  
04:23:26,929 --> 04:23:24,359  
variety of bacterial orders that are

4208  
04:23:30,170 --> 04:23:26,939  
found in and on our worms but

4209  
04:23:32,030 --> 04:23:30,180  
surprisingly 70 of all the bacteria

4210  
04:23:33,769 --> 04:23:32,040  
found are only unique to the worm and

4211  
04:23:35,929 --> 04:23:33,779  
have never been found in microbialite

4212  
04:23:38,030 --> 04:23:35,939  
structures previously meaning that these

4213  
04:23:39,950 --> 04:23:38,040

microbiota are possibly living in

4214

04:23:42,110 --> 04:23:39,960

symbiosis with these pneumatodes and

4215

04:23:43,729 --> 04:23:42,120

offering a variety of functions such as

4216

04:23:45,290 --> 04:23:43,739

phototrophic potential solute

4217

04:23:47,510 --> 04:23:45,300

accumulation and arsenic tolerance that

4218

04:23:49,550 --> 04:23:47,520

allows them to be capable of living in

4219

04:23:51,229 --> 04:23:49,560

this extreme environment so by

4220

04:23:52,729 --> 04:23:51,239

identifying and Reporting these

4221

04:23:54,889 --> 04:23:52,739

communities it can help us understand

4222

04:23:56,510 --> 04:23:54,899

mechanisms that maintain a functional

4223

04:23:59,030 --> 04:23:56,520

ecosystem in some of the most extreme

4224

04:24:00,650 --> 04:23:59,040

environments on Earth and could provide

4225

04:24:04,189 --> 04:24:00,660

information about the evolution of life

4226

04:24:06,110 --> 04:24:04,199

on Earth and also Beyond

4227

04:24:08,030 --> 04:24:06,120

I'd like to thank my lab for all of

4228

04:24:09,170 --> 04:24:08,040

their help and thank you today and I'll

4229

04:24:15,769 --> 04:24:09,180

be at poster for if you have any

4230

04:24:20,450 --> 04:24:18,050

all right thank you Madeline up next we

4231

04:24:31,790 --> 04:24:20,460

have Fernanda Jamel from the University

4232

04:24:38,630 --> 04:24:36,110

hello I'm Fernando I'm a PC student from

4233

04:24:41,990 --> 04:24:38,640

University of Sao Paulo in Brazil

4234

04:24:44,090 --> 04:24:42,000

and I'll talk about my work uh microbial

4235

04:24:46,370 --> 04:24:44,100

mediated carbon mineralization from

4236

04:24:49,969 --> 04:24:46,380

lagova media in Brazil

4237

04:24:52,610 --> 04:24:49,979

so uh the motivation for this works the

4238

04:24:54,590 --> 04:24:52,620

importance of studying the evolution of

4239

04:24:57,290 --> 04:24:54,600

life on Earth as we know that the first

4240

04:25:00,889 --> 04:24:57,300

signs of Life are eliminations and

4241

04:25:02,630 --> 04:25:00,899

fossils of microorganisms and within

4242

04:25:04,729 --> 04:25:02,640

this we have the investigation of

4243

04:25:07,370 --> 04:25:04,739

potential evidence of life such as

4244

04:25:09,410 --> 04:25:07,380

microbial forces and stromatolites that

4245

04:25:11,410 --> 04:25:09,420

we need to differentiate from magnetic

4246

04:25:14,750 --> 04:25:11,420

form of an

4247

04:25:17,150 --> 04:25:14,760

inorganic mineral so therefore oh it's

4248

04:25:19,510 --> 04:25:17,160

necessary to investigate the biogenicity

4249

04:25:23,150 --> 04:25:19,520

that is that if if that was actually

4250

04:25:25,070 --> 04:25:23,160

formed by life or not and also we have

4251  
04:25:27,469 --> 04:25:25,080  
the Dolomite problem that is a major

4252  
04:25:32,710 --> 04:25:27,479  
question that scientists have been

4253  
04:25:37,670 --> 04:25:35,450  
are one of the most important records of

4254  
04:25:39,349 --> 04:25:37,680  
from the past and even if with the

4255  
04:25:42,170 --> 04:25:39,359  
several studies related to development

4256  
04:25:45,410 --> 04:25:42,180  
formation uh the results are still

4257  
04:25:48,889 --> 04:25:45,420  
controversial maybe to the the little

4258  
04:25:51,290 --> 04:25:48,899  
understanding uh that exists and the

4259  
04:25:54,349 --> 04:25:51,300  
difficulty of obtaining this mineral in

4260  
04:25:57,050 --> 04:25:54,359  
laboratory conditions like uh below 50

4261  
04:25:59,689 --> 04:25:57,060  
degrees Celsius so given this we have

4262  
04:26:02,630 --> 04:25:59,699  
the so-called Dolomite problem uh which

4263  
04:26:05,090 --> 04:26:02,640

has been much debated over uh the last

4264

04:26:06,950 --> 04:26:05,100

few years however it is possible to find

4265

04:26:09,889 --> 04:26:06,960

a few current dollar my precipitation

4266

04:26:11,870 --> 04:26:09,899

events in hyper saline lakes and

4267

04:26:15,410 --> 04:26:11,880

alkaline environments such as this

4268

04:26:17,229 --> 04:26:15,420

region of Lago of Emira and Brazil that

4269

04:26:18,889 --> 04:26:17,239

is next to each other

4270

04:26:21,950 --> 04:26:18,899

and

4271

04:26:23,030 --> 04:26:21,960

um so these are one of the few places in

4272

04:26:26,330 --> 04:26:23,040

the world that has dull of my

4273

04:26:27,889 --> 04:26:26,340

precipitation uh today so in these

4274

04:26:30,229 --> 04:26:27,899

places there are microorganisms

4275

04:26:32,389 --> 04:26:30,239

responsible for mediating the carbonate

4276

04:26:34,370 --> 04:26:32,399

precipitation which can serve as a

4277

04:26:38,090 --> 04:26:34,380

nucleation centers for for the mineral

4278

04:26:41,210 --> 04:26:38,100

uh within their biofilm their EPS uh

4279

04:26:44,090 --> 04:26:41,220

exopolymerically extracellular substance

4280

04:26:47,750 --> 04:26:44,100

and this photo was taken during my field

4281

04:26:50,689 --> 04:26:47,760

collection and it shows their a thick

4282

04:26:54,469 --> 04:26:50,699

layer of of dolomite of dolomite

4283

04:26:57,769 --> 04:26:54,479

sediment below and above we can see like

4284

04:26:59,389 --> 04:26:57,779

a microbial match with a biofilm uh in

4285

04:27:04,130 --> 04:26:59,399

the

4286

04:27:06,769 --> 04:27:04,140

so talking briefly about right

4287

04:27:09,590 --> 04:27:06,779

precipitation by microorganisms in

4288

04:27:11,889 --> 04:27:09,600

nature environmental conditions modulate

4289

04:27:14,510 --> 04:27:11,899

the communities and within that a lot of

4290

04:27:17,750 --> 04:27:14,520

microorganisms uh they are known for

4291

04:27:19,429 --> 04:27:17,760

their ability to precipitate minerals so

4292

04:27:22,189 --> 04:27:19,439

these minerals can be precipitated by

4293

04:27:25,250 --> 04:27:22,199

physical methods in which the microbial

4294

04:27:27,649 --> 04:27:25,260

Community serves as a nucleation of a

4295

04:27:31,130 --> 04:27:27,659

nucleation site for the deformation of

4296

04:27:33,729 --> 04:27:31,140

carbonate or it can be in a chemical way

4297

04:27:36,530 --> 04:27:33,739

or an inorganic as an inorganic mineral

4298

04:27:38,809 --> 04:27:36,540

so this precipitation occurs mainly due

4299

04:27:41,149 --> 04:27:38,819

to changes in the pH the amount of

4300

04:27:43,330 --> 04:27:41,159

organic carbon dissolves in the medium

4301

04:27:46,250 --> 04:27:43,340

or the environment

4302

04:27:48,769 --> 04:27:46,260

and the availability of calcium and

4303

04:27:51,889 --> 04:27:48,779

magnesium ions in the case of dolomite

4304

04:27:55,630 --> 04:27:51,899

and the availability of nucleation sites

4305

04:27:58,250 --> 04:27:55,640

uh for Crystal formation that can be the

4306

04:28:02,090 --> 04:27:58,260

exopolymeric substances present in the

4307

04:28:04,849 --> 04:28:02,100

in the biofilms of bacteria

4308

04:28:07,370 --> 04:28:04,859

so some microorganisms have the ability

4309

04:28:09,849 --> 04:28:07,380

to produce biofumes formed by these

4310

04:28:12,189 --> 04:28:09,859

these extracellular polymeric substances

4311

04:28:15,649 --> 04:28:12,199

which are mainly composed of

4312

04:28:18,410 --> 04:28:15,659

exopolysaccharides acidic residues uh

4313

04:28:20,630 --> 04:28:18,420

sugars that have a negative charge and

4314

04:28:24,170 --> 04:28:20,640

and can bind to different ions such as

4315

04:28:26,210 --> 04:28:24,180

calcium magnesium so the role of DPS in

4316

04:28:31,149 --> 04:28:26,220

the precipitation of carbonate occurs in

4317

04:28:33,649 --> 04:28:31,159

two uh from initially the EPS can reduce

4318

04:28:36,590 --> 04:28:33,659

precipitation by sequestering metallic

4319

04:28:42,110 --> 04:28:36,600

ions but during the degradation of the

4320

04:28:44,570 --> 04:28:42,120

DPS by some sulfur reducing bacteria

4321

04:28:47,450 --> 04:28:44,580

the resulting High concentration of of

4322

04:28:49,790 --> 04:28:47,460

calcium calcium magnesium ions can favor

4323

04:28:52,849 --> 04:28:49,800

precipitation and in addition The

4324

04:28:54,889 --> 04:28:52,859

Continuous supply of ions added to a

4325

04:28:58,490 --> 04:28:54,899

more alkaline environment due to micro

4326  
04:29:01,130 --> 04:28:58,500  
the micro environmental generated micro

4327  
04:29:03,710 --> 04:29:01,140  
environment generated by the EPS May

4328  
04:29:05,090 --> 04:29:03,720  
favor the bioprecipitation of of these

4329  
04:29:07,370 --> 04:29:05,100  
minerals

4330  
04:29:10,130 --> 04:29:07,380  
so now moving to the Azure biological

4331  
04:29:12,769 --> 04:29:10,140  
importance it's interesting to know that

4332  
04:29:16,309 --> 04:29:12,779  
the environmental condition of Mars in

4333  
04:29:18,530 --> 04:29:16,319  
the novakian Hesperian periods

4334  
04:29:21,710 --> 04:29:18,540  
um quite similar to why similar to Earth

4335  
04:29:25,490 --> 04:29:21,720  
so at that time it was a much it has it

4336  
04:29:27,530 --> 04:29:25,500  
had a much denser atmosphere a higher

4337  
04:29:29,750 --> 04:29:27,540  
temperatures uh than the possible

4338  
04:29:32,689 --> 04:29:29,760

presence of liquid water on the surface

4339

04:29:34,929 --> 04:29:32,699

which indicates the potential of of the

4340

04:29:37,790 --> 04:29:34,939

planet to have supported microbial life

4341

04:29:41,030 --> 04:29:37,800

so in the face of this some geological

4342

04:29:42,950 --> 04:29:41,040

studies of g0 crater on Mars have

4343

04:29:45,530 --> 04:29:42,960

demonstrated a large carbonate deposits

4344

04:29:47,929 --> 04:29:45,540

in the west region of the crater and on

4345

04:29:49,729 --> 04:29:47,939

on Earth regions of hypersonic shell

4346

04:29:51,950 --> 04:29:49,739

Lakes are closely related to the

4347

04:29:54,130 --> 04:29:51,960

biological deposition of carbonates

4348

04:29:57,469 --> 04:29:54,140

indicating great potential for

4349

04:30:00,110 --> 04:29:57,479

identifying identifying preserved by a

4350

04:30:04,969 --> 04:30:00,120

signature in these regions

4351  
04:30:06,050 --> 04:30:04,979  
uh so I I would just specifically uh for

4352  
04:30:08,269 --> 04:30:06,060  
uh

4353  
04:30:11,630 --> 04:30:08,279  
through these objectives so my

4354  
04:30:13,610 --> 04:30:11,640  
objectives are testing a carbonate

4355  
04:30:15,830 --> 04:30:13,620  
mineral precipitation using allophytic

4356  
04:30:18,469 --> 04:30:15,840  
bacteria from Lego Batman

4357  
04:30:20,149 --> 04:30:18,479  
and do structural morphological and

4358  
04:30:23,349 --> 04:30:20,159  
optic investigation of Carbonite

4359  
04:30:27,969 --> 04:30:23,359  
minerals like x-ray diffraction remin

4360  
04:30:30,950 --> 04:30:27,979  
spectroscopy synchronized techniques

4361  
04:30:32,510 --> 04:30:30,960  
and uh then established by viable

4362  
04:30:34,309 --> 04:30:32,520  
protocols for biosignature

4363  
04:30:38,330 --> 04:30:34,319

identification

4364

04:30:40,550 --> 04:30:38,340

so uh briefly uh you can see more in my

4365

04:30:43,670 --> 04:30:40,560

poster or the precipitation experiment

4366

04:30:46,309 --> 04:30:43,680

the methodology of one tonality uh that

4367

04:30:48,530 --> 04:30:46,319

is a reference that studies this uh this

4368

04:30:50,990 --> 04:30:48,540

region uh was used to test if

4369

04:30:53,630 --> 04:30:51,000

metabolically inactivated cells within

4370

04:30:55,910 --> 04:30:53,640

biofilm could precipitate minerals only

4371

04:30:57,830 --> 04:30:55,920

with the biofilm so the experiment was

4372

04:31:00,590 --> 04:30:57,840

carried out in a controlled environment

4373

04:31:04,189 --> 04:31:00,600

at 30 degrees and was divided into these

4374

04:31:07,250 --> 04:31:04,199

conditions that we had a DPS treatment

4375

04:31:10,610 --> 04:31:07,260

that we let the bacteria grow in for 15

4376

04:31:12,710 --> 04:31:10,620

days then we added the antibiotics to

4377

04:31:15,649 --> 04:31:12,720

inactivate the cells with the biofin

4378

04:31:18,729 --> 04:31:15,659

form then we had the bacteria growing

4379

04:31:21,410 --> 04:31:18,739

normally then we had a treatment with

4380

04:31:23,210 --> 04:31:21,420

antibiotics being added from the

4381

04:31:26,389 --> 04:31:23,220

beginning and we had the control without

4382

04:31:29,330 --> 04:31:26,399

victory so we did this experiment to

4383

04:31:31,130 --> 04:31:29,340

test if this was possible to form uh

4384

04:31:35,570 --> 04:31:31,140

precipitates only with the biofilm but

4385

04:31:38,689 --> 04:31:35,580

we said we said we saw that uh it's uh

4386

04:31:42,469 --> 04:31:38,699

we we've we found a viable cells after

4387

04:31:45,110 --> 04:31:42,479

after some time of of experiment within

4388

04:31:47,809 --> 04:31:45,120

this biofilm so I think that it's really

4389

04:31:51,189 --> 04:31:47,819

hard to inactivate cells in this way so

4390

04:31:53,870 --> 04:31:51,199

we are trying other protocols and

4391

04:31:56,210 --> 04:31:53,880

here here is only my preliminary results

4392

04:31:59,330 --> 04:31:56,220

just giving a brief about this

4393

04:32:01,309 --> 04:31:59,340

oh I'll talk to my poster after

4394

04:32:03,290 --> 04:32:01,319

obtaining these precipitates we analyze

4395

04:32:05,389 --> 04:32:03,300

the X-ray diffraction to identify the

4396

04:32:07,550 --> 04:32:05,399

mineral phases present in the sample of

4397

04:32:10,309 --> 04:32:07,560

the bacteria *Idiomarina* The Strain

4398

04:32:13,969 --> 04:32:10,319

called here in the right we took a

4399

04:32:16,490 --> 04:32:13,979

scanning electron microscopy uh of the

4400

04:32:18,469 --> 04:32:16,500

the precipitates from the same bacteria

4401

04:32:20,809 --> 04:32:18,479

and we can see the difference different

4402

04:32:23,570 --> 04:32:20,819

morphologies such as dumbbells shapes

4403

04:32:25,790 --> 04:32:23,580

and rounded shapes of calcium carbonates

4404

04:32:28,969 --> 04:32:25,800

and this morphology are usually

4405

04:32:31,490 --> 04:32:28,979

associated with biogenic minerals so we

4406

04:32:34,550 --> 04:32:31,500

still need to analyze EDS Spectrum so

4407

04:32:37,189 --> 04:32:34,560

for a conform conform or exactly which

4408

04:32:39,229 --> 04:32:37,199

mineral each morphology relates to and

4409

04:32:41,809 --> 04:32:39,239

finding minor shifts in the the

4410

04:32:44,929 --> 04:32:41,819

phratograms and the the Raman spectrums

4411

04:32:48,889 --> 04:32:44,939

for establishing viable protocols so

4412

04:32:50,570 --> 04:32:48,899

this is my poster session uh 22 and

4413

04:33:00,530 --> 04:32:50,580

that's it

4414

04:33:07,670 --> 04:33:04,849

thank you Fernanda all right next we're

4415

04:33:10,310 --> 04:33:07,680

going to welcome Miriam Fernandez from

4416

04:33:13,310 --> 04:33:10,320

the University of Colorado Boulder thank

4417

04:33:18,109 --> 04:33:15,429

foreign

4418

04:33:21,650 --> 04:33:18,119

and I'm here to talk about the salts of

4419

04:33:24,289 --> 04:33:21,660

the earth and how they could help when

4420

04:33:27,230 --> 04:33:24,299

looking for life in the solar system

4421

04:33:28,910 --> 04:33:27,240

Earth can provide us with analogs

4422

04:33:30,890 --> 04:33:28,920

um that can

4423

04:33:33,230 --> 04:33:30,900

mimic extra planetary environments in

4424

04:33:35,570 --> 04:33:33,240

one of the most ones most often used for

4425

04:33:37,810 --> 04:33:35,580

Mars is the Atacama Desert I'm really

4426

04:33:41,929 --> 04:33:37,820

proud of this graphic

4427

04:33:44,150 --> 04:33:41,939

so in the Atacama life has been shown to

4428

04:33:46,789 --> 04:33:44,160

live off the deli questions of salts but

4429

04:33:48,709 --> 04:33:46,799

can the salts that I studied

4430

04:33:50,990 --> 04:33:48,719

deliquescent in all the common conditions

4431

04:33:53,449 --> 04:33:51,000

so for my project I tried to answer two

4432

04:33:56,510 --> 04:33:53,459

scientific questions could nitrate salts

4433

04:33:58,429 --> 04:33:56,520

or their salt mixtures uptake water or

4434

04:34:02,269 --> 04:33:58,439

release water

4435

04:34:03,709 --> 04:34:02,279

autocom environmental conditions and

4436

04:34:07,670 --> 04:34:03,719

could the temperature and relative

4437

04:34:09,529 --> 04:34:07,680

humidity values lead to nitrate salt

4438

04:34:11,810 --> 04:34:09,539

deliquesins

4439

04:34:14,029 --> 04:34:11,820

so to answer this we used a Ramen

4440

04:34:15,830 --> 04:34:14,039

microscope attached to an environmental

4441

04:34:17,449 --> 04:34:15,840

cell in which the temperature and

4442

04:34:18,890 --> 04:34:17,459

relative humidity could be controlled

4443

04:34:21,470 --> 04:34:18,900

and we use this to study the phase

4444

04:34:23,150 --> 04:34:21,480

transitions of our salts of Interest

4445

04:34:25,189 --> 04:34:23,160

so we can answer our first question

4446

04:34:26,869 --> 04:34:25,199

could nitrate salts or salt mixtures

4447

04:34:28,910 --> 04:34:26,879

take up water under autonomic conditions

4448

04:34:30,170 --> 04:34:28,920

well yes and thank you for coming to my

4449

04:34:31,670 --> 04:34:30,180

talk

4450

04:34:33,529 --> 04:34:31,680

um so

4451  
04:34:34,970 --> 04:34:33,539  
but let me tell you why and so the first

4452  
04:34:36,109 --> 04:34:34,980  
thing that we're going to do is look at

4453  
04:34:38,449 --> 04:34:36,119  
the spectral series of the pure

4454  
04:34:39,949 --> 04:34:38,459  
magnesium nitrate

4455  
04:34:41,390 --> 04:34:39,959  
um so if we look at the crystalline

4456  
04:34:43,310 --> 04:34:41,400  
nitrate which is going to be shown by

4457  
04:34:44,869 --> 04:34:43,320  
the black Spectra at the bottom it

4458  
04:34:48,590 --> 04:34:44,879  
starts off at a higher wave number of

4459  
04:34:50,689 --> 04:34:48,600  
1062 and as we increase the as we

4460  
04:34:52,010 --> 04:34:50,699  
decrease the Rel sorry increase the

4461  
04:34:53,990 --> 04:34:52,020  
decrease the temperature and increase

4462  
04:34:55,730 --> 04:34:54,000  
the relative humidity it's going to stay

4463  
04:34:58,970 --> 04:34:55,740

there until it reaches the deliques it's

4464

04:35:00,529 --> 04:34:58,980

relative humidity of 63 percent

4465

04:35:03,949 --> 04:35:00,539

um at which point it shifts the lower

4466

04:35:05,090 --> 04:35:03,959

wave number of 1052 so it's going to

4467

04:35:07,131 --> 04:35:05,100

stay here

4468

04:35:10,010 --> 04:35:07,141

and this is really cool it's going to

4469

04:35:11,209 --> 04:35:10,020

stay here and as we increase the

4470

04:35:12,949 --> 04:35:11,219

temperature and decrease the relative

4471

04:35:15,109 --> 04:35:12,959

humidity it stays at that lower wave

4472

04:35:18,109 --> 04:35:15,119

number until the efflorescence relative

4473

04:35:20,570 --> 04:35:18,119

humidity of 23 and that means that

4474

04:35:22,730 --> 04:35:20,580

magnesium nitrate the Pier 1 can

4475

04:35:26,990 --> 04:35:22,740

maintain a metal stable brine for over a

4476

04:35:30,470 --> 04:35:28,849

um so we repeated these experiments

4477

04:35:31,970 --> 04:35:30,480

multiple times over different

4478

04:35:33,369 --> 04:35:31,980

temperatures and we made this lovely

4479

04:35:35,750 --> 04:35:33,379

phase diagram

4480

04:35:37,970 --> 04:35:35,760

uh and it's as temperature versus

4481

04:35:39,890 --> 04:35:37,980

relative humidity so for the pure

4482

04:35:41,150 --> 04:35:39,900

magnesium nitrate has a hydrate the Dell

4483

04:35:43,429 --> 04:35:41,160

questions is going to be shown by the

4484

04:35:46,070 --> 04:35:43,439

blue dots and the efflorescence is shown

4485

04:35:47,750 --> 04:35:46,080

by the orange squares and it was

4486

04:35:50,570 --> 04:35:47,760

relatively temperature independent and

4487

04:35:53,150 --> 04:35:50,580

occurred around 25 RH

4488

04:35:54,890 --> 04:35:53,160

so magnesium nitrate exhibited a very

4489

04:35:56,990 --> 04:35:54,900

large hysteresis which you can tell by

4490

04:35:58,849 --> 04:35:57,000

the gap between the Della questions and

4491

04:36:00,949 --> 04:35:58,859

the fluorescence relative humidity and

4492

04:36:02,150 --> 04:36:00,959

this is going to be our metastable brine

4493

04:36:07,369 --> 04:36:02,160

region

4494

04:36:09,349 --> 04:36:07,379

what about them so we

4495

04:36:10,189 --> 04:36:09,359

did the exact same experiment but we

4496

04:36:12,349 --> 04:36:10,199

used

4497

04:36:14,510 --> 04:36:12,359

um different salts so we have magnesium

4498

04:36:18,890 --> 04:36:14,520

nitrate so this is a one-to-one mixture

4499

04:36:22,131 --> 04:36:18,900

and we have magnesium nitrate on the

4500

04:36:25,189 --> 04:36:22,141

left and magnesium perchlorine on the

4501  
04:36:26,929 --> 04:36:25,199  
right and we see that same shift in the

4502  
04:36:28,670 --> 04:36:26,939  
nitrate Peak which we use to determine

4503  
04:36:33,051 --> 04:36:28,680  
when Della questions would occur

4504  
04:36:34,910 --> 04:36:33,061  
and so we took different ratios of

4505  
04:36:36,349 --> 04:36:34,920  
chlorine nitrate and we looked at how

4506  
04:36:39,230 --> 04:36:36,359  
the pcori could influence the water

4507  
04:36:41,631 --> 04:36:39,240  
uptake of the nitrate salts in the soil

4508  
04:36:43,490 --> 04:36:41,641  
and so the blue dots once again are

4509  
04:36:46,670 --> 04:36:43,500  
going to be the Dell questions and the

4510  
04:36:48,529 --> 04:36:46,680  
orange triangles are the efflorescence

4511  
04:36:51,051 --> 04:36:48,539  
um and then the lines in between is the

4512  
04:36:53,090 --> 04:36:51,061  
average of the experiment so what we can

4513  
04:36:55,609 --> 04:36:53,100

see is that for chlorate seem to be

4514

04:36:58,250 --> 04:36:55,619

helping or assisting with the magnesium

4515

04:37:01,310 --> 04:36:58,260

nitrate water uptake or deliquescence

4516

04:37:04,189 --> 04:37:01,320

and so if we look at our overall picture

4517

04:37:07,551 --> 04:37:04,199

so this is pure magnesium nitrate and

4518

04:37:09,289 --> 04:37:07,561

its Dell questions is at 60 RH

4519

04:37:11,570 --> 04:37:09,299

however if we look at our epichlorate

4520

04:37:13,369 --> 04:37:11,580

mixtures we can see that the water

4521

04:37:15,109 --> 04:37:13,379

uptake seems to be assisted by that and

4522

04:37:16,369 --> 04:37:15,119

we see this with the downward facing

4523

04:37:18,410 --> 04:37:16,379

Trend

4524

04:37:19,970 --> 04:37:18,420

um so we also wanted to look at what

4525

04:37:21,949 --> 04:37:19,980

affects a less hygroscopic or

4526  
04:37:24,051 --> 04:37:21,959  
deliquisite salt would have on that and

4527  
04:37:26,150 --> 04:37:24,061  
so we did a one-to-one mixture with

4528  
04:37:27,830 --> 04:37:26,160  
sulfate nitrates and we saw that this

4529  
04:37:30,109 --> 04:37:27,840  
did not inhibit the water uptake of

4530  
04:37:32,150 --> 04:37:30,119  
nitrate because it's still below the

4531  
04:37:34,849 --> 04:37:32,160  
deloquiescence relative humidity of

4532  
04:37:38,150 --> 04:37:34,859  
magnesium nitrate so finally we can

4533  
04:37:39,709 --> 04:37:38,160  
answer our last question

4534  
04:37:41,750 --> 04:37:39,719  
which is could the temperature and

4535  
04:37:43,631 --> 04:37:41,760  
relative humidity values lead to nitrate

4536  
04:37:48,051 --> 04:37:43,641  
salt double croissants in the soil

4537  
04:37:49,789 --> 04:37:48,061  
so we took our phase diagram and we took

4538  
04:37:51,109 --> 04:37:49,799

relative humidity and temperature DNS

4539

04:37:53,750 --> 04:37:51,119

from these two slides in the Atacama

4540

04:37:55,310 --> 04:37:53,760

Desert and both of these sides contain

4541

04:37:58,369 --> 04:37:55,320

nitrates perchlorates in the soil

4542

04:38:01,609 --> 04:37:58,379

composition and also sulfates so site a

4543

04:38:03,709 --> 04:38:01,619

which you see above was relatively close

4544

04:38:06,349 --> 04:38:03,719

to the ocean and was therefore warmer

4545

04:38:08,269 --> 04:38:06,359

and more humid this was likely a

4546

04:38:10,490 --> 04:38:08,279

contributor to why the nitrate cells in

4547

04:38:11,869 --> 04:38:10,500

the soil could maintain a stable liquid

4548

04:38:13,670 --> 04:38:11,879

brine which is shown by the dark blue

4549

04:38:15,051 --> 04:38:13,680

highlights and it made a stable line

4550

04:38:16,910 --> 04:38:15,061

which is the light blue highlights

4551

04:38:20,150 --> 04:38:16,920

throughout most of the year

4552

04:38:22,070 --> 04:38:20,160

then if we look at site B this was more

4553

04:38:23,150 --> 04:38:22,080

Inland and therefore significantly drier

4554

04:38:25,551 --> 04:38:23,160

and colder

4555

04:38:28,131 --> 04:38:25,561

but despite this we do have points

4556

04:38:31,010 --> 04:38:28,141

throughout the year in which the salts

4557

04:38:33,890 --> 04:38:31,020

could uptake and deliquis and maintain a

4558

04:38:35,990 --> 04:38:33,900

medicinal place so of course this is

4559

04:38:37,369 --> 04:38:36,000

very highly variable and that could be

4560

04:38:39,470 --> 04:38:37,379

due to the different environmental

4561

04:38:41,449 --> 04:38:39,480

conditions as well as the different soil

4562

04:38:43,189 --> 04:38:41,459

compositions and would need to be

4563

04:38:44,810 --> 04:38:43,199

further studied

4564

04:38:46,789 --> 04:38:44,820

so

4565

04:38:49,609 --> 04:38:46,799

um if you have any questions comments

4566

04:38:59,029 --> 04:38:49,619

concerns or a job please stop by my

4567

04:39:04,189 --> 04:39:01,789

thank you Miriam I like the splash of

4568

04:39:07,070 --> 04:39:04,199

humor in there keep us awake this time

4569

04:39:08,929 --> 04:39:07,080

of day so next we have povolus simonis

4570

04:39:18,349 --> 04:39:08,939

from the University of California Santa

4571

04:39:24,289 --> 04:39:21,189

hello everyone I'm Paula schimones

4572

04:39:26,869 --> 04:39:24,299

a researcher from Lithuania currently

4573

04:39:28,990 --> 04:39:26,879

located at Santa Cruz and my professor

4574

04:39:32,449 --> 04:39:29,000

is David dimmer

4575

04:39:35,449 --> 04:39:32,459

so organic compounds including building

4576  
04:39:37,490 --> 04:39:35,459  
blocks of life may be synthesized in the

4577  
04:39:38,448 --> 04:39:37,500  
accretion disk of newly forming solar

4578  
04:39:41,030 --> 04:39:38,458  
system

4579  
04:39:43,788 --> 04:39:41,040  
and may fall down to earth as a

4580  
04:39:46,330 --> 04:39:43,798  
meteorites and thus

4581  
04:39:49,490 --> 04:39:46,340  
phosphates uh

4582  
04:39:51,948 --> 04:39:49,500  
ribose and all nuclear bases were all

4583  
04:39:54,470 --> 04:39:51,958  
found in meteorites and under certain

4584  
04:39:56,750 --> 04:39:54,480  
conditions May recombine into your

4585  
04:39:58,250 --> 04:39:56,760  
nucleotides which are present in all

4586  
04:40:01,430 --> 04:39:58,260  
contemporary life

4587  
04:40:05,390 --> 04:40:01,440  
another essential compound is lipid

4588  
04:40:09,708 --> 04:40:05,400

which is a membrane forming

4589

04:40:11,570 --> 04:40:09,718

antipipilic molecule and simple lipids

4590

04:40:14,868 --> 04:40:11,580

were also found in carbonaceous

4591

04:40:18,470 --> 04:40:14,878

chondrites and even though their

4592

04:40:19,610 --> 04:40:18,480

structure was way more simple they can

4593

04:40:21,288 --> 04:40:19,620

form

4594

04:40:24,350 --> 04:40:21,298

vesicles

4595

04:40:27,288 --> 04:40:24,360

so if these compounds fall down to the

4596

04:40:29,868 --> 04:40:27,298

oceans they are lost in a dilute buffer

4597

04:40:33,708 --> 04:40:29,878

but if we make it down to the surfaces

4598

04:40:36,530 --> 04:40:33,718

of volcanic landmass they get a shot at

4599

04:40:37,970 --> 04:40:36,540

Birth participating in the origin of

4600

04:40:40,550 --> 04:40:37,980

life

4601  
04:40:44,150 --> 04:40:40,560  
so compounds falling in from space

4602  
04:40:47,150 --> 04:40:44,160  
synthesized in the biogenic atmosphere

4603  
04:40:49,490 --> 04:40:47,160  
cooked up in hydrothermal systems

4604  
04:40:51,948 --> 04:40:49,500  
or through work very through Rock

4605  
04:40:54,350 --> 04:40:51,958  
weathering May accumulate on the surface

4606  
04:40:56,090 --> 04:40:54,360  
perhaps finding their way in a volcanic

4607  
04:40:58,010 --> 04:40:56,100  
caldera

4608  
04:41:00,890 --> 04:40:58,020  
and the key to getting things to

4609  
04:41:04,430 --> 04:41:00,900  
interact is concentration so

4610  
04:41:07,490 --> 04:41:04,440  
small hot spring pools may be perfect

4611  
04:41:09,410 --> 04:41:07,500  
place to go come cook up some soup of

4612  
04:41:11,208 --> 04:41:09,420  
life

4613  
04:41:13,670 --> 04:41:11,218

and uh

4614

04:41:15,770 --> 04:41:13,680

hydrothermal fields of interconnected

4615

04:41:19,868 --> 04:41:15,780

pools could not only concentrate the

4616

04:41:22,070 --> 04:41:19,878

compounds but intermix them between

4617

04:41:24,788 --> 04:41:22,080

reservoirs subjecting them to different

4618

04:41:30,050 --> 04:41:24,798

temperature pH

4619

04:41:31,850 --> 04:41:30,060

Elemental and mineral compositions

4620

04:41:35,690 --> 04:41:31,860

and

4621

04:41:38,448 --> 04:41:35,700

for any system to move from simple to

4622

04:41:40,490 --> 04:41:38,458

more complex one is it must be subject

4623

04:41:43,730 --> 04:41:40,500

to cycling

4624

04:41:45,770 --> 04:41:43,740

and the flows of compounds including

4625

04:41:48,830 --> 04:41:45,780

building blocks of membranes and

4626  
04:41:51,288 --> 04:41:48,840  
polymers may find their way into a pool

4627  
04:41:54,530 --> 04:41:51,298  
which fills up by a pulse from nearby

4628  
04:41:57,230 --> 04:41:54,540  
geyser dries down and fills up again a

4629  
04:41:59,570 --> 04:41:57,240  
cycle or an engine

4630  
04:42:04,490 --> 04:41:59,580  
oh

4631  
04:42:09,288 --> 04:42:04,500  
is then formed

4632  
04:42:11,570 --> 04:42:09,298  
when a polymers between dry lipid layers

4633  
04:42:13,250 --> 04:42:11,580  
uh

4634  
04:42:17,208 --> 04:42:13,260  
are synthesized

4635  
04:42:20,750 --> 04:42:17,218  
and during rehydration they may assemble

4636  
04:42:23,810 --> 04:42:20,760  
into membrane-bounded protocols

4637  
04:42:27,410 --> 04:42:23,820  
and the stabilizing effects of polymers

4638  
04:42:30,530 --> 04:42:27,420

and membranes allow the protocells to be

4639

04:42:34,730 --> 04:42:30,540

tested with some surviving next dry down

4640

04:42:37,788 --> 04:42:34,740

as a protocell aggregate together they

4641

04:42:39,288 --> 04:42:37,798

form gel like phase where metabolic

4642

04:42:41,930 --> 04:42:39,298

Cycles can arise

4643

04:42:45,410 --> 04:42:41,940

and as a grade fully dries down

4644

04:42:48,350 --> 04:42:45,420

the protocells can uh

4645

04:42:51,070 --> 04:42:48,360

are merging and forming lamellar

4646

04:42:55,128 --> 04:42:51,080

structures where polymerase can

4647

04:42:56,868 --> 04:42:55,138

resynthesize template and allocate so

4648

04:42:59,628 --> 04:42:56,878

after many search Cycles simple

4649

04:43:02,390 --> 04:42:59,638

biological functions can emerge

4650

04:43:04,070 --> 04:43:02,400

which

4651  
04:43:05,270 --> 04:43:04,080  
uh

4652  
04:43:08,230 --> 04:43:05,280  
yeah

4653  
04:43:09,788 --> 04:43:08,240  
a simple biological functions can emerge

4654  
04:43:13,490 --> 04:43:09,798  
and

4655  
04:43:18,410 --> 04:43:13,500  
these ideas are backed by many studies

4656  
04:43:19,550 --> 04:43:18,420  
and here you can see a model of lasagna

4657  
04:43:22,448 --> 04:43:19,560  
of life

4658  
04:43:25,070 --> 04:43:22,458  
where

4659  
04:43:28,310 --> 04:43:25,080  
nucleotides are trapped between layers

4660  
04:43:31,128 --> 04:43:28,320  
of lipid membranes and such structures

4661  
04:43:32,868 --> 04:43:31,138  
are confirmed by x-ray diffraction

4662  
04:43:36,590 --> 04:43:32,878  
experiment

4663  
04:43:41,350 --> 04:43:36,600

and the trapping of nucleotides between

4664

04:43:44,570 --> 04:43:41,360

the layers are beneficial because

4665

04:43:45,770 --> 04:43:44,580

such structures allow pre-polymers to

4666

04:43:48,010 --> 04:43:45,780

form

4667

04:43:50,830 --> 04:43:48,020

and not only that

4668

04:43:55,970 --> 04:43:50,840

here you can see that

4669

04:43:59,288 --> 04:43:55,980

blue lines are with lipid present and if

4670

04:44:01,430 --> 04:43:59,298

we compare the deprotonation

4671

04:44:04,390 --> 04:44:01,440

reactions which are degradation of

4672

04:44:07,910 --> 04:44:04,400

purine nuclear nucleotides

4673

04:44:12,708 --> 04:44:07,920

in the samples with lipid present those

4674

04:44:15,470 --> 04:44:12,718

reactions are really inhibited

4675

04:44:18,350 --> 04:44:15,480

if we cook up such lasagna at

4676  
04:44:21,368 --> 04:44:18,360  
sufficiently height temperatures you can

4677  
04:44:26,530 --> 04:44:21,378  
see in the last graph at 90 degrees

4678  
04:44:29,330 --> 04:44:26,540  
of the nucleotides can really undergo

4679  
04:44:33,890 --> 04:44:29,340  
condensation reactions and become

4680  
04:44:36,288 --> 04:44:33,900  
well oligonic nucleotides so RNA or DNA

4681  
04:44:39,650 --> 04:44:36,298  
like molecules

4682  
04:44:42,050 --> 04:44:39,660  
and the the most important message from

4683  
04:44:44,690 --> 04:44:42,060  
all this presentation is that this is a

4684  
04:44:48,110 --> 04:44:44,700  
real system like you can take your

4685  
04:44:50,270 --> 04:44:48,120  
Prebiotic soup and go to Kamchatka or

4686  
04:44:53,030 --> 04:44:50,280  
New Zealand or even in California the

4687  
04:44:55,930 --> 04:44:53,040  
hot spring pool pour it down and after a

4688  
04:44:59,270 --> 04:44:55,940

couple of Cycles you will see like real

4689

04:45:02,030 --> 04:44:59,280

protocells with oligonucleotides which

4690

04:45:03,890 --> 04:45:02,040

are of sufficient length to already have

4691

04:45:06,350 --> 04:45:03,900

enzymatic functions

4692

04:45:08,270 --> 04:45:06,360

so my goal for a rest of air is to use

4693

04:45:12,350 --> 04:45:08,280

nanopore sequencing to study those

4694

04:45:16,570 --> 04:45:12,360

sequences to check whether I can find

4695

04:45:19,550 --> 04:45:16,580

some functional ones

4696

04:45:23,448 --> 04:45:19,560

so these ideas and results brought our

4697

04:45:25,910 --> 04:45:23,458

team to a city where we are running a

4698

04:45:28,610 --> 04:45:25,920

Genesis engine which is simulation

4699

04:45:30,530 --> 04:45:28,620

chamber of volcanic land mass with a lot

4700

04:45:31,670 --> 04:45:30,540

of poles where we can test the different

4701  
04:45:34,490 --> 04:45:31,680  
conditions

4702  
04:45:37,368 --> 04:45:34,500  
and our goal is to

4703  
04:45:40,310 --> 04:45:37,378  
understand what fraction of habitable

4704  
04:45:42,050 --> 04:45:40,320  
planets are actually durable and by

4705  
04:45:44,390 --> 04:45:42,060  
durable I mean

4706  
04:45:46,788 --> 04:45:44,400  
what fraction of habitat in what

4707  
04:45:49,430 --> 04:45:46,798  
fraction of habitable planets the life

4708  
04:45:51,350 --> 04:45:49,440  
can actually start

4709  
04:45:54,410 --> 04:45:51,360  
not many people are talking about that

4710  
04:45:55,850 --> 04:45:54,420  
but conditions for a life to start will

4711  
04:45:58,490 --> 04:45:55,860  
be very different

4712  
04:46:00,050 --> 04:45:58,500  
than the conditions which are needed for

4713  
04:46:01,550 --> 04:46:00,060

our life to thrive

4714

04:46:03,350 --> 04:46:01,560

yes

4715

04:46:07,310 --> 04:46:03,360

so if you are interested in this project

4716

04:46:10,070 --> 04:46:07,320

you can learn more on a set website and

4717

04:46:12,830 --> 04:46:10,080

I invite you to stop by my poster where

4718

04:46:15,470 --> 04:46:12,840

we can discuss how we can cook some soup

4719

04:46:23,390 --> 04:46:15,480

of life and maybe even start the second

4720

04:46:27,708 --> 04:46:25,310

all right thank you so much now I'm

4721

04:46:31,128 --> 04:46:27,718

craving lasagna

4722

04:46:37,970 --> 04:46:31,138

up next we have Michaela Liang from the

4723

04:46:42,410 --> 04:46:40,310

alrighty hi everyone thanks for having

4724

04:46:44,270 --> 04:46:42,420

me today um my name is Michaela Liang

4725

04:46:46,368 --> 04:46:44,280

I'm currently a PhD candidate at the

4726  
04:46:48,530 --> 04:46:46,378  
University of California Riverside

4727  
04:46:50,690 --> 04:46:48,540  
um I'll be talking to you today about my

4728  
04:46:52,368 --> 04:46:50,700  
work on novel methylated biosignatures

4729  
04:46:54,288 --> 04:46:52,378  
and specifically their application to

4730  
04:46:55,310 --> 04:46:54,298  
exoplanets which I usually don't have to

4731  
04:46:58,128 --> 04:46:55,320  
say because I'm usually talking to

4732  
04:47:00,170 --> 04:46:58,138  
astronomers so that's kind of fun

4733  
04:47:02,448 --> 04:47:00,180  
um there's a little bit of a breakdown

4734  
04:47:04,368 --> 04:47:02,458  
diagram here on the far side that's my

4735  
04:47:06,350 --> 04:47:04,378  
left so you're right

4736  
04:47:07,788 --> 04:47:06,360  
um that's kind of showing the processing

4737  
04:47:10,250 --> 04:47:07,798  
of these molecules all the way from

4738  
04:47:11,930 --> 04:47:10,260

surface fluxes atmospheric chemistry

4739

04:47:13,190 --> 04:47:11,940

um the production of spectral features

4740

04:47:15,708 --> 04:47:13,200

and we're kind of thinking about how

4741

04:47:17,868 --> 04:47:15,718

this will vary across a variety of

4742

04:47:20,510 --> 04:47:17,878

Stellar types so that's kind of just a

4743

04:47:22,490 --> 04:47:20,520

very quick uh summary breakdown

4744

04:47:24,350 --> 04:47:22,500

um so let's jump into talking about why

4745

04:47:27,410 --> 04:47:24,360

we're specifically interested in these

4746

04:47:29,448 --> 04:47:27,420

methylated gases um and the answer is

4747

04:47:31,010 --> 04:47:29,458

largely that there's a major false

4748

04:47:33,050 --> 04:47:31,020

positive problem

4749

04:47:34,610 --> 04:47:33,060

um for the first biosignature detections

4750

04:47:36,650 --> 04:47:34,620

a lot of molecules

4751  
04:47:38,570 --> 04:47:36,660  
um Like Oxygen ozone methane things like

4752  
04:47:41,750 --> 04:47:38,580  
that that we expect to be potentially

4753  
04:47:43,730 --> 04:47:41,760  
the first molecules detected that could

4754  
04:47:45,470 --> 04:47:43,740  
be connected to life in terrestrial

4755  
04:47:47,868 --> 04:47:45,480  
exoplanet atmospheres can also be

4756  
04:47:49,610 --> 04:47:47,878  
produced by a variety of planetary

4757  
04:47:51,890 --> 04:47:49,620  
processes including thermodynamic

4758  
04:47:54,948 --> 04:47:51,900  
equilibrium chemistry and so these

4759  
04:47:57,770 --> 04:47:54,958  
methylated gases are specifically uh

4760  
04:47:59,330 --> 04:47:57,780  
almost exclusively produced by life and

4761  
04:48:01,430 --> 04:47:59,340  
all of the other Pathways that we've

4762  
04:48:03,708 --> 04:48:01,440  
investigated have been very minimal so

4763  
04:48:05,330 --> 04:48:03,718

we're really excited that these gases

4764

04:48:08,330 --> 04:48:05,340

could potentially be a very strong

4765

04:48:10,368 --> 04:48:08,340

affirmative uh signal of life

4766

04:48:13,010 --> 04:48:10,378

um and these gases are generated by the

4767

04:48:16,310 --> 04:48:13,020

process of volatile methylation which

4768

04:48:19,250 --> 04:48:16,320

actually we believe to be a descendant

4769

04:48:21,470 --> 04:48:19,260

or perhaps a Rel relative in some way of

4770

04:48:22,850 --> 04:48:21,480

the process of DNA methylation which for

4771

04:48:25,070 --> 04:48:22,860

you biologists out there I'm sure you're

4772

04:48:27,410 --> 04:48:25,080

all much more familiar with than I but

4773

04:48:29,690 --> 04:48:27,420

we see volatile methylation in a variety

4774

04:48:32,270 --> 04:48:29,700

of different ecosystems including

4775

04:48:33,650 --> 04:48:32,280

microbial mats the open ocean and

4776

04:48:37,430 --> 04:48:33,660

primarily actually a lot of terrestrial

4777

04:48:39,288 --> 04:48:37,440

Marine kind of crossover ecosystems we

4778

04:48:41,628 --> 04:48:39,298

also see it done by a variety of

4779

04:48:43,190 --> 04:48:41,638

organisms primarily a single cellular

4780

04:48:45,530 --> 04:48:43,200

life but we do also see everyone's

4781

04:48:49,490 --> 04:48:45,540

favorite Brassica vegetables

4782

04:48:51,230 --> 04:48:49,500

um also produce methylated gases and we

4783

04:48:52,670 --> 04:48:51,240

think in particular that methylation is

4784

04:48:55,010 --> 04:48:52,680

connected to the process of

4785

04:48:56,810 --> 04:48:55,020

environmental detoxification

4786

04:48:58,788 --> 04:48:56,820

um and that the Need For Life to kind of

4787

04:49:00,288 --> 04:48:58,798

control its environment is possibly a

4788

04:49:02,030 --> 04:49:00,298

fundamental characteristic of life

4789

04:49:03,590 --> 04:49:02,040

itself and so when we're thinking about

4790

04:49:06,650 --> 04:49:03,600

you know what life might look like under

4791

04:49:08,090 --> 04:49:06,660

fundamentally different biogeochemistry

4792

04:49:09,470 --> 04:49:08,100

um you know we're it's probably still

4793

04:49:10,788 --> 04:49:09,480

going to need to be controlling that

4794

04:49:12,650 --> 04:49:10,798

surroundings in some ways we're really

4795

04:49:15,170 --> 04:49:12,660

excited about that potential tie-in as

4796

04:49:17,270 --> 04:49:15,180

well we're not the first people to think

4797

04:49:19,430 --> 04:49:17,280

about methylated biosignatures there are

4798

04:49:22,730 --> 04:49:19,440

a previous study specifically cigarette

4799

04:49:25,368 --> 04:49:22,740

all 2005 and Domingo Goldman at all 2011

4800

04:49:28,368 --> 04:49:25,378

which specifically show one an enhanced

4801  
04:49:30,050 --> 04:49:28,378  
buildup level around M dwarfs and two a

4802  
04:49:32,810 --> 04:49:30,060  
secondary ethane biosignature that's

4803  
04:49:35,030 --> 04:49:32,820  
produced by atmospheric photolysis of

4804  
04:49:36,170 --> 04:49:35,040  
dimethyl sulfide and dimethyl disulfide

4805  
04:49:38,330 --> 04:49:36,180  
um and that produces a potentially

4806  
04:49:39,650 --> 04:49:38,340  
detectable ethane signature

4807  
04:49:42,230 --> 04:49:39,660  
um and so we're going to follow a

4808  
04:49:44,090 --> 04:49:42,240  
relatively similar uh pathway we're

4809  
04:49:45,770 --> 04:49:44,100  
jumping from labland that we've been in

4810  
04:49:47,270 --> 04:49:45,780  
for the last couple of talks to modeling

4811  
04:49:49,850 --> 04:49:47,280  
land

4812  
04:49:51,590 --> 04:49:49,860  
um and uh primarily we're going to be

4813  
04:49:52,970 --> 04:49:51,600

talking about uh photochemical and

4814

04:49:54,650 --> 04:49:52,980

spectral modeling basically thinking

4815

04:49:55,850 --> 04:49:54,660

about how these gases are processed in

4816

04:49:57,650 --> 04:49:55,860

the atmosphere

4817

04:49:59,150 --> 04:49:57,660

um and what those potential signals uh

4818

04:50:01,250 --> 04:49:59,160

might look like

4819

04:50:03,708 --> 04:50:01,260

um just jumping into some results

4820

04:50:05,990 --> 04:50:03,718

um we have first here methyl bromide

4821

04:50:07,970 --> 04:50:06,000

which is again on your left

4822

04:50:10,010 --> 04:50:07,980

um and we have methyl iodine which is on

4823

04:50:12,288 --> 04:50:10,020

I think you're right

4824

04:50:14,150 --> 04:50:12,298

um and you'll notice that as I said

4825

04:50:15,770 --> 04:50:14,160

before for methyl chloride they see an

4826  
04:50:18,350 --> 04:50:15,780  
atmospheric buildup level that's much

4827  
04:50:21,170 --> 04:50:18,360  
higher around these M dwarf uh cooler

4828  
04:50:23,390 --> 04:50:21,180  
redder stars and we actually see that uh

4829  
04:50:25,250 --> 04:50:23,400  
buildup replicated and actually uh even

4830  
04:50:26,868 --> 04:50:25,260  
more enhanced for methyl bromide and

4831  
04:50:28,610 --> 04:50:26,878  
this result for methyl iodide is from

4832  
04:50:30,050 --> 04:50:28,620  
like literally last week um so that's

4833  
04:50:31,730 --> 04:50:30,060  
brand new

4834  
04:50:33,230 --> 04:50:31,740  
um and we're also seeing again the same

4835  
04:50:35,390 --> 04:50:33,240  
sort of enhanced buildup you'll notice

4836  
04:50:36,530 --> 04:50:35,400  
that it's to a lesser degree and we

4837  
04:50:38,690 --> 04:50:36,540  
think that's probably because it's just

4838  
04:50:42,110 --> 04:50:38,700

a larger molecule and so it's a larger

4839

04:50:44,208 --> 04:50:42,120

molecule it's going to be hit by more uh

4840

04:50:45,350 --> 04:50:44,218

potentially active uh photochemical

4841

04:50:48,050 --> 04:50:45,360

light

4842

04:50:50,690 --> 04:50:48,060

so we use this photochemical model to to

4843

04:50:51,948 --> 04:50:50,700

create profiles of gases in the

4844

04:50:53,990 --> 04:50:51,958

atmosphere and kind of figure out where

4845

04:50:55,310 --> 04:50:54,000

everything is where where it's at in the

4846

04:50:57,350 --> 04:50:55,320

atmosphere and then we're using like I

4847

04:50:59,390 --> 04:50:57,360

said a series of spectral models

4848

04:51:00,708 --> 04:50:59,400

um so this these are mid-infrared

4849

04:51:02,270 --> 04:51:00,718

emission Spectra

4850

04:51:03,830 --> 04:51:02,280

um and the most important thing that

4851  
04:51:05,810 --> 04:51:03,840  
I'll call your attention to here there's

4852  
04:51:07,250 --> 04:51:05,820  
kind of a lot going on but the bottom

4853  
04:51:09,050 --> 04:51:07,260  
row is actually showing an experiment

4854  
04:51:11,448 --> 04:51:09,060  
that we did where we add multiple

4855  
04:51:13,010 --> 04:51:11,458  
methylated gases in this case methyl

4856  
04:51:14,750 --> 04:51:13,020  
chloride and methyl bromide and you'll

4857  
04:51:16,850 --> 04:51:14,760  
actually notice that the features that

4858  
04:51:17,930 --> 04:51:16,860  
we see especially for Proxima Centauri

4859  
04:51:19,670 --> 04:51:17,940  
which is going to be that plot all the

4860  
04:51:21,230 --> 04:51:19,680  
way down in the bottom corner

4861  
04:51:22,970 --> 04:51:21,240  
um that feature is actually a little bit

4862  
04:51:24,350 --> 04:51:22,980  
wider and a little bit deeper than just

4863  
04:51:25,970 --> 04:51:24,360

kind of the simple sum of the features

4864

04:51:27,948 --> 04:51:25,980

and that's partially because we're doing

4865

04:51:29,270 --> 04:51:27,958

self-consistent photochemistry

4866

04:51:31,910 --> 04:51:29,280

um and so you do get higher buildup

4867

04:51:33,590 --> 04:51:31,920

levels and also because this absorption

4868

04:51:35,208 --> 04:51:33,600

feature in here 10 microns is actually

4869

04:51:37,070 --> 04:51:35,218

the acetah halogen Bond and so

4870

04:51:38,990 --> 04:51:37,080

acetochlorine and Cedar bromine are sort

4871

04:51:40,310 --> 04:51:39,000

of uh next to each other and overlapping

4872

04:51:42,050 --> 04:51:40,320

a little bit but really creating this

4873

04:51:43,850 --> 04:51:42,060

much larger feature um so we're

4874

04:51:46,310 --> 04:51:43,860

optimistic that a future telescope

4875

04:51:48,770 --> 04:51:46,320

capable of minute infrared emission

4876

04:51:50,810 --> 04:51:48,780

spectroscopy could detect these

4877

04:51:52,788 --> 04:51:50,820

um and we also think that while this

4878

04:51:54,410 --> 04:51:52,798

could detect a methylated gas we could

4879

04:51:57,410 --> 04:51:54,420

potentially fingerprint a specific

4880

04:52:00,590 --> 04:51:57,420

methylated gas using extremely high

4881

04:52:02,930 --> 04:52:00,600

resolution ground-based spectroscopy

4882

04:52:05,390 --> 04:52:02,940

um and potentially one mode that we

4883

04:52:06,890 --> 04:52:05,400

could use for the emission spectroscopy

4884

04:52:09,230 --> 04:52:06,900

that I was just showing is the life

4885

04:52:10,550 --> 04:52:09,240

telescope which is a concept Mission

4886

04:52:11,810 --> 04:52:10,560

um that's actually run by the European

4887

04:52:13,670 --> 04:52:11,820

Space Agency where they're using

4888

04:52:16,670 --> 04:52:13,680

interferometry to essentially get a

4889

04:52:17,930 --> 04:52:16,680

larger uh approximation of a telescope

4890

04:52:19,070 --> 04:52:17,940

rather than putting like 100 meter

4891

04:52:20,390 --> 04:52:19,080

telescope in space because that's

4892

04:52:21,230 --> 04:52:20,400

actually going to be very difficult to

4893

04:52:22,550 --> 04:52:21,240

do

4894

04:52:24,948 --> 04:52:22,560

um and so you could see here that

4895

04:52:26,208 --> 04:52:24,958

there's um simulated error bars for the

4896

04:52:27,590 --> 04:52:26,218

observations

4897

04:52:29,628 --> 04:52:27,600

um and that there's kind of a noticeable

4898

04:52:31,490 --> 04:52:29,638

difference uh between the atmospheres

4899

04:52:33,590 --> 04:52:31,500

without these methylated gases and

4900

04:52:36,050 --> 04:52:33,600

especially the higher flux cases

4901

04:52:39,170 --> 04:52:36,060

um and we can also look at this as a

4902

04:52:40,310 --> 04:52:39,180

kind of comparison to the uh Sigma of

4903

04:52:41,810 --> 04:52:40,320

the detection and you can see we get

4904

04:52:43,430 --> 04:52:41,820

some pretty significantly large features

4905

04:52:45,830 --> 04:52:43,440

here and we're optimistic again that if

4906

04:52:47,448 --> 04:52:45,840

any biosignatures are detectable on

4907

04:52:49,430 --> 04:52:47,458

these planets um these are very

4908

04:52:51,288 --> 04:52:49,440

optimistic planets where uh simulating

4909

04:52:53,990 --> 04:52:51,298

for but hopefully these methylated gases

4910

04:52:55,550 --> 04:52:54,000

will be among uh those bio signatures

4911

04:52:57,288 --> 04:52:55,560

that it's possible to detect so I will

4912

04:52:59,030 --> 04:52:57,298

leave you with my conclusions I think I

4913

04:53:01,250 --> 04:52:59,040

am right on time

4914

04:53:03,050 --> 04:53:01,260

um I'm at poster nine which is right on

4915

04:53:04,730 --> 04:53:03,060

the other side of this wall or you can

4916

04:53:12,470 --> 04:53:04,740

feel free to contact me my information

4917

04:53:19,070 --> 04:53:16,010

thank you Michaela up next we have

4918

04:53:25,010 --> 04:53:19,080

Jordan mccague from Georgia Institute of

4919

04:53:28,490 --> 04:53:26,330

all right hello everyone my name is

4920

04:53:30,350 --> 04:53:28,500

Jordan mckaig and I am a PhD candidate

4921

04:53:31,910 --> 04:53:30,360

at Georgia Tech I'm working with Dr

4922

04:53:34,430 --> 04:53:31,920

Chris Carr on using solid state

4923

04:53:36,110 --> 04:53:34,440

nanopores to detect biosignatures and

4924

04:53:37,550 --> 04:53:36,120

think about potential for agnostic life

4925

04:53:39,288 --> 04:53:37,560

detection

4926  
04:53:40,490 --> 04:53:39,298  
so throughout our universe or throughout

4927  
04:53:42,410 --> 04:53:40,500  
our solar system rather there are a

4928  
04:53:44,090 --> 04:53:42,420  
variety of planetary bodies that have

4929  
04:53:45,830 --> 04:53:44,100  
conditions thought to be hospitable for

4930  
04:53:47,510 --> 04:53:45,840  
life so things that are in the middle of

4931  
04:53:50,270 --> 04:53:47,520  
this fine diagram containing the right

4932  
04:53:52,070 --> 04:53:50,280  
raw materials energy sources solvents

4933  
04:53:54,288 --> 04:53:52,080  
and climate conditions for living things

4934  
04:53:55,970 --> 04:53:54,298  
to possibly persist many of these

4935  
04:53:57,350 --> 04:53:55,980  
environments are aqueous and saline

4936  
04:53:59,868 --> 04:53:57,360  
environments and as we've discussed

4937  
04:54:01,610 --> 04:53:59,878  
previously today and yesterday salts

4938  
04:54:03,530 --> 04:54:01,620

have a major influence on the ability of

4939

04:54:05,690 --> 04:54:03,540

an organism to live in an environment as

4940

04:54:07,788 --> 04:54:05,700

well as the potential for Bio signature

4941

04:54:09,530 --> 04:54:07,798

um excuse me sorry biosignature

4942

04:54:12,288 --> 04:54:09,540

preservation and I'm particularly

4943

04:54:13,970 --> 04:54:12,298

interested in how salts can interact

4944

04:54:16,250 --> 04:54:13,980

with these biomolecules in terms of

4945

04:54:18,350 --> 04:54:16,260

doing detection with nanopores

4946

04:54:20,090 --> 04:54:18,360

so specifically the biosignatures that

4947

04:54:22,550 --> 04:54:20,100

I'm interested in are nucleic acids and

4948

04:54:24,948 --> 04:54:22,560

ribosomes nucleic acids that's your DNA

4949

04:54:26,628 --> 04:54:24,958

and RNA it's a linear charge polymer

4950

04:54:29,270 --> 04:54:26,638

that is responsible for storing and

4951  
04:54:30,948 --> 04:54:29,280  
regulating genetic information ribosomes

4952  
04:54:33,890 --> 04:54:30,958  
are cellular Machinery that translate

4953  
04:54:34,550 --> 04:54:33,900  
this information into usable proteins

4954  
04:54:35,930 --> 04:54:34,560  
um

4955  
04:54:37,788 --> 04:54:35,940  
oh sorry

4956  
04:54:39,890 --> 04:54:37,798  
excuse me nucleic acids and ribosomes

4957  
04:54:41,628 --> 04:54:39,900  
are ubiquitous to all known life and are

4958  
04:54:43,670 --> 04:54:41,638  
part of the central dogma biology so

4959  
04:54:45,590 --> 04:54:43,680  
this is a paradigm in biology that

4960  
04:54:47,570 --> 04:54:45,600  
traces the flow of information from

4961  
04:54:50,510 --> 04:54:47,580  
these charged Polymers of DNA and RNA

4962  
04:54:52,730 --> 04:54:50,520  
through proteins

4963  
04:54:54,170 --> 04:54:52,740

so it's been proposed that molecules of

4964

04:54:55,610 --> 04:54:54,180

similar structure and function but

4965

04:54:56,868 --> 04:54:55,620

different biochemistry from some of

4966

04:54:59,390 --> 04:54:56,878

these things could actually serve as

4967

04:55:01,190 --> 04:54:59,400

evidence for life as we don't know it

4968

04:55:02,930 --> 04:55:01,200

um in 2017 it was proposed that linear

4969

04:55:05,270 --> 04:55:02,940

charged polymers with repeating units

4970

04:55:07,550 --> 04:55:05,280

analogous to nucleic acids like DNA and

4971

04:55:09,110 --> 04:55:07,560

RNA could serve as an agnostic by a

4972

04:55:10,670 --> 04:55:09,120

signature and we are also working on a

4973

04:55:12,650 --> 04:55:10,680

paper arguing that translation

4974

04:55:14,750 --> 04:55:12,660

performing molecules of a quantized size

4975

04:55:16,610 --> 04:55:14,760

analogous ribosomes could similarly

4976

04:55:18,110 --> 04:55:16,620

serve this function since these don't

4977

04:55:19,490 --> 04:55:18,120

have the same biochemistry of Life as we

4978

04:55:20,990 --> 04:55:19,500

know it here on Earth it would require

4979

04:55:22,550 --> 04:55:21,000

detection with a method that doesn't

4980

04:55:24,770 --> 04:55:22,560

necessitate any specific chemical

4981

04:55:28,368 --> 04:55:24,780

composition which leads us to solid

4982

04:55:31,490 --> 04:55:28,378

state nanopores this is an agnostic mode

4983

04:55:33,110 --> 04:55:31,500

of detection which requires a molecule

4984

04:55:35,868 --> 04:55:33,120

to be suspended in a conductive solution

4985

04:55:37,128 --> 04:55:35,878

so your nanopore here is a nanometer

4986

04:55:39,350 --> 04:55:37,138

scale pore that's drilled into a

4987

04:55:40,850 --> 04:55:39,360

membrane a current is passed over it and

4988

04:55:43,310 --> 04:55:40,860

a voltage or a pressure differential

4989

04:55:44,390 --> 04:55:43,320

drives molecules through the pore as

4990

04:55:45,948 --> 04:55:44,400

things go through on these

4991

04:55:47,150 --> 04:55:45,958

translocations create blockages and

4992

04:55:49,310 --> 04:55:47,160

current which can be used to get

4993

04:55:50,930 --> 04:55:49,320

information about the biomolecules

4994

04:55:52,430 --> 04:55:50,940

and I just want to highlight again this

4995

04:55:53,868 --> 04:55:52,440

does not require specific biochemistry

4996

04:55:55,250 --> 04:55:53,878

making it exciting for not only

4997

04:55:56,628 --> 04:55:55,260

investigating living things here on

4998

04:55:57,948 --> 04:55:56,638

Earth but also potentially elsewhere in

4999

04:55:59,990 --> 04:55:57,958

the solar system

5000

04:56:01,670 --> 04:56:00,000

so what we did was show a proof of

5001

04:56:03,590 --> 04:56:01,680

concept for something called the

5002

04:56:05,570 --> 04:56:03,600

anterior Nano counter which was a

5003

04:56:07,010 --> 04:56:05,580

proprietary solid state nanoportin

5004

04:56:08,750 --> 04:56:07,020

shreds and these are all the different

5005

04:56:11,690 --> 04:56:08,760

biomolecules that we analyze including

5006

04:56:13,128 --> 04:56:11,700

some DNA samples RNA and ribosomes and

5007

04:56:15,050 --> 04:56:13,138

if you'd like to hear more details about

5008

04:56:16,850 --> 04:56:15,060

how specifically this went down please

5009

04:56:19,910 --> 04:56:16,860

come talk to me at my poster

5010

04:56:23,690 --> 04:56:19,920

and then also I have some of the example

5011

04:56:25,190 --> 04:56:23,700

um results so first we have a few graphs

5012

04:56:27,350 --> 04:56:25,200

showing just different example events

5013

04:56:29,750 --> 04:56:27,360

with signature specific events for each

5014

04:56:31,250 --> 04:56:29,760

biomolecule structure and then some heat

5015

04:56:33,110 --> 04:56:31,260

maps showing the change in conductance

5016

04:56:35,030 --> 04:56:33,120

in the dwell time for all the events in

5017

04:56:36,948 --> 04:56:35,040

a specific run and then some overlaid

5018

04:56:39,050 --> 04:56:36,958

samples of what all these events looked

5019

04:56:41,448 --> 04:56:39,060

like and what I just want to highlight

5020

04:56:42,890 --> 04:56:41,458

here is um let's see do I have

5021

04:56:45,708 --> 04:56:42,900

okay great

5022

04:56:48,050 --> 04:56:45,718

um I have overlay DNA events all here in

5023

04:56:50,330 --> 04:56:48,060

the blue this is a circular plasmid um

5024

04:56:52,368 --> 04:56:50,340

so it's just a circular piece of DNA and

5025

04:56:54,050 --> 04:56:52,378

it is a pretty short dwell time but also

5026

04:56:55,070 --> 04:56:54,060

a much larger change in current and this

5027

04:56:57,410 --> 04:56:55,080

is probably due to the circular

5028

04:56:59,448 --> 04:56:57,420

structure instead of a linear polymer

5029

04:57:00,948 --> 04:56:59,458

um so when you have a circular piece of

5030

04:57:03,288 --> 04:57:00,958

DNA going through the nanopore you would

5031

04:57:04,910 --> 04:57:03,298

have four strands of DNA instead of the

5032

04:57:07,310 --> 04:57:04,920

two strands that's in a regular linear

5033

04:57:08,990 --> 04:57:07,320

fragment similarly for linear fragments

5034

04:57:10,970 --> 04:57:09,000

we have these two right here with this

5035

04:57:12,350 --> 04:57:10,980

one in red being a shorter fragment and

5036

04:57:14,390 --> 04:57:12,360

the one in black being a longer fragment

5037

04:57:15,590 --> 04:57:14,400

which is reflected in that longer dwell

5038

04:57:17,570 --> 04:57:15,600

time

5039

04:57:19,550 --> 04:57:17,580

then I also have the data for the

5040

04:57:22,250 --> 04:57:19,560

ribosomal detection so there are a few

5041

04:57:24,110 --> 04:57:22,260

key classes of results here the ones in

5042

04:57:27,170 --> 04:57:24,120

box a we interpreted as being intact

5043

04:57:28,610 --> 04:57:27,180

ribosomes since they are larger and then

5044

04:57:29,930 --> 04:57:28,620

things in box B would have been smaller

5045

04:57:31,850 --> 04:57:29,940

particles which we actually think were

5046

04:57:33,470 --> 04:57:31,860

ribosomal fragments so we thought that

5047

04:57:35,750 --> 04:57:33,480

maybe we had some issues with the buffer

5048

04:57:38,270 --> 04:57:35,760

causing that precipitation which allows

5049

04:57:39,830 --> 04:57:38,280

us not only analyze the exact intact

5050

04:57:41,270 --> 04:57:39,840

ribosomes as well as fragments

5051  
04:57:42,650 --> 04:57:41,280  
themselves so if you'd like to hear more

5052  
04:57:44,628 --> 04:57:42,660  
please come talk to me at my poster I'll

5053  
04:57:52,070 --> 04:57:44,638  
be at number 19 which is um kind of over

5054  
04:57:58,368 --> 04:57:55,550  
wonderful thank you so much Jordan

5055  
04:58:00,830 --> 04:57:58,378  
um up next last but not least Justin

5056  
04:58:07,550 --> 04:58:00,840  
Park coming from Rensselaer Polytechnic

5057  
04:58:12,110 --> 04:58:10,490  
hello everybody my name is Justin Park I

5058  
04:58:14,448 --> 04:58:12,120  
am a second year PhD student at

5059  
04:58:15,708 --> 04:58:14,458  
Rensselaer Polytechnic Institute and one

5060  
04:58:17,390 --> 04:58:15,718  
thing we're interested in doing in our

5061  
04:58:19,368 --> 04:58:17,400  
Labs is reconstructing ancient

5062  
04:58:21,288 --> 04:58:19,378  
atmospheres as they pertain to important

5063  
04:58:22,970 --> 04:58:21,298

evolutionary steps in our atmosphere's

5064

04:58:25,368 --> 04:58:22,980

history

5065

04:58:27,110 --> 04:58:25,378

so what I do is I look at ancient

5066

04:58:29,270 --> 04:58:27,120

atmospheres trapped in halite fluid

5067

04:58:30,890 --> 04:58:29,280

inclusions so halite as we've seen in

5068

04:58:32,990 --> 04:58:30,900

previous talks is an evaporative mineral

5069

04:58:34,730 --> 04:58:33,000

it forms in these really dry arid

5070

04:58:37,190 --> 04:58:34,740

environments where evaporation is the

5071

04:58:38,510 --> 04:58:37,200

dominating Force as it does so it can

5072

04:58:40,490 --> 04:58:38,520

form these things called fluid

5073

04:58:42,948 --> 04:58:40,500

inclusions as shown in the top right up

5074

04:58:45,530 --> 04:58:42,958

here and they can encapture air or brine

5075

04:58:47,810 --> 04:58:45,540

in the mineral Matrix now these can be

5076  
04:58:49,910 --> 04:58:47,820  
primary or secondary meaning they form

5077  
04:58:51,530 --> 04:58:49,920  
at the time the mineral precipitates or

5078  
04:58:53,810 --> 04:58:51,540  
forming sometime later with some

5079  
04:58:55,788 --> 04:58:53,820  
secondary fluid event and oftentimes

5080  
04:58:58,850 --> 04:58:55,798  
they form an assemblages of hundreds or

5081  
04:59:00,590 --> 04:58:58,860  
thousands of inclusions at once now what

5082  
04:59:02,208 --> 04:59:00,600  
I'm interested in doing is looking at

5083  
04:59:04,128 --> 04:59:02,218  
the gases that are trapped in these

5084  
04:59:06,170 --> 04:59:04,138  
primary inclusions and saying something

5085  
04:59:08,448 --> 04:59:06,180  
about the evolving composition of the

5086  
04:59:10,788 --> 04:59:08,458  
atmosphere

5087  
04:59:12,230 --> 04:59:10,798  
now we do have some evidence for what we

5088  
04:59:14,570 --> 04:59:12,240

think the atmosphere looked like and how

5089

04:59:16,610 --> 04:59:14,580

it evolved here I have plotted one of

5090

04:59:19,190 --> 04:59:16,620

the major models suggesting the change

5091

04:59:22,010 --> 04:59:19,200

in partial pressure of nitrogen oxygen

5092

04:59:23,930 --> 04:59:22,020

or CO<sub>2</sub> and methane as a function of time

5093

04:59:26,628 --> 04:59:23,940

starting with the moon forming event 4.5

5094

04:59:28,368 --> 04:59:26,638

billion years ago now if you'll notice

5095

04:59:30,050 --> 04:59:28,378

here there is a lot of uncertainty in

5096

04:59:32,448 --> 04:59:30,060

these measurements and this is due to

5097

04:59:33,530 --> 04:59:32,458

them being made with indirect proxy

5098

04:59:36,590 --> 04:59:33,540

measurements

5099

04:59:39,530 --> 04:59:36,600

now also in the period between 2 and 1

5100

04:59:41,990 --> 04:59:39,540

billion years ago here

5101  
04:59:43,788 --> 04:59:42,000  
we have this period known as the boring

5102  
04:59:45,770 --> 04:59:43,798  
billion and it's aptly named for the

5103  
04:59:46,788 --> 04:59:45,780  
apparent stagnancy of the atmospheric

5104  
04:59:48,708 --> 04:59:46,798  
evolution

5105  
04:59:50,390 --> 04:59:48,718  
now what we're interested in doing is

5106  
04:59:53,330 --> 04:59:50,400  
providing ancient atmospheric

5107  
04:59:55,250 --> 04:59:53,340  
constraints using fluid inclusions in

5108  
04:59:58,070 --> 04:59:55,260  
the period between these two points

5109  
05:00:00,350 --> 04:59:58,080  
using direct analysis from 1.4 billion

5110  
05:00:02,810 --> 05:00:00,360  
year old fluid inclusions

5111  
05:00:05,270 --> 05:00:02,820  
so we can do this by loading our samples

5112  
05:00:07,610 --> 05:00:05,280  
into a special crushing device crushing

5113  
05:00:09,470 --> 05:00:07,620

them this ruptures our inclusions and we

5114

05:00:11,510 --> 05:00:09,480  
can pass the gas directly into a

5115

05:00:13,670 --> 05:00:11,520  
quadrupole mass spectrometer

5116

05:00:15,830 --> 05:00:13,680  
when we do so we see peaks in our signal

5117

05:00:17,510 --> 05:00:15,840  
that correspond to each Crush these

5118

05:00:19,730 --> 05:00:17,520  
Peaks can be integrated and Quantified

5119

05:00:21,530 --> 05:00:19,740  
by comparing to known calibration points

5120

05:00:23,510 --> 05:00:21,540  
thus we can get an idea of the

5121

05:00:26,510 --> 05:00:23,520  
composition and known amount of moles of

5122

05:00:27,890 --> 05:00:26,520  
nitrogen oxygen argon and CO<sub>2</sub> present in

5123

05:00:29,510 --> 05:00:27,900  
these inclusions

5124

05:00:31,128 --> 05:00:29,520  
when we backtrack and calculate the

5125

05:00:32,810 --> 05:00:31,138  
ancient atmosphere composition we do

5126

05:00:34,788 --> 05:00:32,820

have to be wary of any aqueous

5127

05:00:36,530 --> 05:00:34,798

contributions as we know Henry's law

5128

05:00:38,030 --> 05:00:36,540

tells us this atmosphere may also be

5129

05:00:39,770 --> 05:00:38,040

dissolved in the brine phase and

5130

05:00:42,050 --> 05:00:39,780

equilibrium

5131

05:00:44,208 --> 05:00:42,060

so when we did this we saw some

5132

05:00:46,250 --> 05:00:44,218

variability in our results here I have

5133

05:00:48,830 --> 05:00:46,260

plotted the mole fraction of nitrogen

5134

05:00:51,350 --> 05:00:48,840

oxygen argon and CO<sub>2</sub> as a function of

5135

05:00:53,628 --> 05:00:51,360

the size of each sample one thing we can

5136

05:00:55,128 --> 05:00:53,638

notice is that the primary and secondary

5137

05:00:57,050 --> 05:00:55,138

inclusions do capture different

5138

05:00:59,810 --> 05:00:57,060

atmospheres that are distinct from one

5139

05:01:01,788 --> 05:00:59,820

of one another now we're very interested

5140

05:01:03,650 --> 05:01:01,798

in the primary inclusions as that's the

5141

05:01:05,750 --> 05:01:03,660

environment that the mineral formed in

5142

05:01:07,970 --> 05:01:05,760

and we can compute a average partial

5143

05:01:10,070 --> 05:01:07,980

pressure or density of each gas and

5144

05:01:11,810 --> 05:01:10,080

compare it to the modern atmosphere

5145

05:01:14,390 --> 05:01:11,820

when we do that we saw some very

5146

05:01:16,310 --> 05:01:14,400

interesting things back 1.4 billion

5147

05:01:18,110 --> 05:01:16,320

years ago we found atmospheric nitrogen

5148

05:01:20,510 --> 05:01:18,120

was roughly the same partial pressure as

5149

05:01:22,310 --> 05:01:20,520

it is today atmospheric oxygen was

5150

05:01:24,708 --> 05:01:22,320

around a tenth as dense

5151

05:01:26,270 --> 05:01:24,718

argon was about half as dense and carbon

5152

05:01:28,788 --> 05:01:26,280

dioxide was actually eight times more

5153

05:01:31,010 --> 05:01:28,798

dense now each of these gases has really

5154

05:01:32,390 --> 05:01:31,020

important implications but due to time

5155

05:01:34,610 --> 05:01:32,400

I'm only going to have time to talk

5156

05:01:36,650 --> 05:01:34,620

about oxygen today

5157

05:01:38,390 --> 05:01:36,660

so when we looked at our oxygen results

5158

05:01:40,070 --> 05:01:38,400

there are measured partial pressure

5159

05:01:42,230 --> 05:01:40,080

revealed some pretty interesting things

5160

05:01:44,030 --> 05:01:42,240

here I have it compared to many of the

5161

05:01:46,368 --> 05:01:44,040

predicted models that have been proposed

5162

05:01:48,050 --> 05:01:46,378

what we saw is that we captured more

5163

05:01:50,390 --> 05:01:48,060

oxygen than these models would have

5164

05:01:51,890 --> 05:01:50,400

proposed this indicates that these

5165

05:01:53,390 --> 05:01:51,900

direct measurements might be able to

5166

05:01:54,470 --> 05:01:53,400

capture things that the proxies are

5167

05:01:55,970 --> 05:01:54,480

unable to

5168

05:01:58,310 --> 05:01:55,980

and this has some pretty important

5169

05:02:00,650 --> 05:01:58,320

implications the oxygen that we measured

5170

05:02:02,510 --> 05:02:00,660

is above theoretical lower limits

5171

05:02:04,610 --> 05:02:02,520

necessary for the early evolution of

5172

05:02:06,170 --> 05:02:04,620

life and it's also an agreement with

5173

05:02:08,750 --> 05:02:06,180

some evidence suggesting there was a

5174

05:02:11,150 --> 05:02:08,760

developed ozone layer at this time

5175

05:02:13,368 --> 05:02:11,160

now on the right here I have plotted a

5176  
05:02:15,788 --> 05:02:13,378  
phylogenetic tree showing the marked

5177  
05:02:18,470 --> 05:02:15,798  
diversification of red algae in the

5178  
05:02:20,030 --> 05:02:18,480  
mesopoterozoic Now red algae are very

5179  
05:02:22,128 --> 05:02:20,040  
important as they're some of the first

5180  
05:02:23,868 --> 05:02:22,138  
photosynthetic eukaryotes that gives

5181  
05:02:25,128 --> 05:02:23,878  
them an evolutionary advantage to

5182  
05:02:26,330 --> 05:02:25,138  
produce more oxygen than their

5183  
05:02:28,368 --> 05:02:26,340  
predecessors

5184  
05:02:30,650 --> 05:02:28,378  
and this becomes really interesting when

5185  
05:02:32,628 --> 05:02:30,660  
we compare this to our timing of the

5186  
05:02:35,030 --> 05:02:32,638  
deposition of our samples we can see

5187  
05:02:37,070 --> 05:02:35,040  
they're roughly contemporaneous and thus

5188  
05:02:39,050 --> 05:02:37,080

our elevated oxygen measurements are

5189

05:02:41,868 --> 05:02:39,060

likely due to the presence of these red

5190

05:02:44,208 --> 05:02:41,878

algae so I hope I've shown here today

5191

05:02:46,070 --> 05:02:44,218

that the atmospheric oxygen here is

5192

05:02:47,510 --> 05:02:46,080

pointing a more Dynamic picture of the

5193

05:02:49,910 --> 05:02:47,520

boring billion and it might not have

5194

05:02:52,430 --> 05:02:49,920

been so boring at all we have important

5195

05:02:54,350 --> 05:02:52,440

implications of these ancient red algae

5196

05:02:56,150 --> 05:02:54,360

evolving at this time period that led to

5197

05:03:00,470 --> 05:02:56,160

this

5198

05:03:02,510 --> 05:03:00,480

inclusions can capture and maintain

5199

05:03:04,190 --> 05:03:02,520

direct evidence of ancient atmospheres

5200

05:03:05,270 --> 05:03:04,200

for hundreds of millions of years if not

5201  
05:03:07,430 --> 05:03:05,280  
billions

5202  
05:03:08,868 --> 05:03:07,440  
with mass spectrometry we can probe the

5203  
05:03:10,670 --> 05:03:08,878  
contents of the gas that are trapped

5204  
05:03:12,890 --> 05:03:10,680  
within these and we can look into how

5205  
05:03:14,930 --> 05:03:12,900  
the atmosphere has evolved we aimed to

5206  
05:03:17,090 --> 05:03:14,940  
make compositional measurements of the

5207  
05:03:18,650 --> 05:03:17,100  
atmosphere 1.4 billion years ago and we

5208  
05:03:20,628 --> 05:03:18,660  
found something very different than our

5209  
05:03:22,490 --> 05:03:20,638  
present atmosphere hopefully in the

5210  
05:03:23,990 --> 05:03:22,500  
future we can make isotopic ratio

5211  
05:03:27,170 --> 05:03:24,000  
measurements and see any further

5212  
05:03:28,788 --> 05:03:27,180  
Evolution trends so with that thank you

5213  
05:03:30,230 --> 05:03:28,798

all for listening if you have any

5214

05:03:38,890 --> 05:03:30,240

questions I'd be happy to talk to you

5215

05:03:43,368 --> 05:03:41,868

wonderful thank you so much Justin all

5216

05:03:45,708 --> 05:03:43,378

right guys so

5217

05:03:47,330 --> 05:03:45,718

um our final poster session of the

5218

05:03:50,150 --> 05:03:47,340

conference will be beginning just now

5219

05:03:53,208 --> 05:03:50,160

out here and we will meet back here at 3

5220

05:03:56,510 --> 05:03:53,218

30 for our sadly final talk session

5221

05:03:57,890 --> 05:03:56,520

techno signatures and life detection all

5222

05:04:00,288 --> 05:03:57,900

right we'll see you then and I want to

5223

05:04:04,670 --> 05:04:00,298

say one more time if anyone is

5224

05:04:07,550 --> 05:04:04,680

interested in having a party like we did

5225

05:04:20,040 --> 05:04:07,560

come and talk to one of us okay thank

5226  
05:04:43,868 --> 05:04:31,900  
[Music]

5227  
05:04:54,570 --> 05:04:45,708  
thank you

5228  
05:05:15,890 --> 05:05:04,930  
[Music]

5229  
05:05:15,900 --> 05:05:20,500  
foreign

5230  
05:06:31,090 --> 05:05:46,450  
[Music]

5231  
05:06:31,100 --> 05:06:38,360  
thank you

5232  
05:06:38,370 --> 05:06:45,368  
[Music]

5233  
05:06:45,378 --> 05:06:48,720  
thank you

5234  
05:07:25,070 --> 05:07:04,300  
[Music]

5235  
05:07:25,080 --> 05:07:30,250  
foreign

5236  
05:07:30,260 --> 05:07:50,750  
[Music]

5237  
05:07:59,480 --> 05:07:51,720  
thank you

5238  
05:08:27,850 --> 05:08:06,200

[Music]

5239

05:08:27,860 --> 05:08:32,480

thank you

5240

05:08:32,490 --> 05:08:40,868

[Music]

5241

05:08:40,878 --> 05:08:48,080

thank you

5242

05:09:32,170 --> 05:09:14,030

[Music]

5243

05:09:32,180 --> 05:09:35,500

thank you

5244

05:10:51,368 --> 05:09:43,130

[Music]

5245

05:10:51,378 --> 05:10:57,810

thank you

5246

05:10:57,820 --> 05:11:04,570

[Music]

5247

05:11:04,580 --> 05:11:15,170

thank you

5248

05:11:56,390 --> 05:11:26,960

[Music]

5249

05:11:56,400 --> 05:12:00,040

thank you

5250

05:12:00,050 --> 05:12:10,970

[Music]

5251  
05:12:10,980 --> 05:12:15,670  
foreign

5252  
05:13:14,590 --> 05:12:41,590  
[Music]

5253  
05:13:24,650 --> 05:13:17,530  
thank you

5254  
05:13:24,660 --> 05:13:33,480  
foreign

5255  
05:14:18,730 --> 05:13:43,820  
[Music]

5256  
05:14:18,740 --> 05:14:25,380  
thank you

5257  
05:14:25,390 --> 05:14:42,850  
[Music]

5258  
05:14:42,860 --> 05:14:46,850  
thank you

5259  
05:15:24,250 --> 05:14:54,510  
[Music]

5260  
05:15:24,260 --> 05:15:27,630  
thank you

5261  
05:15:50,350 --> 05:15:43,210  
[Music]

5262  
05:15:50,360 --> 05:15:55,250  
thank you

5263  
05:16:15,010 --> 05:16:09,150

[Music]

5264

05:16:15,020 --> 05:16:26,510

thank you

5265

05:16:43,490 --> 05:16:38,270

[Music]

5266

05:16:43,500 --> 05:17:01,020

foreign

5267

05:17:19,750 --> 05:17:11,410

[Music]

5268

05:17:19,760 --> 05:17:27,010

thank you

5269

05:18:07,330 --> 05:17:32,770

[Music]

5270

05:18:07,340 --> 05:18:16,370

thank you

5271

05:18:35,180 --> 05:18:33,490

[Music]

5272

05:18:44,450 --> 05:18:35,190

thank you

5273

05:19:52,550 --> 05:19:00,590

[Music]

5274

05:20:21,100 --> 05:19:54,280

thank you

5275

05:21:22,010 --> 05:20:23,090

[Music]

5276  
05:21:49,550 --> 05:21:23,710  
thank you

5277  
05:21:49,560 --> 05:22:03,368  
[Music]

5278  
05:22:15,560 --> 05:22:09,490  
thank you

5279  
05:23:34,628 --> 05:22:24,950  
[Music]

5280  
05:23:34,638 --> 05:23:37,970  
thank you

5281  
05:24:12,470 --> 05:23:57,540  
[Music]

5282  
05:24:12,480 --> 05:25:07,070  
foreign

5283  
05:25:07,080 --> 05:25:28,368  
thank you

5284  
05:25:28,378 --> 05:26:13,550  
foreign

5285  
05:26:13,560 --> 05:26:44,448  
thank you

5286  
05:26:44,458 --> 05:27:41,708  
foreign

5287  
05:28:41,990 --> 05:27:53,330  
thank you

5288  
05:28:42,000 --> 05:29:08,270

foreign

5289

05:29:08,280 --> 05:30:00,368

um

5290

05:30:00,378 --> 05:30:16,970

thank you

5291

05:36:02,208 --> 05:31:30,890

foreign

5292

05:36:02,218 --> 05:36:24,288

thank you

5293

05:36:24,298 --> 05:36:45,120

foreign

5294

05:37:13,990 --> 05:37:05,200

[Music]

5295

05:37:14,000 --> 05:37:18,430

thank you

5296

05:37:18,440 --> 05:37:37,510

[Music]

5297

05:37:40,500 --> 05:37:39,470

thank you

5298

05:38:00,600 --> 05:37:40,510

foreign

5299

05:39:20,930 --> 05:38:08,250

[Music]

5300

05:39:20,940 --> 05:39:32,280

foreign

5301  
05:39:48,590 --> 05:39:39,590  
[Music]

5302  
05:39:48,600 --> 05:39:59,970  
foreign

5303  
05:39:59,980 --> 05:40:12,128  
[Music]

5304  
05:40:27,660 --> 05:40:13,850  
thank you

5305  
05:40:44,170 --> 05:40:35,040  
[Music]

5306  
05:40:44,180 --> 05:40:50,470  
thank you

5307  
05:41:22,110 --> 05:41:02,630  
[Music]

5308  
05:41:25,010 --> 05:41:22,120  
foreign

5309  
05:41:57,948 --> 05:41:25,020  
[Music]

5310  
05:41:57,958 --> 05:42:18,430  
foreign

5311  
05:42:18,440 --> 05:42:26,470  
[Music]

5312  
05:42:53,550 --> 05:42:46,030  
thank you

5313  
05:42:53,560 --> 05:43:13,930

[Music]

5314

05:43:13,940 --> 05:43:21,250

thank you

5315

05:43:21,260 --> 05:43:41,990

[Music]

5316

05:43:42,000 --> 05:43:46,120

thank you

5317

05:43:46,130 --> 05:43:53,708

[Music]

5318

05:43:53,718 --> 05:44:13,510

thank you

5319

05:44:35,570 --> 05:44:24,850

[Music]

5320

05:44:43,570 --> 05:44:38,110

foreign

5321

05:45:07,670 --> 05:44:49,440

[Music]

5322

05:45:07,680 --> 05:45:24,860

foreign

5323

05:45:47,090 --> 05:45:42,550

[Music]

5324

05:45:47,100 --> 05:45:54,860

foreign

5325

05:46:52,310 --> 05:46:07,270

[Music]

5326  
05:46:52,320 --> 05:46:55,000  
thank you

5327  
05:47:30,350 --> 05:47:07,270  
[Music]

5328  
05:47:30,360 --> 05:47:37,270  
foreign

5329  
05:48:19,368 --> 05:47:43,030  
[Music]

5330  
05:48:19,378 --> 05:48:24,990  
foreign

5331  
05:48:25,000 --> 05:48:42,230  
[Music]

5332  
05:48:54,840 --> 05:48:43,560  
foreign

5333  
05:49:23,510 --> 05:49:13,560  
[Music]

5334  
05:49:42,990 --> 05:49:24,840  
foreign

5335  
05:49:43,000 --> 05:49:53,628  
[Music]

5336  
05:50:13,570 --> 05:49:54,860  
foreign

5337  
05:51:07,070 --> 05:50:24,870  
[Music]

5338  
05:51:13,530 --> 05:51:07,280

foreign

5339

05:51:49,460 --> 05:51:25,010

[Music]

5340

05:51:54,990 --> 05:51:49,470

thank you

5341

05:52:24,990 --> 05:52:07,270

[Music]

5342

05:52:43,020 --> 05:52:25,000

foreign

5343

05:53:04,430 --> 05:52:54,970

[Music]

5344

05:53:04,440 --> 05:53:13,560

foreign

5345

05:53:34,368 --> 05:53:19,490

[Music]

5346

05:53:34,378 --> 05:53:43,570

foreign

5347

05:55:22,190 --> 05:53:53,920

[Music]

5348

05:55:37,250 --> 05:55:25,000

foreign

5349

05:55:59,868 --> 05:55:42,640

[Music]

5350

05:55:59,878 --> 05:56:07,250

foreign

5351  
05:56:35,448 --> 05:56:13,010  
[Music]

5352  
05:56:54,980 --> 05:56:37,240  
thank you

5353  
05:57:11,390 --> 05:57:07,260  
[Music]

5354  
05:57:25,000 --> 05:57:13,010  
foreign

5355  
05:57:25,010 --> 05:57:58,788  
[Music]

5356  
05:57:58,798 --> 05:58:08,910  
thank you

5357  
05:58:25,730 --> 05:58:20,980  
[Music]

5358  
05:58:25,740 --> 05:58:32,560  
foreign

5359  
05:58:32,570 --> 05:58:59,448  
[Music]

5360  
05:58:59,458 --> 05:59:07,320  
thank you

5361  
05:59:30,170 --> 05:59:24,380  
[Music]

5362  
05:59:30,180 --> 05:59:37,310  
thank you

5363  
05:59:37,320 --> 06:00:01,900

foreign

5364

06:00:01,910 --> 06:00:06,948

[Music]

5365

06:00:06,958 --> 06:00:13,580

thank you

5366

06:00:13,590 --> 06:00:46,730

[Music]

5367

06:01:44,150 --> 06:00:48,340

foreign

5368

06:01:44,160 --> 06:01:49,970

[Music]

5369

06:02:09,190 --> 06:02:00,170

foreign

5370

06:02:09,200 --> 06:02:31,850

[Music]

5371

06:02:31,860 --> 06:02:46,470

thank you

5372

06:02:46,480 --> 06:03:00,350

[Music]

5373

06:03:08,510 --> 06:03:01,910

relax

5374

06:03:08,520 --> 06:03:25,210

foreign

5375

06:04:15,910 --> 06:03:35,690

[Music]

5376  
06:04:15,920 --> 06:04:19,070  
thank you

5377  
06:04:19,080 --> 06:04:25,910  
foreign

5378  
06:04:25,920 --> 06:05:25,250  
[Music]

5379  
06:06:19,730 --> 06:05:27,090  
thank you

5380  
06:06:23,150 --> 06:06:21,250  
[Music]

5381  
06:06:37,350 --> 06:06:23,160  
thank you

5382  
06:06:37,360 --> 06:07:57,250  
[Music]

5383  
06:07:57,260 --> 06:08:11,280  
thank you

5384  
06:08:31,670 --> 06:08:12,548  
[Music]

5385  
06:08:31,680 --> 06:09:04,120  
foreign

5386  
06:09:32,948 --> 06:09:05,470  
[Music]

5387  
06:09:32,958 --> 06:09:55,190  
thank you

5388  
06:10:26,560 --> 06:09:56,950

foreign

5389

06:10:26,570 --> 06:10:33,830

[Music]

5390

06:10:33,840 --> 06:10:52,610

thank you

5391

06:10:52,620 --> 06:11:07,390

foreign

5392

06:11:45,410 --> 06:11:25,030

[Music]

5393

06:11:45,420 --> 06:12:19,150

foreign

5394

06:12:47,270 --> 06:12:34,208

thank you

5395

06:13:28,750 --> 06:12:56,210

[Music]

5396

06:15:39,310 --> 06:14:58,868

thank you

5397

06:15:39,320 --> 06:15:55,970

[Music]

5398

06:16:27,300 --> 06:16:00,830

foreign

5399

06:16:27,310 --> 06:16:37,430

[Music]

5400

06:17:15,360 --> 06:17:09,530

thank you

5401  
06:17:48,048 --> 06:17:32,150  
[Music]

5402  
06:17:48,058 --> 06:17:59,250  
foreign

5403  
06:18:19,190 --> 06:18:11,540  
[Music]

5404  
06:18:35,320 --> 06:18:28,490  
foreign

5405  
06:19:08,030 --> 06:18:43,560  
[Music]

5406  
06:19:08,040 --> 06:19:39,170  
foreign

5407  
06:19:39,180 --> 06:19:56,350  
today

5408  
06:19:56,360 --> 06:20:13,930  
[Music]

5409  
06:20:13,940 --> 06:20:19,580  
thank you

5410  
06:21:27,170 --> 06:20:51,390  
[Music]

5411  
06:21:27,180 --> 06:21:32,340  
foreign

5412  
06:21:32,350 --> 06:22:01,430  
[Music]

5413  
06:22:01,440 --> 06:22:07,910

thank you

5414

06:22:07,920 --> 06:22:36,260

foreign

5415

06:23:17,930 --> 06:22:43,290

[Music]

5416

06:23:52,010 --> 06:23:19,310

thank you

5417

06:23:52,020 --> 06:24:22,390

foreign

5418

06:24:22,400 --> 06:24:28,270

thank you

5419

06:24:28,280 --> 06:24:32,810

[Music]

5420

06:25:16,270 --> 06:25:10,128

foreign

5421

06:25:42,170 --> 06:25:32,270

[Music]

5422

06:27:45,788 --> 06:25:47,990

foreign

5423

06:27:45,798 --> 06:28:12,590

thank you

5424

06:28:12,600 --> 06:28:29,530

foreign

5425

06:29:48,590 --> 06:29:09,190

thank you

5426  
06:32:35,110 --> 06:31:22,910  
foreign

5427  
06:33:42,650 --> 06:33:12,410  
thank you

5428  
06:41:05,180 --> 06:34:52,548  
foreign

5429  
06:41:42,650 --> 06:41:06,890  
[Music]

5430  
06:41:42,660 --> 06:41:47,750  
okay

5431  
06:42:23,690 --> 06:42:11,868  
thanks

5432  
06:42:23,700 --> 06:43:02,750  
foreign

5433  
06:43:02,760 --> 06:43:37,610  
thank you

5434  
06:43:37,620 --> 06:44:22,868  
foreign

5435  
06:44:22,878 --> 06:44:49,910  
thank you

5436  
06:44:49,920 --> 06:45:27,250  
foreign

5437  
06:46:38,990 --> 06:46:08,650  
thank you

5438  
06:46:39,000 --> 06:47:14,150

foreign

5439

06:47:14,160 --> 06:47:52,090

in it

5440

06:47:52,100 --> 06:48:29,510

thank you

5441

06:49:22,670 --> 06:48:32,150

seconds

5442

06:49:22,680 --> 06:49:55,090

foreign

5443

06:50:50,448 --> 06:50:13,670

thank you

5444

06:51:34,310 --> 06:51:03,288

foreign

5445

06:51:56,570 --> 06:51:51,180

[Music]

5446

06:51:59,330 --> 06:51:56,580

but before we start the talk session

5447

06:52:01,128 --> 06:51:59,340

officially Jaime Cordova would like to

5448

06:52:05,930 --> 06:52:01,138

make a quick announcement so I'm going

5449

06:52:12,708 --> 06:52:09,410

alrighty so hi everyone uh so I'm Jaime

5450

06:52:15,708 --> 06:52:12,718

I'm at UW Madison uh this is Rachel uh

5451  
06:52:17,208 --> 06:52:15,718  
from UCR we are both part of the early

5452  
06:52:19,968 --> 06:52:17,218  
career committee for the new life

5453  
06:52:22,070 --> 06:52:19,978  
research coordination Network

5454  
06:52:24,110 --> 06:52:22,080  
just to make you all aware so life

5455  
06:52:27,110 --> 06:52:24,120  
research for the life RCN is the newest

5456  
06:52:28,730 --> 06:52:27,120  
RCN uh part of NASA Astro bio we are a

5457  
06:52:30,410 --> 06:52:28,740  
network of astrobiologists focused on

5458  
06:52:33,048 --> 06:52:30,420  
the evolution of or on the co-evolution

5459  
06:52:34,968 --> 06:52:33,058  
of Earth and life uh we are looking to

5460  
06:52:36,590 --> 06:52:34,978  
explore ways to advance the science and

5461  
06:52:38,570 --> 06:52:36,600  
its implications for the search for life

5462  
06:52:40,190 --> 06:52:38,580  
on other worlds uh we just wanted to

5463  
06:52:42,110 --> 06:52:40,200

make you all aware of this so you could

5464

06:52:43,310 --> 06:52:42,120

uh see our website here we have a

5465

06:52:45,948 --> 06:52:43,320

Twitter and we also have a YouTube

5466

06:52:48,110 --> 06:52:45,958

channel where we have our seminar series

5467

06:52:51,048 --> 06:52:48,120

the QR code that is on the screen right

5468

06:52:52,850 --> 06:52:51,058

now is for uh our main website but we do

5469

06:52:54,770 --> 06:52:52,860

have a seminar series that we started uh

5470

06:52:56,930 --> 06:52:54,780

we just had our first seminar series uh

5471

06:53:00,110 --> 06:52:56,940

last month we actually know this month

5472

06:53:02,570 --> 06:53:00,120

pass uh we just started in May our next

5473

06:53:05,628 --> 06:53:02,580

seminar it will be taking place on June

5474

06:53:08,390 --> 06:53:05,638

5th uh this is by uh Dr Maria revolia

5475

06:53:11,390 --> 06:53:08,400

Gomez from uh UCI and she'll be talking

5476  
06:53:13,128 --> 06:53:11,400  
about Innovations and constraints uh

5477  
06:53:15,048 --> 06:53:13,138  
evolution of metabolic rules and their

5478  
06:53:17,390 --> 06:53:15,058  
ecological relevance

5479  
06:53:19,368 --> 06:53:17,400  
you are welcome to scan the QR code

5480  
06:53:21,830 --> 06:53:19,378  
that's there uh then that'll take you to

5481  
06:53:23,090 --> 06:53:21,840  
our resume registration it is uh all

5482  
06:53:25,070 --> 06:53:23,100  
virtual

5483  
06:53:26,448 --> 06:53:25,080  
and it's going to be taking place on the

5484  
06:53:29,030 --> 06:53:26,458  
first Monday of ever

5485  
06:53:30,530 --> 06:53:29,040  
anything else you want to have

5486  
06:53:32,510 --> 06:53:30,540  
um as many of you know we also have

5487  
06:53:34,610 --> 06:53:32,520  
stickers for the life RCN so if you

5488  
06:53:36,590 --> 06:53:34,620

would like one come see one of us yeah

5489

06:53:39,410 --> 06:53:36,600

yeah we're probably already given out

5490

06:53:40,850 --> 06:53:39,420

like a lot 100 of these but if you want

5491

06:53:42,708 --> 06:53:40,860

more we've got more so well you're

5492

06:53:44,570 --> 06:53:42,718

welcome to come get get some from uh

5493

06:53:46,730 --> 06:53:44,580

from either of us and uh if you have any

5494

06:53:49,070 --> 06:53:46,740

questions about the life RCN uh please

5495

06:53:58,610 --> 06:53:49,080

uh come up to us and uh we're happy to

5496

06:54:03,350 --> 06:54:01,250

all right thank you so much guys and we

5497

06:54:05,810 --> 06:54:03,360

already have our first presenter on

5498

06:54:08,030 --> 06:54:05,820

standby I'm here to welcome Rachel

5499

06:54:13,850 --> 06:54:08,040

Sabrina from the University of

5500

06:54:18,170 --> 06:54:15,530

great hi everyone

5501  
06:54:19,548 --> 06:54:18,180  
um yeah so my name is Rachel surprise

5502  
06:54:21,530 --> 06:54:19,558  
um I'm a PhD candidate at the University

5503  
06:54:24,110 --> 06:54:21,540  
of California Riverside and today I'm

5504  
06:54:25,850 --> 06:54:24,120  
going to be talking to you all about the

5505  
06:54:27,830 --> 06:54:25,860  
sedimentological signatures of

5506  
06:54:29,868 --> 06:54:27,840  
backgrounds in the pre-cambrian a novel

5507  
06:54:31,430 --> 06:54:29,878  
method for their detection

5508  
06:54:33,530 --> 06:54:31,440  
um automated detection in remote

5509  
06:54:35,090 --> 06:54:33,540  
contexts and implications for the search

5510  
06:54:36,948 --> 06:54:35,100  
for Life on Mars

5511  
06:54:38,990 --> 06:54:36,958  
so

5512  
06:54:40,610 --> 06:54:39,000  
it's well accepted that in Mars has

5513  
06:54:43,250 --> 06:54:40,620

passed there was liquid water on the

5514

06:54:44,690 --> 06:54:43,260

surface right so this provides the

5515

06:54:47,270 --> 06:54:44,700

potential for there to have been past

5516

06:54:49,070 --> 06:54:47,280

microbial life and when we're thinking

5517

06:54:50,750 --> 06:54:49,080

about looking for evidence of this past

5518

06:54:51,770 --> 06:54:50,760

microbial life a lot of people in this

5519

06:54:53,208 --> 06:54:51,780

room

5520

06:54:55,310 --> 06:54:53,218

um like to think about

5521

06:54:58,430 --> 06:54:55,320

signatures of this microbial life that

5522

06:55:00,850 --> 06:54:58,440

are microscopic or molecular but as a

5523

06:55:03,708 --> 06:55:00,860

paleontologist I'm more interested in

5524

06:55:05,868 --> 06:55:03,718

macroscopic textural signatures that we

5525

06:55:09,170 --> 06:55:05,878

can observe in the sedimentological

5526

06:55:11,448 --> 06:55:09,180

record from standard imagery right

5527

06:55:13,968 --> 06:55:11,458

so to find these types of signatures

5528

06:55:15,948 --> 06:55:13,978

that could be useful for the search for

5529

06:55:17,390 --> 06:55:15,958

Life on Mars we can turn to the

5530

06:55:20,330 --> 06:55:17,400

Precambrian Earth

5531

06:55:21,410 --> 06:55:20,340

which is a really useful data set for us

5532

06:55:23,868 --> 06:55:21,420

to think about

5533

06:55:25,730 --> 06:55:23,878

how past microbial life expresses itself

5534

06:55:31,010 --> 06:55:25,740

in the sedimentological record because

5535

06:55:32,448 --> 06:55:31,020

it is dominated by a record of organic

5536

06:55:35,030 --> 06:55:32,458

matte grounds

5537

06:55:37,788 --> 06:55:35,040

um during a time when life on Earth was

5538

06:55:38,510 --> 06:55:37,798

very simple right

5539

06:55:41,810 --> 06:55:38,520

um

5540

06:55:43,968 --> 06:55:41,820

and luckily uh these organic backgrounds

5541

06:55:46,910 --> 06:55:43,978

formed by a consortia of prokaryotes and

5542

06:55:48,708 --> 06:55:46,920

eukaryotes mainly single cellular

5543

06:55:50,628 --> 06:55:48,718

um have a significant impact on the

5544

06:55:52,548 --> 06:55:50,638

sedimentological record

5545

06:55:53,930 --> 06:55:52,558

um we heard earlier today about

5546

06:55:56,628 --> 06:55:53,940

something called the extracellular

5547

06:55:58,610 --> 06:55:56,638

polymeric substance that microbes

5548

06:56:00,770 --> 06:55:58,620

excrete when they are forming a

5549

06:56:03,110 --> 06:56:00,780

background that is just kind of this

5550

06:56:05,750 --> 06:56:03,120

like sticky substrate and this has an

5551

06:56:08,690 --> 06:56:05,760

impact on the sedimentological record in

5552

06:56:11,330 --> 06:56:08,700

that it binds baffles and traps sediment

5553

06:56:13,548 --> 06:56:11,340

that it is living on and within and thus

5554

06:56:16,368 --> 06:56:13,558

prevents erosion and stabilizes sediment

5555

06:56:17,750 --> 06:56:16,378

in part this contributes to in carbonate

5556

06:56:19,010 --> 06:56:17,760

settings things that you'll probably

5557

06:56:21,230 --> 06:56:19,020

you're probably familiar with like

5558

06:56:23,510 --> 06:56:21,240

microbialites and stromatolites

5559

06:56:25,190 --> 06:56:23,520

but I'm more interested in how this is

5560

06:56:27,110 --> 06:56:25,200

expressed in sollicit clastic settings

5561

06:56:29,390 --> 06:56:27,120

which is broadly applicable to the

5562

06:56:31,548 --> 06:56:29,400

Martian geologic environment right and

5563

06:56:33,288 --> 06:56:31,558

one way that it can be expressed is in

5564

06:56:35,330 --> 06:56:33,298

texture organic surfaces or iterative

5565

06:56:36,770 --> 06:56:35,340

Organo sedimentary surface textures I'm

5566

06:56:38,628 --> 06:56:36,780

showing you an example of that up here

5567

06:56:40,310 --> 06:56:38,638

on the right that's actually a fossil

5568

06:56:43,010 --> 06:56:40,320

surface

5569

06:56:45,410 --> 06:56:43,020

um and they also impact

5570

06:56:48,590 --> 06:56:45,420

um sedimentological packaging in a way

5571

06:56:49,910 --> 06:56:48,600

that we can identify and cross-section

5572

06:56:52,128 --> 06:56:49,920

so

5573

06:56:53,448 --> 06:56:52,138

when I'm talking about kind of these not

5574

06:56:55,310 --> 06:56:53,458

ground bio signatures I think this

5575

06:56:56,750 --> 06:56:55,320

brings up a really important question

5576

06:56:59,330 --> 06:56:56,760

that I want to kind of frame my whole

5577

06:57:01,430 --> 06:56:59,340

talk in in which is that if life ever

5578

06:57:03,110 --> 06:57:01,440

existed on Mars was it ever abundant

5579

06:57:05,510 --> 06:57:03,120

enough to form organic backgrounds and

5580

06:57:07,490 --> 06:57:05,520

impact the sedimentological record on a

5581

06:57:08,868 --> 06:57:07,500

macro macroscopic scale like we see in

5582

06:57:11,990 --> 06:57:08,878

the Precambrian

5583

06:57:13,030 --> 06:57:12,000

and my answer to that is I don't know

5584

06:57:15,230 --> 06:57:13,040

um

5585

06:57:17,810 --> 06:57:15,240

and the more I think about it the less

5586

06:57:20,390 --> 06:57:17,820

I'm convinced that it ever did but this

5587

06:57:22,968 --> 06:57:20,400

is still an outstanding question that we

5588

06:57:24,468 --> 06:57:22,978

need to think about and there's one way

5589

06:57:26,510 --> 06:57:24,478

to find out

5590

06:57:29,090 --> 06:57:26,520

um and again this is to Leverage The

5591

06:57:31,968 --> 06:57:29,100

pre-came Brand Rock record so as I

5592

06:57:34,490 --> 06:57:31,978

mentioned we have billions of years of

5593

06:57:37,128 --> 06:57:34,500

evidence of backgrounds existing in the

5594

06:57:38,810 --> 06:57:37,138

pre-cambrian a lot of which is fossil

5595

06:57:40,070 --> 06:57:38,820

evidence of mats like what I'm showing

5596

06:57:41,810 --> 06:57:40,080

up here on the right

5597

06:57:43,368 --> 06:57:41,820

these are not great bio signatures for

5598

06:57:45,250 --> 06:57:43,378

the search for Life on Mars because it

5599

06:57:49,310 --> 06:57:45,260

to identify them you would need to

5600

06:57:51,350 --> 06:57:49,320

excavate betting planes and it also

5601  
06:57:53,930 --> 06:57:51,360  
relies on the fossilization of these

5602  
06:57:57,048 --> 06:57:53,940  
surfaces that

5603  
06:57:58,670 --> 06:57:57,058  
um necessitates a lot of comp like a

5604  
06:58:00,110 --> 06:57:58,680  
suite of complex topanomic or

5605  
06:58:02,750 --> 06:58:00,120  
preservational processes that are not

5606  
06:58:05,208 --> 06:58:02,760  
guaranteed to have existed on Mars

5607  
06:58:09,410 --> 06:58:05,218  
um so instead I'm interested in looking

5608  
06:58:11,030 --> 06:58:09,420  
at the impacts of matte grounds and that

5609  
06:58:13,070 --> 06:58:11,040  
that extra polymeric substance

5610  
06:58:14,448 --> 06:58:13,080  
extracellular polymeric substance that

5611  
06:58:17,810 --> 06:58:14,458  
they secrete

5612  
06:58:19,968 --> 06:58:17,820  
um on sedimentological packaging

5613  
06:58:21,770 --> 06:58:19,978

um as it manifests as discrete

5614

06:58:23,690 --> 06:58:21,780

sedimentary structures

5615

06:58:26,270 --> 06:58:23,700

um that cannot occur in the absence of

5616

06:58:28,670 --> 06:58:26,280

biological mediation

5617

06:58:30,368 --> 06:58:28,680

so one of these sedimentological

5618

06:58:33,288 --> 06:58:30,378

signatures that I'm talking about today

5619

06:58:35,030 --> 06:58:33,298

are called Palm cess ripples so I'm

5620

06:58:36,830 --> 06:58:35,040

showing you images of those here these

5621

06:58:39,048 --> 06:58:36,840

are from the nilpina edio national park

5622

06:58:41,270 --> 06:58:39,058

in South Australia which was recently

5623

06:58:43,788 --> 06:58:41,280

opened as a national park oh my

5624

06:58:45,048 --> 06:58:43,798

animations are weird sorry about that

5625

06:58:46,430 --> 06:58:45,058

um but if you want to read more about it

5626  
06:58:47,628 --> 06:58:46,440  
it was published

5627  
06:58:49,490 --> 06:58:47,638  
um

5628  
06:58:51,948 --> 06:58:49,500  
a little story about the national park

5629  
06:58:54,770 --> 06:58:51,958  
in NASA astrobiology recently

5630  
06:58:58,430 --> 06:58:54,780  
um but Palm says ripples are defined as

5631  
06:59:00,410 --> 06:58:58,440  
stacks of sandstone bedding planes that

5632  
06:59:02,448 --> 06:59:00,420  
have rippled bottoms and ripple top

5633  
06:59:04,010 --> 06:59:02,458  
surfaces so

5634  
06:59:05,930 --> 06:59:04,020  
we can see if we look at this bedding

5635  
06:59:07,010 --> 06:59:05,940  
plane here their ripples preserved on

5636  
06:59:09,410 --> 06:59:07,020  
the top

5637  
06:59:11,390 --> 06:59:09,420  
as well as on the bottom but what does

5638  
06:59:13,250 --> 06:59:11,400

this mean in terms of like evidence for

5639

06:59:15,350 --> 06:59:13,260

life right

5640

06:59:16,968 --> 06:59:15,360

um we can look at this figure here to

5641

06:59:18,770 --> 06:59:16,978

see kind of the biological processes

5642

06:59:22,070 --> 06:59:18,780

behind the formation of these palmsest

5643

06:59:24,048 --> 06:59:22,080

ripples so looking at uh section B of

5644

06:59:26,690 --> 06:59:24,058

this figure when we think about

5645

06:59:29,330 --> 06:59:26,700

pre-cambrian ecosystems microbial mats

5646

06:59:31,430 --> 06:59:29,340

were ubiquitous within the world's

5647

06:59:34,368 --> 06:59:31,440

oceans covering the sea floor

5648

06:59:36,230 --> 06:59:34,378

so when these mats grew on the sea floor

5649

06:59:38,030 --> 06:59:36,240

what they would do is stabilize the

5650

06:59:41,750 --> 06:59:38,040

rippled surfaces

5651  
06:59:43,548 --> 06:59:41,760  
so when a new depositional event

5652  
06:59:46,968 --> 06:59:43,558  
occurred

5653  
06:59:48,890 --> 06:59:46,978  
the ripples were not eroded

5654  
06:59:50,570 --> 06:59:48,900  
um and are thus cast on the base of the

5655  
06:59:52,730 --> 06:59:50,580  
new depositional event

5656  
06:59:54,650 --> 06:59:52,740  
and then the two bedding planes remain

5657  
06:59:56,208 --> 06:59:54,660  
as discrete bed forms that are not

5658  
06:59:59,150 --> 06:59:56,218  
Amalgamated together

5659  
07:00:01,310 --> 06:59:59,160  
so this then

5660  
07:00:02,930 --> 07:00:01,320  
continues as a process resulting in

5661  
07:00:05,690 --> 07:00:02,940  
stacks of these Sandstone bedding planes

5662  
07:00:09,948 --> 07:00:05,700  
with no fine-grained inner beds

5663  
07:00:12,288 --> 07:00:09,958

um and is a definitive signature of past

5664

07:00:13,788 --> 07:00:12,298

life that cannot occur in the absence of

5665

07:00:15,410 --> 07:00:13,798

biological mediation so this is

5666

07:00:17,208 --> 07:00:15,420

potentially a really interesting

5667

07:00:18,288 --> 07:00:17,218

biosignature for us to keep in mind when

5668

07:00:19,548 --> 07:00:18,298

we're thinking about the search for Life

5669

07:00:22,250 --> 07:00:19,558

on Mars

5670

07:00:24,410 --> 07:00:22,260

and just you can compare it to kind of

5671

07:00:26,390 --> 07:00:24,420

modern processes

5672

07:00:28,310 --> 07:00:26,400

um or a broadleaf and Resort conditions

5673

07:00:29,750 --> 07:00:28,320

where we don't have backgrounds if you

5674

07:00:32,868 --> 07:00:29,760

get the deposition of sandstone on

5675

07:00:34,430 --> 07:00:32,878

Sandstone the ripples are going to erode

5676

07:00:35,930 --> 07:00:34,440

and the betting planes are going to

5677

07:00:37,490 --> 07:00:35,940

become Amalgamated resulting in a

5678

07:00:39,468 --> 07:00:37,500

cross-section something like this so you

5679

07:00:42,590 --> 07:00:39,478

can tell that they're very distinct

5680

07:00:46,610 --> 07:00:42,600

um cross-sections one with definitive

5681

07:00:48,530 --> 07:00:46,620

evidence of past microbial life

5682

07:00:50,390 --> 07:00:48,540

so all in all we can see that Palm says

5683

07:00:52,610 --> 07:00:50,400

ripples are

5684

07:00:53,868 --> 07:00:52,620

potentially good biosignatures for us to

5685

07:00:56,270 --> 07:00:53,878

keep in mind because they cannot be

5686

07:00:58,070 --> 07:00:56,280

formed by abiotic processes

5687

07:00:59,390 --> 07:00:58,080

and they can occur when and that is very

5688

07:01:01,730 --> 07:00:59,400

thin so they can even occur under

5689

07:01:04,128 --> 07:01:01,740

biofilm mediation so where it's not

5690

07:01:05,990 --> 07:01:04,138

dependent on the presence of eukaryotes

5691

07:01:07,968 --> 07:01:06,000

and they're easily identifiable as

5692

07:01:10,128 --> 07:01:07,978

macroscopic features in standard imagery

5693

07:01:12,890 --> 07:01:10,138

so you don't need a ton of analytical

5694

07:01:14,270 --> 07:01:12,900

methods to identify them

5695

07:01:16,850 --> 07:01:14,280

but this is not to say there are no

5696

07:01:18,650 --> 07:01:16,860

limitations right firstly this is

5697

07:01:20,750 --> 07:01:18,660

restricted to rippled faces you have to

5698

07:01:22,548 --> 07:01:20,760

have ripples occurring

5699

07:01:23,930 --> 07:01:22,558

um in order for this to be identifiable

5700

07:01:25,850 --> 07:01:23,940

and cross-section

5701  
07:01:28,910 --> 07:01:25,860  
but we know these are preserved on Mars

5702  
07:01:31,128 --> 07:01:28,920  
so this doesn't preclude the use of this

5703  
07:01:32,810 --> 07:01:31,138  
feature as a biosignature and

5704  
07:01:34,910 --> 07:01:32,820  
additionally the lithological criteria

5705  
07:01:37,788 --> 07:01:34,920  
is narrow you have to be able to

5706  
07:01:39,948 --> 07:01:37,798  
identify the fact that this

5707  
07:01:42,288 --> 07:01:39,958  
cross-section is comprised of only

5708  
07:01:44,930 --> 07:01:42,298  
sandstone and nothing no like Clays or

5709  
07:01:45,830 --> 07:01:44,940  
silts um but again this is an ability we

5710  
07:01:49,510 --> 07:01:45,840  
have

5711  
07:01:52,850 --> 07:01:49,520  
um to ascertain on the Martian surface

5712  
07:01:54,410 --> 07:01:52,860  
so with this in mind we can kind of

5713  
07:01:56,628 --> 07:01:54,420

think about well then how would we

5714

07:01:58,670 --> 07:01:56,638

detect them right I could go through by

5715

07:02:00,590 --> 07:01:58,680

hand and look at all of the images

5716

07:02:02,208 --> 07:02:00,600

coming out from the Mars perseverance

5717

07:02:03,948 --> 07:02:02,218

Rover

5718

07:02:05,208 --> 07:02:03,958

um but that's time consuming right so

5719

07:02:08,990 --> 07:02:05,218

there's some things we need to consider

5720

07:02:10,368 --> 07:02:09,000

in actually using this as a biosignature

5721

07:02:12,170 --> 07:02:10,378

um first you know there's a large number

5722

07:02:13,850 --> 07:02:12,180

of images

5723

07:02:16,968 --> 07:02:13,860

we would ideally like to have rapid

5724

07:02:18,948 --> 07:02:16,978

identification of these features like as

5725

07:02:20,510 --> 07:02:18,958

the images are taken so we can identify

5726

07:02:22,788 --> 07:02:20,520

Target sites of interest for further

5727

07:02:24,890 --> 07:02:22,798

analysis because Palm says ripples alone

5728

07:02:27,410 --> 07:02:24,900

will not be enough evidence for us to be

5729

07:02:29,330 --> 07:02:27,420

like oh there was life

5730

07:02:30,530 --> 07:02:29,340

um you would need expertise in

5731

07:02:32,090 --> 07:02:30,540

backgrounds and their impact on the

5732

07:02:33,590 --> 07:02:32,100

sentimentological record

5733

07:02:36,250 --> 07:02:33,600

and of course you want to minimize human

5734

07:02:39,110 --> 07:02:36,260

error so with all these caveats in mind

5735

07:02:41,090 --> 07:02:39,120

I was kind of thinking you know maybe

5736

07:02:42,170 --> 07:02:41,100

the best way for us to approach this

5737

07:02:45,530 --> 07:02:42,180

problem

5738

07:02:46,610 --> 07:02:45,540

is to use an automated technique to

5739

07:02:48,350 --> 07:02:46,620

identify

5740

07:02:49,850 --> 07:02:48,360

um polystyrene ripples in images of cross

5741

07:02:53,868 --> 07:02:49,860

sections

5742

07:02:56,208 --> 07:02:53,878

so this is exactly what I did but I am

5743

07:02:58,250 --> 07:02:56,218

not an expert in this so I collaborated

5744

07:03:00,830 --> 07:02:58,260

with the visualization in intelligent

5745

07:03:02,930 --> 07:03:00,840

systems laboratory or viz lab in the

5746

07:03:05,330 --> 07:03:02,940

College of Engineering at UCR and worked

5747

07:03:08,510 --> 07:03:05,340

with Dr birbanu and Panama genital Agata

5748

07:03:09,948 --> 07:03:08,520

who did a lot of this work with me

5749

07:03:12,468 --> 07:03:09,958

and the first thing I did was show them

5750

07:03:14,868 --> 07:03:12,478

my data set from the pre-cambrian

5751  
07:03:17,570 --> 07:03:14,878  
sedimentological record of we had

5752  
07:03:19,430 --> 07:03:17,580  
starting about 200 images of palm cess

5753  
07:03:22,850 --> 07:03:19,440  
ripples because this project was born in

5754  
07:03:23,510 --> 07:03:22,860  
covid and I had no access to the field

5755  
07:03:25,010 --> 07:03:23,520  
um

5756  
07:03:27,468 --> 07:03:25,020  
so we started with this relatively

5757  
07:03:28,788 --> 07:03:27,478  
limited data set and identified caveats

5758  
07:03:31,368 --> 07:03:28,798  
of the data set that the program would

5759  
07:03:33,468 --> 07:03:31,378  
need to overcome including variable

5760  
07:03:35,208 --> 07:03:33,478  
scale of images variable resolution of

5761  
07:03:36,650 --> 07:03:35,218  
images and it would need to have the

5762  
07:03:38,208 --> 07:03:36,660  
ability to account for extraneous

5763  
07:03:40,850 --> 07:03:38,218

features that are not related to pound

5764

07:03:42,948 --> 07:03:40,860

test ripples like plants fractures Talus

5765

07:03:45,288 --> 07:03:42,958

dust and shadows

5766

07:03:47,570 --> 07:03:45,298

um and all three of these problems are

5767

07:03:50,570 --> 07:03:47,580

problems that we would also have

5768

07:03:53,030 --> 07:03:50,580

um in like Mars or images coming from

5769

07:03:54,110 --> 07:03:53,040

Mars besides the plants

5770

07:03:56,590 --> 07:03:54,120

um

5771

07:04:00,110 --> 07:03:56,600

so we started developing this program

5772

07:04:02,030 --> 07:04:00,120

and phase one we developed the scene

5773

07:04:04,548 --> 07:04:02,040

aware perception augmentation using

5774

07:04:05,810 --> 07:04:04,558

composite embedding for segmentation or

5775

07:04:10,548 --> 07:04:05,820

space egg

5776  
07:04:11,810 --> 07:04:10,558  
which uses quora and sge to identify

5777  
07:04:16,490 --> 07:04:11,820  
images

5778  
07:04:18,110 --> 07:04:16,500  
crop so these are just kind of a

5779  
07:04:20,090 --> 07:04:18,120  
schematic of those different different

5780  
07:04:22,670 --> 07:04:20,100  
methodologies if you're interested in

5781  
07:04:23,868 --> 07:04:22,680  
the actual computer vision aspect of it

5782  
07:04:27,170 --> 07:04:23,878  
I encourage you to look at our paper

5783  
07:04:30,530 --> 07:04:27,180  
genre legada at all 2021

5784  
07:04:33,230 --> 07:04:30,540  
and this first past this first pass

5785  
07:04:36,170 --> 07:04:33,240  
their phase one development

5786  
07:04:37,910 --> 07:04:36,180  
um was able to identify policest ripples

5787  
07:04:40,310 --> 07:04:37,920  
in cross-section so you can see in the

5788  
07:04:41,690 --> 07:04:40,320

pink box that is space egg and it

5789

07:04:44,390 --> 07:04:41,700

outperforms other state-of-the-art

5790

07:04:47,990 --> 07:04:44,400

techniques for identifying

5791

07:04:50,208 --> 07:04:48,000

um planar features in imagery

5792

07:04:53,270 --> 07:04:50,218

and identifies Palm says Ripple bed

5793

07:04:55,968 --> 07:04:53,280

Junctions with an 89 accuracy rate

5794

07:04:58,430 --> 07:04:55,978

but 89 is not that great we thought we

5795

07:05:00,048 --> 07:04:58,440

could do more if we had more images so

5796

07:05:04,610 --> 07:05:00,058

once covered restrictions lifted a

5797

07:05:06,110 --> 07:05:04,620

little bit we took 800 more images to uh

5798

07:05:09,590 --> 07:05:06,120

kind of do phase two of this project

5799

07:05:12,590 --> 07:05:09,600

wherein we developed SpaceX 2.0

5800

07:05:15,530 --> 07:05:12,600

which instead uses used a combination of

5801  
07:05:19,610 --> 07:05:15,540  
Aurora and base net shown here this

5802  
07:05:23,750 --> 07:05:19,620  
paper is currently in review and this

5803  
07:05:26,270 --> 07:05:23,760  
um gave us a 92.32 accuracy so much

5804  
07:05:28,850 --> 07:05:26,280  
improved and again we see that it

5805  
07:05:31,610 --> 07:05:28,860  
outperforms other techniques

5806  
07:05:34,368 --> 07:05:31,620  
as well as our original space egg

5807  
07:05:36,170 --> 07:05:34,378  
so you can see it's much better at

5808  
07:05:39,048 --> 07:05:36,180  
segmenting out the planar features that

5809  
07:05:42,530 --> 07:05:39,058  
we are interested in and like really

5810  
07:05:43,788 --> 07:05:42,540  
concentrating on the regions of Interest

5811  
07:05:45,468 --> 07:05:43,798  
so

5812  
07:05:49,250 --> 07:05:45,478  
to kind of

5813  
07:05:50,930 --> 07:05:49,260

conclude Palm says ripples are an

5814

07:05:52,788 --> 07:05:50,940

important and definitive biosignature

5815

07:05:55,250 --> 07:05:52,798

that should be included in Target

5816

07:05:57,048 --> 07:05:55,260

structures on Mars and we have developed

5817

07:05:59,930 --> 07:05:57,058

a technique for accurately detecting

5818

07:06:01,730 --> 07:05:59,940

them using automated methodologies which

5819

07:06:03,170 --> 07:06:01,740

is potentially useful for our search for

5820

07:06:05,330 --> 07:06:03,180

Life on Mars

5821

07:06:07,070 --> 07:06:05,340

um and just to say our next steps this

5822

07:06:09,708 --> 07:06:07,080

project is not done our next step is to

5823

07:06:11,750 --> 07:06:09,718

develop a classifier where we can feed

5824

07:06:13,430 --> 07:06:11,760

through a bulk of images of different

5825

07:06:15,590 --> 07:06:13,440

different geologic features it will be

5826  
07:06:17,750 --> 07:06:15,600  
able to sort out between likely pound

5827  
07:06:20,868 --> 07:06:17,760  
says Ripples and non-palm test Ripple

5828  
07:06:23,030 --> 07:06:20,878  
cross sections and then those likely

5829  
07:06:25,548 --> 07:06:23,040  
poems as Ripple cross sections will be

5830  
07:06:28,250 --> 07:06:25,558  
fed into space egg 2.0 and that will

5831  
07:06:31,070 --> 07:06:28,260  
give us a probability of

5832  
07:06:32,990 --> 07:06:31,080  
um the presence of a pound cess Ripples

5833  
07:06:35,448 --> 07:06:33,000  
and we'll also have the ability to

5834  
07:06:36,530 --> 07:06:35,458  
classify morphology in other aspects of

5835  
07:06:41,208 --> 07:06:36,540  
these features

5836  
07:06:43,368 --> 07:06:41,218  
so with that I would like to think on my

5837  
07:06:45,048 --> 07:06:43,378  
funding sources as well as everyone who

5838  
07:06:47,208 --> 07:06:45,058

contributed to this product project

5839

07:06:49,610 --> 07:06:47,218

through taking imagery or ground true

5840

07:06:51,230 --> 07:06:49,620

thing and I would like to thank Ross and

5841

07:06:53,750 --> 07:06:51,240

June Fargo for access to the nolpinia

5842

07:06:55,730 --> 07:06:53,760

national park on their property and

5843

07:06:57,530 --> 07:06:55,740

acknowledge that this land lies within

5844

07:06:58,968 --> 07:06:57,540

the item on a traditional lands and

5845

07:07:00,170 --> 07:06:58,978

again there's the QR code for the life

5846

07:07:07,070 --> 07:07:00,180

RCN

5847

07:07:10,968 --> 07:07:09,530

okay fantastic Rachel do we have any

5848

07:07:16,250 --> 07:07:10,978

questions

5849

07:07:20,150 --> 07:07:18,048

uh I was wondering and first of all

5850

07:07:22,070 --> 07:07:20,160

thank you for a great talk uh I was

5851  
07:07:24,230 --> 07:07:22,080  
wondering does anything about those

5852  
07:07:25,430 --> 07:07:24,240  
Ripples and texture or any other factors

5853  
07:07:26,750 --> 07:07:25,440  
change

5854  
07:07:29,030 --> 07:07:26,760  
um over the course of the Precambrian

5855  
07:07:30,948 --> 07:07:29,040  
it's like are there any connections like

5856  
07:07:33,410 --> 07:07:30,958  
major events like oxygenation or other

5857  
07:07:35,990 --> 07:07:33,420  
things and if so like can we infer

5858  
07:07:38,090 --> 07:07:36,000  
anything can we infer any like make any

5859  
07:07:40,010 --> 07:07:38,100  
past climate inferences for something

5860  
07:07:43,548 --> 07:07:40,020  
like Mars this is a really good question

5861  
07:07:47,448 --> 07:07:43,558  
and talk to me after I finish my postdoc

5862  
07:07:47,458 --> 07:07:56,330  
anyone else

5863  
07:08:00,410 --> 07:07:58,190

so I'm wondering if there's any images

5864

07:08:02,810 --> 07:08:00,420

from Mars that this can be applied to

5865

07:08:04,850 --> 07:08:02,820

now or we just have to reorient the

5866

07:08:06,230 --> 07:08:04,860

cameras to sort of start doing that

5867

07:08:08,330 --> 07:08:06,240

there are definitely images that this

5868

07:08:10,128 --> 07:08:08,340

can be applied to it like that's kind of

5869

07:08:12,590 --> 07:08:10,138

why I'm like harping on this bio

5870

07:08:13,730 --> 07:08:12,600

signature because it's like most of our

5871

07:08:17,390 --> 07:08:13,740

imagery we're getting is of

5872

07:08:20,150 --> 07:08:17,400

cross-sections from the Martian surface

5873

07:08:21,410 --> 07:08:20,160

um so yeah where once we have the

5874

07:08:23,270 --> 07:08:21,420

classifier we're going to start running

5875

07:08:25,010 --> 07:08:23,280

them through from what I've seen just

5876

07:08:25,968 --> 07:08:25,020

like looking at them I don't see

5877

07:08:28,128 --> 07:08:25,978

anything

5878

07:08:32,930 --> 07:08:28,138

um that would look like it but it's an

5879

07:08:37,730 --> 07:08:35,690

I I was just wondering I wondering if

5880

07:08:39,770 --> 07:08:37,740

you guys were using any kind of like uh

5881

07:08:41,868 --> 07:08:39,780

like depth data uh for this because it

5882

07:08:43,730 --> 07:08:41,878

feels like the these uh sort of in the

5883

07:08:45,250 --> 07:08:43,740

images that looked very like quite 3D

5884

07:08:47,690 --> 07:08:45,260

and you know if you have like two images

5885

07:08:50,090 --> 07:08:47,700

yeah so we did

5886

07:08:52,850 --> 07:08:50,100

we did um take that into consideration

5887

07:08:55,850 --> 07:08:52,860

kind of looking at the the depth of the

5888

07:08:57,410 --> 07:08:55,860

images and it didn't really change

5889

07:08:59,510 --> 07:08:57,420

um kind of the performance of the

5890

07:09:02,208 --> 07:08:59,520

program so I believe it's incorporated

5891

07:09:05,510 --> 07:09:02,218

into it but it's not a huge aspect of it

5892

07:09:15,890 --> 07:09:07,128

we're going to take one more over here

5893

07:09:19,730 --> 07:09:18,410

hi interesting talk kind of similar um

5894

07:09:21,708 --> 07:09:19,740

have you ever thought about applying

5895

07:09:24,948 --> 07:09:21,718

this to like maybe like

5896

07:09:27,410 --> 07:09:24,958

um debated diagnostic like bio faces

5897

07:09:31,548 --> 07:09:27,420

that are in the fossil record like um

5898

07:09:36,590 --> 07:09:34,548

I'm not quite clear on what you're like

5899

07:09:39,048 --> 07:09:36,600

um just similar like at least other like

5900

07:09:41,510 --> 07:09:39,058

sure matter later microbial systems that

5901  
07:09:43,548 --> 07:09:41,520  
like have debated like um sources yeah

5902  
07:09:44,390 --> 07:09:43,558  
that's a really interesting question

5903  
07:09:46,850 --> 07:09:44,400  
um

5904  
07:09:50,390 --> 07:09:46,860  
no so this is like specifically

5905  
07:09:52,010 --> 07:09:50,400  
developed just for like this one feature

5906  
07:09:54,770 --> 07:09:52,020  
um I think it is work that other people

5907  
07:09:57,288 --> 07:09:54,780  
are doing that are not me

5908  
07:09:59,448 --> 07:09:57,298  
um but yeah there's definitely other

5909  
07:10:00,948 --> 07:09:59,458  
like computer vision programs that have

5910  
07:10:01,968 --> 07:10:00,958  
been developed to identify similar

5911  
07:10:05,208 --> 07:10:01,978  
features

5912  
07:10:08,510 --> 07:10:07,010  
all right we're gonna let Mike ask a

5913  
07:10:13,910 --> 07:10:08,520

question he's been working hard for us

5914

07:10:16,548 --> 07:10:15,590

okay this is actually my question not

5915

07:10:18,890 --> 07:10:16,558

online

5916

07:10:20,330 --> 07:10:18,900

um I'm just curious uh if you did see

5917

07:10:21,890 --> 07:10:20,340

something on Mars what would you need to

5918

07:10:23,270 --> 07:10:21,900

actually confirm that could you do it

5919

07:10:24,890 --> 07:10:23,280

visually or would you need sample return

5920

07:10:26,750 --> 07:10:24,900

or

5921

07:10:28,430 --> 07:10:26,760

yeah that's a really good question I'm

5922

07:10:31,430 --> 07:10:28,440

from my perspective I think it's like a

5923

07:10:34,250 --> 07:10:31,440

first pass ID I think like

5924

07:10:36,590 --> 07:10:34,260

there's it is a definitive bio signature

5925

07:10:39,650 --> 07:10:36,600

but I wouldn't never want to just like

5926  
07:10:41,868 --> 07:10:39,660  
say oh space egg 2.0 said there's like a

5927  
07:10:43,788 --> 07:10:41,878  
99 chance and that's definitive evidence

5928  
07:10:46,990 --> 07:10:43,798  
I think

5929  
07:10:49,430 --> 07:10:47,000  
um yeah sample return or like further

5930  
07:10:52,490 --> 07:10:49,440  
analysis of

5931  
07:10:56,150 --> 07:10:52,500  
um that section would be needed to like

5932  
07:10:56,160 --> 07:11:05,990  
foreign

5933  
07:11:11,090 --> 07:11:09,170  
thank you Rachel our next speaker is

5934  
07:11:17,330 --> 07:11:11,100  
John Malloy from Arizona State

5935  
07:11:21,650 --> 07:11:18,830  
thank you

5936  
07:11:23,390 --> 07:11:21,660  
um yeah I'm here to talk about a

5937  
07:11:25,670 --> 07:11:23,400  
different kind of biosignature

5938  
07:11:26,930 --> 07:11:25,680

um kind of introduce assembly Theory

5939

07:11:28,968 --> 07:11:26,940

I don't know if this is the right group

5940

07:11:31,250 --> 07:11:28,978

to be very controversial about it with

5941

07:11:33,288 --> 07:11:31,260

or if you guys all accept it so we're

5942

07:11:36,350 --> 07:11:33,298

gonna we're gonna see what happens

5943

07:11:37,548 --> 07:11:36,360

um but mostly the main reason I'm a fan

5944

07:11:39,530 --> 07:11:37,558

of this Theory the reason really talked

5945

07:11:42,708 --> 07:11:39,540

about it is that there's two major

5946

07:11:45,170 --> 07:11:42,718

problems that is currently in the field

5947

07:11:46,430 --> 07:11:45,180

of astrobiology at least from my opinion

5948

07:11:48,708 --> 07:11:46,440

um the first one is that we don't have a

5949

07:11:50,208 --> 07:11:48,718

universal definition of life

5950

07:11:51,410 --> 07:11:50,218

um again not sure if you guys agree with

5951  
07:11:52,968 --> 07:11:51,420  
this or if that's really controversial

5952  
07:11:54,830 --> 07:11:52,978  
no idea

5953  
07:11:58,850 --> 07:11:54,840  
um but honestly we don't know what we're

5954  
07:12:01,010 --> 07:11:58,860  
looking for out elsewhere and

5955  
07:12:03,288 --> 07:12:01,020  
because of that kind of the biochemistry

5956  
07:12:05,270 --> 07:12:03,298  
that we see or could potentially see we

5957  
07:12:08,510 --> 07:12:05,280  
have no idea what that could look like

5958  
07:12:12,468 --> 07:12:08,520  
comparison on Earth so kind of what we

5959  
07:12:13,490 --> 07:12:12,478  
need to do is find a universal pattern

5960  
07:12:15,468 --> 07:12:13,500  
of life

5961  
07:12:17,690 --> 07:12:15,478  
first and then build our detection

5962  
07:12:19,070 --> 07:12:17,700  
methods based on that

5963  
07:12:20,628 --> 07:12:19,080

um I think going out there seeing what

5964

07:12:22,548 --> 07:12:20,638

we see is incredibly useful incredibly

5965

07:12:24,410 --> 07:12:22,558

interesting but then you end up with

5966

07:12:26,150 --> 07:12:24,420

like a phosphine problem of how do we

5967

07:12:27,530 --> 07:12:26,160

explain what we see

5968

07:12:29,570 --> 07:12:27,540

um if we determine what we're looking

5969

07:12:31,850 --> 07:12:29,580

for first and then build a method based

5970

07:12:34,430 --> 07:12:31,860

on that Universal Property we're able to

5971

07:12:35,510 --> 07:12:34,440

be a little more stringent a little more

5972

07:12:37,070 --> 07:12:35,520

um

5973

07:12:38,390 --> 07:12:37,080

a little more robust about what we're

5974

07:12:41,270 --> 07:12:38,400

actually finding

5975

07:12:42,590 --> 07:12:41,280

so given that given that kind of

5976

07:12:44,990 --> 07:12:42,600

solution

5977

07:12:48,410 --> 07:12:45,000

um the basic idea of assembly theory is

5978

07:12:50,208 --> 07:12:48,420

that life produces complex things for

5979

07:12:52,070 --> 07:12:50,218

example if we were to go to Enceladus

5980

07:12:53,390 --> 07:12:52,080

and find an iPhone sitting on the bottom

5981

07:12:56,448 --> 07:12:53,400

of the ocean

5982

07:12:58,128 --> 07:12:56,458

um somehow unless Steve Jobs flew on a

5983

07:13:00,590 --> 07:12:58,138

plane and put it there

5984

07:13:03,590 --> 07:13:00,600

um we would say something Enceladus made

5985

07:13:05,570 --> 07:13:03,600

a complex thing made it made an iPhone

5986

07:13:06,708 --> 07:13:05,580

um that's weird that's interesting that

5987

07:13:08,090 --> 07:13:06,718

would certainly be a really interesting

5988

07:13:08,690 --> 07:13:08,100

bio signature

5989

07:13:10,788 --> 07:13:08,700

um

5990

07:13:13,250 --> 07:13:10,798

especially if we saw thousands of them

5991

07:13:15,350 --> 07:13:13,260

if it was littered in iPhones there'd be

5992

07:13:19,070 --> 07:13:15,360

some kind of process on Enceladus that

5993

07:13:20,150 --> 07:13:19,080

would create and select for a complex

5994

07:13:23,030 --> 07:13:20,160

object

5995

07:13:25,070 --> 07:13:23,040

so it's kind of idea is that life makes

5996

07:13:27,708 --> 07:13:25,080

complex things it makes a lot of them

5997

07:13:29,930 --> 07:13:27,718

and what assembly Theory does is

5998

07:13:31,610 --> 07:13:29,940

specifically measure that give a measure

5999

07:13:32,510 --> 07:13:31,620

of the complexity you can measure of how

6000

07:13:34,788 --> 07:13:32,520

much

6001

07:13:36,350 --> 07:13:34,798

memory is

6002

07:13:40,968 --> 07:13:36,360

um part of the system that makes

6003

07:13:42,708 --> 07:13:40,978

something really complex in a lot of it

6004

07:13:45,110 --> 07:13:42,718

so kind of what this is what we're

6005

07:13:47,390 --> 07:13:45,120

talking about is specifically it's a

6006

07:13:49,310 --> 07:13:47,400

number of joining steps required to

6007

07:13:51,350 --> 07:13:49,320

build an object from a base set of

6008

07:13:52,910 --> 07:13:51,360

fragments that's a lot of words that's

6009

07:13:55,310 --> 07:13:52,920

really confusing

6010

07:13:58,010 --> 07:13:55,320

um so start with Legos and we'll go up

6011

07:14:01,368 --> 07:13:58,020

from there if you were to make this

6012

07:14:03,350 --> 07:14:01,378

thing like this big Square rectangle

6013

07:14:05,868 --> 07:14:03,360

whatever thing you would start with this

6014

07:14:07,610 --> 07:14:05,878

green and green and red block and you

6015

07:14:09,288 --> 07:14:07,620

would start joining them together in the

6016

07:14:11,330 --> 07:14:09,298

most optimal way possible essentially

6017

07:14:13,368 --> 07:14:11,340

the way that minimizes the joining steps

6018

07:14:15,110 --> 07:14:13,378

to make that thing at the end

6019

07:14:18,110 --> 07:14:15,120

um specifically there's five of them

6020

07:14:21,530 --> 07:14:18,120

here you notice that you reuse this

6021

07:14:23,930 --> 07:14:21,540

double a couple times and you reuse the

6022

07:14:25,788 --> 07:14:23,940

square once as well so you're able to

6023

07:14:27,830 --> 07:14:25,798

reuse the thing you already make there's

6024

07:14:30,288 --> 07:14:27,840

five joining steps the ma of this

6025

07:14:31,788 --> 07:14:30,298

particular Lego block will be five

6026

07:14:33,230 --> 07:14:31,798

um and you can do this for lots of

6027

07:14:35,570 --> 07:14:33,240

different things you can do this for

6028

07:14:37,128 --> 07:14:35,580

Strings like Gage was talking about

6029

07:14:39,708 --> 07:14:37,138

um yesterday where if you want to make

6030

07:14:40,968 --> 07:14:39,718

Abacadabra you're going to have a

6031

07:14:44,628 --> 07:14:40,978

number of steps particularly seven

6032

07:14:46,910 --> 07:14:44,638

you're going to reuse Abra along the way

6033

07:14:50,390 --> 07:14:46,920

and you can do this for chemicals which

6034

07:14:51,770 --> 07:14:50,400

is kind of more astrological relevant

6035

07:14:55,010 --> 07:14:51,780

um you're able to start with your base

6036

07:14:56,448 --> 07:14:55,020

fragments in this case it's a element a

6037

07:14:58,150 --> 07:14:56,458

bond and a different element which is

6038

07:15:00,650 --> 07:14:58,160

defined by the thing you're looking for

6039

07:15:01,730 --> 07:15:00,660

and you're able to build up the steps

6040

07:15:03,288 --> 07:15:01,740

along the way

6041

07:15:04,968 --> 07:15:03,298

I think one thing I want to emphasize is

6042

07:15:06,948 --> 07:15:04,978

that these steps don't necessarily have

6043

07:15:08,868 --> 07:15:06,958

any physical meaning like this window

6044

07:15:10,788 --> 07:15:08,878

guy isn't

6045

07:15:12,288 --> 07:15:10,798

maybe maybe you can't make this in a lab

6046

07:15:14,330 --> 07:15:12,298

who knows

6047

07:15:16,730 --> 07:15:14,340

um and it doesn't particularly matter

6048

07:15:18,530 --> 07:15:16,740

for this metric um this is not what I'm

6049

07:15:21,890 --> 07:15:18,540

saying this is a physical property it's

6050

07:15:24,410 --> 07:15:21,900

a theoretical way of reusing the

6051  
07:15:26,810 --> 07:15:24,420  
symmetry of the object that you're

6052  
07:15:28,610 --> 07:15:26,820  
ending up with so

6053  
07:15:29,390 --> 07:15:28,620  
kind of keep that in mind

6054  
07:15:31,070 --> 07:15:29,400  
um

6055  
07:15:33,948 --> 07:15:31,080  
when you're doing this this is all from

6056  
07:15:36,170 --> 07:15:33,958  
paper in 2021 from Stuart Marshall and

6057  
07:15:39,590 --> 07:15:36,180  
Cole Mathis both at the University of

6058  
07:15:40,910 --> 07:15:39,600  
Glasgow and we're able to do ma over a

6059  
07:15:42,948 --> 07:15:40,920  
ton of things

6060  
07:15:45,048 --> 07:15:42,958  
um it unsurprisingly correlates with

6061  
07:15:47,150 --> 07:15:45,058  
molecular weights because as things get

6062  
07:15:49,548 --> 07:15:47,160  
bigger you get more steps to make them

6063  
07:15:51,590 --> 07:15:49,558

but it's not a one-to-one ratio there's

6064

07:15:52,850 --> 07:15:51,600

a lot of things kind of here that are

6065

07:15:54,948 --> 07:15:52,860

high molecular weight below assembly

6066

07:15:57,708 --> 07:15:54,958

Theory because they have high symmetry

6067

07:16:00,230 --> 07:15:57,718

um so they're not necessarily as complex

6068

07:16:03,110 --> 07:16:00,240

they require less steps to make

6069

07:16:05,270 --> 07:16:03,120

um just again keep that in mind

6070

07:16:06,530 --> 07:16:05,280

and the reason why we're so excited

6071

07:16:09,230 --> 07:16:06,540

about this the reason why we want to use

6072

07:16:12,410 --> 07:16:09,240

this for an astrobiological signature is

6073

07:16:14,208 --> 07:16:12,420

that when you look at these compounds in

6074

07:16:16,310 --> 07:16:14,218

a mass spec

6075

07:16:19,548 --> 07:16:16,320

um you're able to see a lot of these

6076  
07:16:21,830 --> 07:16:19,558  
different Peaks a mass spec takes a

6077  
07:16:23,090 --> 07:16:21,840  
compound fragments it based on

6078  
07:16:24,948 --> 07:16:23,100  
ionization a lot of different things

6079  
07:16:27,170 --> 07:16:24,958  
there's lots of ways to do it this one

6080  
07:16:29,448 --> 07:16:27,180  
particularly was an orbitrap so if

6081  
07:16:32,090 --> 07:16:29,458  
fragments things twice and you end up

6082  
07:16:33,830 --> 07:16:32,100  
with a number of different Peaks now

6083  
07:16:35,868 --> 07:16:33,840  
kind of notice as a correlation the

6084  
07:16:37,490 --> 07:16:35,878  
lower things the lower ma things the

6085  
07:16:40,610 --> 07:16:37,500  
less complex things don't have as many

6086  
07:16:41,930 --> 07:16:40,620  
Peaks as the higher complex things

6087  
07:16:43,570 --> 07:16:41,940  
um again kind of make sense bigger

6088  
07:16:45,530 --> 07:16:43,580

things are more complex

6089

07:16:46,730 --> 07:16:45,540

there's a really strong correlation

6090

07:16:49,128 --> 07:16:46,740

between the two

6091

07:16:51,890 --> 07:16:49,138

which is really really exciting again

6092

07:16:53,270 --> 07:16:51,900

it's not intuitively obvious that you

6093

07:16:55,250 --> 07:16:53,280

have a theoretical measure that has no

6094

07:16:58,310 --> 07:16:55,260

correlation in physical reality actually

6095

07:17:01,128 --> 07:16:58,320

corresponds to a mass spec signature

6096

07:17:02,390 --> 07:17:01,138

um so when we saw this

6097

07:17:04,070 --> 07:17:02,400

we kind of ran with this and we're

6098

07:17:05,448 --> 07:17:04,080

saying hey we can put a mask back in

6099

07:17:09,170 --> 07:17:05,458

space we've done it before we've done it

6100

07:17:11,448 --> 07:17:09,180

since the 1970s so why don't we look at

6101  
07:17:14,330 --> 07:17:11,458  
what kind of mass specs are needed think

6102  
07:17:15,190 --> 07:17:14,340  
about ma as a specific bio signature and

6103  
07:17:18,830 --> 07:17:15,200  
then

6104  
07:17:21,468 --> 07:17:18,840  
use Mass Spec to go out and find it and

6105  
07:17:24,110 --> 07:17:21,478  
the thing we're looking for specifically

6106  
07:17:25,548 --> 07:17:24,120  
again from this 2021 paper is that all

6107  
07:17:28,250 --> 07:17:25,558  
of biochemistry

6108  
07:17:30,468 --> 07:17:28,260  
has an MA greater than 15.

6109  
07:17:31,128 --> 07:17:30,478  
um anything below 15 leads to see on

6110  
07:17:33,468 --> 07:17:31,138  
Earth

6111  
07:17:35,750 --> 07:17:33,478  
is a mixture of biotic abiotic things

6112  
07:17:36,830 --> 07:17:35,760  
they're found throughout the geosphere

6113  
07:17:39,170 --> 07:17:36,840

and everything

6114

07:17:41,208 --> 07:17:39,180

but above 15 is only things made by

6115

07:17:43,788 --> 07:17:41,218

things that we know are alive

6116

07:17:45,468 --> 07:17:43,798

um like whiskey a few other things they

6117

07:17:47,750 --> 07:17:45,478

kind of had some phono Glasgow measuring

6118

07:17:50,750 --> 07:17:47,760

a bunch of stuff but essentially

6119

07:17:51,890 --> 07:17:50,760

anything above 15 what we say is hey

6120

07:17:53,810 --> 07:17:51,900

this

6121

07:17:55,548 --> 07:17:53,820

from what we know about life on Earth

6122

07:17:59,150 --> 07:17:55,558

let's extrapolate it to be a universal

6123

07:18:01,128 --> 07:17:59,160

property that's something that's complex

6124

07:18:03,948 --> 07:18:01,138

um for the rest of the talk I think just

6125

07:18:05,628 --> 07:18:03,958

15 it might be a little fuzzy I also

6126

07:18:07,730 --> 07:18:05,638

measured 20.

6127

07:18:09,468 --> 07:18:07,740

um I consider 20 as about as about as a

6128

07:18:11,570 --> 07:18:09,478

specific bio signature so you'll see two

6129

07:18:12,590 --> 07:18:11,580

numbers later on um that's where the 20

6130

07:18:14,090 --> 07:18:12,600

comes from is just give it a little

6131

07:18:16,250 --> 07:18:14,100

wiggle room

6132

07:18:17,628 --> 07:18:16,260

so now the issue with that if we're

6133

07:18:19,310 --> 07:18:17,638

going to send a mass back into space it

6134

07:18:20,510 --> 07:18:19,320

needs to be high resolution

6135

07:18:22,548 --> 07:18:20,520

um you can't have something like this

6136

07:18:24,650 --> 07:18:22,558

where you only have a couple Peaks

6137

07:18:25,788 --> 07:18:24,660

you need something that has the right

6138

07:18:28,010 --> 07:18:25,798

number of peaks in order to find

6139

07:18:29,390 --> 07:18:28,020

something that's high and complex

6140

07:18:30,830 --> 07:18:29,400

um if you find something send something

6141

07:18:32,330 --> 07:18:30,840

that's low resolution it's not going to

6142

07:18:33,948 --> 07:18:32,340

be good enough

6143

07:18:37,010 --> 07:18:33,958

um so

6144

07:18:38,690 --> 07:18:37,020

and when we look at stuff today you'll

6145

07:18:40,368 --> 07:18:38,700

see this chart a couple times so we want

6146

07:18:41,510 --> 07:18:40,378

to explain it real fast this is

6147

07:18:47,150 --> 07:18:41,520

essentially

6148

07:18:49,128 --> 07:18:47,160

of how big the molecule is and this is

6149

07:18:52,850 --> 07:18:49,138

the mass resolution of the particular

6150

07:18:55,310 --> 07:18:52,860

objects times 10 000.

6151

07:18:57,048 --> 07:18:55,320

um all of these ones off here are off

6152

07:18:59,390 --> 07:18:57,058

the chart like they just have really

6153

07:19:01,490 --> 07:18:59,400

have Big M over Z ratios and these two

6154

07:19:03,170 --> 07:19:01,500

would have a really high resolution

6155

07:19:06,048 --> 07:19:03,180

um so this is good

6156

07:19:07,548 --> 07:19:06,058

now these things take up rooms

6157

07:19:08,930 --> 07:19:07,558

um like an orbitrap it's not that big

6158

07:19:11,208 --> 07:19:08,940

but you need a bunch of vacuum stuff

6159

07:19:13,610 --> 07:19:11,218

like it's about as big as this Podium

6160

07:19:14,930 --> 07:19:13,620

roughly if you want a really good one

6161

07:19:16,128 --> 07:19:14,940

um you can't just launch that on a

6162

07:19:19,128 --> 07:19:16,138

spaceship that's like it's really mad

6163

07:19:19,968 --> 07:19:19,138

when you want something that big so how

6164

07:19:22,010 --> 07:19:19,978

do we

6165

07:19:24,048 --> 07:19:22,020

like the stuff we do today is roughly

6166

07:19:25,968 --> 07:19:24,058

down here um Ricky yaravalo's group in

6167

07:19:29,810 --> 07:19:25,978

University of Maryland College Park

6168

07:19:33,110 --> 07:19:29,820

um has this mini orbitrap that's decent

6169

07:19:35,090 --> 07:19:33,120

but still like not still on that scale

6170

07:19:37,190 --> 07:19:35,100

um so how could how could can we get how

6171

07:19:40,670 --> 07:19:37,200

is that good enough how much do we need

6172

07:19:41,868 --> 07:19:40,680

in order to determine definitively that

6173

07:19:44,330 --> 07:19:41,878

you have a mass spec signal stick

6174

07:19:46,128 --> 07:19:44,340

signature

6175

07:19:48,830 --> 07:19:46,138

um so what we did we did some chemical

6176

07:19:50,750 --> 07:19:48,840

enumeration we built some graphs

6177

07:19:52,850 --> 07:19:50,760

um specifically built some formulas and

6178

07:19:55,190 --> 07:19:52,860

said hey given a specific number of

6179

07:19:57,410 --> 07:19:55,200

chemicals this case Zero to six carbons

6180

07:19:59,510 --> 07:19:57,420

any number of hydrogens then nitrogen

6181

07:20:01,070 --> 07:19:59,520

oxofosphorus sulfur how many different

6182

07:20:02,390 --> 07:20:01,080

formulas do we get how big is the

6183

07:20:03,708 --> 07:20:02,400

chemical space that could potentially be

6184

07:20:05,930 --> 07:20:03,718

out there

6185

07:20:08,090 --> 07:20:05,940

um answer is pretty big you get lots of

6186

07:20:10,730 --> 07:20:08,100

different formulas unsurprising

6187

07:20:13,430 --> 07:20:10,740

um they can be modeled with a normal

6188

07:20:15,770 --> 07:20:13,440

normal curve so I can do this for any

6189

07:20:18,770 --> 07:20:15,780

number of upper limit and any number

6190

07:20:20,510 --> 07:20:18,780

like up to 10 atoms up to five atoms if

6191

07:20:22,310 --> 07:20:20,520

I want to measure more I can do a

6192

07:20:23,270 --> 07:20:22,320

different normal curve

6193

07:20:25,190 --> 07:20:23,280

um

6194

07:20:27,048 --> 07:20:25,200

now this next slide might trigger people

6195

07:20:29,090 --> 07:20:27,058

I apologize

6196

07:20:31,250 --> 07:20:29,100

um I did random chemistry based on that

6197

07:20:32,810 --> 07:20:31,260

because again we don't know what that is

6198

07:20:35,030 --> 07:20:32,820

going to look like

6199

07:20:36,230 --> 07:20:35,040

um so I built random I built random

6200

07:20:37,910 --> 07:20:36,240

structures from random formulas

6201  
07:20:39,650 --> 07:20:37,920  
essentially building putting random

6202  
07:20:41,510 --> 07:20:39,660  
bonds together

6203  
07:20:44,510 --> 07:20:41,520  
um this might not exist this probably

6204  
07:20:45,590 --> 07:20:44,520  
doesn't exist anywhere but um I kind of

6205  
07:20:46,730 --> 07:20:45,600  
hope it doesn't because that would be

6206  
07:20:47,390 --> 07:20:46,740  
weird

6207  
07:20:50,270 --> 07:20:47,400  
um

6208  
07:20:52,430 --> 07:20:50,280  
but what we what we did is we built it

6209  
07:20:53,990 --> 07:20:52,440  
we put it through RG kits 3D and better

6210  
07:20:55,310 --> 07:20:54,000  
software so we know this is at least

6211  
07:20:57,288 --> 07:20:55,320  
physically possible it doesn't break the

6212  
07:20:58,730 --> 07:20:57,298  
rules of physics the thermodynamics are

6213  
07:21:01,368 --> 07:20:58,740

really weird who knows how long this

6214

07:21:02,810 --> 07:21:01,378

lasts but again our assumptions we don't

6215

07:21:03,890 --> 07:21:02,820

know what this looks like

6216

07:21:05,390 --> 07:21:03,900

um and this actually is a good

6217

07:21:06,530 --> 07:21:05,400

assumption you'll see a few graphs later

6218

07:21:08,390 --> 07:21:06,540

that we're not actually that far off

6219

07:21:10,910 --> 07:21:08,400

from reality but

6220

07:21:13,670 --> 07:21:10,920

um just bear with me for now so I did

6221

07:21:15,048 --> 07:21:13,680

this for 10 000 different structures

6222

07:21:17,690 --> 07:21:15,058

um made a bunch of made a bunch of

6223

07:21:19,910 --> 07:21:17,700

random chemicals and found the m a of

6224

07:21:21,350 --> 07:21:19,920

them so we have molecular weights we

6225

07:21:22,968 --> 07:21:21,360

have assembly index

6226  
07:21:25,430 --> 07:21:22,978  
and you see that most of them started to

6227  
07:21:28,430 --> 07:21:25,440  
get high m a and you get a likelihood

6228  
07:21:31,070 --> 07:21:28,440  
very quickly of well what is the

6229  
07:21:34,010 --> 07:21:31,080  
likelihood of finding a high m a object

6230  
07:21:35,208 --> 07:21:34,020  
at a particular molecular weight

6231  
07:21:37,010 --> 07:21:35,218  
so

6232  
07:21:39,048 --> 07:21:37,020  
we have a number we have a size of

6233  
07:21:40,430 --> 07:21:39,058  
chemical space we have molecular weights

6234  
07:21:43,190 --> 07:21:40,440  
and we know how often those things are

6235  
07:21:45,530 --> 07:21:43,200  
high m a we're essentially able to then

6236  
07:21:47,448 --> 07:21:45,540  
put that on a Precision curve and say

6237  
07:21:49,368 --> 07:21:47,458  
what's the Precision which can be

6238  
07:21:50,410 --> 07:21:49,378

translated into resolution of the

6239

07:21:52,490 --> 07:21:50,420

particular

6240

07:21:54,590 --> 07:21:52,500

number of

6241

07:21:56,570 --> 07:21:54,600

chemical species that have a high  $m_a$  in

6242

07:21:59,930 --> 07:21:56,580

that case or that particular  $M$  over  $Z$

6243

07:22:01,548 --> 07:21:59,940

ratio we take the integral of that

6244

07:22:05,090 --> 07:22:01,558

particular line our goal is to find 10

6245

07:22:06,170 --> 07:22:05,100

or fewer just to put a number on it and

6246

07:22:07,670 --> 07:22:06,180

then we end up with something looks like

6247

07:22:10,730 --> 07:22:07,680

this

6248

07:22:14,868 --> 07:22:10,740

um so our in an ideal case

6249

07:22:17,270 --> 07:22:14,878

what we have is something about 552 000

6250

07:22:18,650 --> 07:22:17,280

um  $M$  over  $\Delta M$  Mass resolution Which

6251  
07:22:20,570 --> 07:22:18,660  
is far fewer than what we have in

6252  
07:22:23,208 --> 07:22:20,580  
commercial orbitraps those are on the

6253  
07:22:24,770 --> 07:22:23,218  
orders like Millions 10 Millions

6254  
07:22:26,690 --> 07:22:24,780  
um but it's not what we've sent to space

6255  
07:22:28,548 --> 07:22:26,700  
it's about four times better than what

6256  
07:22:29,270 --> 07:22:28,558  
we've sent the space so far

6257  
07:22:31,190 --> 07:22:29,280  
um

6258  
07:22:32,868 --> 07:22:31,200  
those ones we sent so those ones set

6259  
07:22:35,090 --> 07:22:32,878  
into space are decent like in this

6260  
07:22:37,548 --> 07:22:35,100  
little curve here they're good they're

6261  
07:22:39,890 --> 07:22:37,558  
able to determine High m a molecules but

6262  
07:22:41,510 --> 07:22:39,900  
we still want to get as high up on this

6263  
07:22:42,650 --> 07:22:41,520

graph as possible

6264

07:22:44,448 --> 07:22:42,660

um so it's more of an engineering

6265

07:22:45,948 --> 07:22:44,458

challenge this is more saying hey

6266

07:22:47,930 --> 07:22:45,958

Engineers if you can go out and build

6267

07:22:49,310 --> 07:22:47,940

something like this give an unknown

6268

07:22:50,930 --> 07:22:49,320

chemical space we're confident that

6269

07:22:53,090 --> 07:22:50,940

you'll be able to detect a high ma

6270

07:22:56,330 --> 07:22:53,100

molecule if it's out there

6271

07:22:58,670 --> 07:22:56,340

um and quickly just to finish up

6272

07:23:01,730 --> 07:22:58,680

um I know the chemicals were really bad

6273

07:23:04,490 --> 07:23:01,740

and really not Earth-like

6274

07:23:06,948 --> 07:23:04,500

um so we determine our spacecraft our

6275

07:23:10,010 --> 07:23:06,958

sermon our resolution based on existing

6276  
07:23:11,990 --> 07:23:10,020  
chemistry we used keg keto Encyclopedia

6277  
07:23:14,628 --> 07:23:12,000  
of genes of genomes I'm mostly saying

6278  
07:23:16,430 --> 07:23:14,638  
how good is our prediction based on

6279  
07:23:19,070 --> 07:23:16,440  
those random chemicals

6280  
07:23:21,288 --> 07:23:19,080  
um this is MOMA this is the one that's

6281  
07:23:23,150 --> 07:23:21,298  
launching soon to Mars

6282  
07:23:24,350 --> 07:23:23,160  
um it's not that great at distinguishing

6283  
07:23:26,930 --> 07:23:24,360  
formulas

6284  
07:23:28,430 --> 07:23:26,940  
um there's a lot of overlaps but if you

6285  
07:23:30,590 --> 07:23:28,440  
look at something like corals or our

6286  
07:23:31,910 --> 07:23:30,600  
recommended one you're not you're really

6287  
07:23:34,548 --> 07:23:31,920  
not that bad you're getting maximum of

6288  
07:23:35,330 --> 07:23:34,558

five so it's pretty good

6289

07:23:40,070 --> 07:23:35,340

um

6290

07:23:41,628 --> 07:23:40,080

and even better when we start saying hey

6291

07:23:43,070 --> 07:23:41,638

does random chemistry correspond with

6292

07:23:45,288 --> 07:23:43,080

reality

6293

07:23:47,330 --> 07:23:45,298

um it does thankfully

6294

07:23:50,330 --> 07:23:47,340

um kind of as a test we took 200

6295

07:23:51,770 --> 07:23:50,340

formulas from that form of enumeration

6296

07:23:53,150 --> 07:23:51,780

um got a hundred different isomers of

6297

07:23:55,310 --> 07:23:53,160

those formulas both from Pub chem so

6298

07:23:56,868 --> 07:23:55,320

existing chemistry GDB which from John

6299

07:23:58,788 --> 07:23:56,878

Louise Raymond's group and burn which is

6300

07:24:00,708 --> 07:23:58,798

a generated database of potential

6301  
07:24:03,770 --> 07:24:00,718  
chemistry here on Earth and then random

6302  
07:24:05,390 --> 07:24:03,780  
structure generation like we did and if

6303  
07:24:07,910 --> 07:24:05,400  
they were separate we'd say we have a

6304  
07:24:09,288 --> 07:24:07,920  
problem but all of these kind of the ma

6305  
07:24:12,890 --> 07:24:09,298  
space of all those chemicals is about

6306  
07:24:15,110 --> 07:24:12,900  
the same so we actually end up roughly a

6307  
07:24:16,968 --> 07:24:15,120  
recommendation on random chemistry seems

6308  
07:24:18,230 --> 07:24:16,978  
to be sufficient based on life we see

6309  
07:24:18,948 --> 07:24:18,240  
today

6310  
07:24:21,650 --> 07:24:18,958  
um

6311  
07:24:23,390 --> 07:24:21,660  
so kind of a recommendation if we take

6312  
07:24:24,590 --> 07:24:23,400  
this melt blacker assembly Theory as a

6313  
07:24:27,170 --> 07:24:24,600

biosignature

6314

07:24:29,930 --> 07:24:27,180

we have a mass range of mass specs to

6315

07:24:31,968 --> 07:24:29,940

shoot for we have a resolution and it's

6316

07:24:34,070 --> 07:24:31,978

a worst case scenario and what we're

6317

07:24:37,070 --> 07:24:34,080

showing is that this roughly represents

6318

07:24:39,048 --> 07:24:37,080

m a of chemical space

6319

07:24:41,030 --> 07:24:39,058

um there's lots of people to thank

6320

07:24:42,708 --> 07:24:41,040

um mostly the ASU group that is mostly

6321

07:24:50,810 --> 07:24:42,718

sitting at the front table so thank you

6322

07:24:50,820 --> 07:24:55,368

thank you John any questions

6323

07:24:55,378 --> 07:25:00,410

felt all freaked out by the chemistry

6324

07:25:07,448 --> 07:25:03,830

hi great talk

6325

07:25:11,448 --> 07:25:07,458

um I'm wondering why is the random set

6326  
07:25:12,708 --> 07:25:11,458  
smaller on the area that it takes than a

6327  
07:25:13,910 --> 07:25:12,718  
pumpkin

6328  
07:25:16,610 --> 07:25:13,920  
yeah

6329  
07:25:19,730 --> 07:25:16,620  
um that is a that's a great question

6330  
07:25:23,030 --> 07:25:19,740  
um I think my answer is that it's

6331  
07:25:26,208 --> 07:25:23,040  
possibly a sampling issue of random

6332  
07:25:28,490 --> 07:25:26,218  
space is probably bigger but the density

6333  
07:25:30,590 --> 07:25:28,500  
of different compounds that it could

6334  
07:25:32,868 --> 07:25:30,600  
sample in random chemistry is just so

6335  
07:25:34,968 --> 07:25:32,878  
high on that little part right there

6336  
07:25:36,708 --> 07:25:34,978  
like I'm just not sampling enough to get

6337  
07:25:39,650 --> 07:25:36,718  
a distribution

6338  
07:25:41,868 --> 07:25:39,660

um or or or I am and I'm not

6339

07:25:43,250 --> 07:25:41,878

um getting the edges as much

6340

07:25:44,868 --> 07:25:43,260

um I think it's interesting question of

6341

07:25:46,548 --> 07:25:44,878

how life can be a little more spread out

6342

07:25:49,730 --> 07:25:46,558

I think there's an interesting function

6343

07:25:52,070 --> 07:25:49,740

a functionality argument going on um I

6344

07:25:54,770 --> 07:25:52,080

think yeah random chemistry I think it's

6345

07:25:56,030 --> 07:25:54,780

so dense in the middle that I'm just not

6346

07:25:56,750 --> 07:25:56,040

exploring the edges as well as I could

6347

07:26:01,368 --> 07:25:56,760

be

6348

07:26:07,910 --> 07:26:05,030

hi uh this is very very interesting so

6349

07:26:09,770 --> 07:26:07,920

um I guess would you mind uh maybe going

6350

07:26:10,788 --> 07:26:09,780

over the

6351

07:26:13,730 --> 07:26:10,798

um

6352

07:26:15,890 --> 07:26:13,740

uh basically what led you to your

6353

07:26:19,910 --> 07:26:15,900

resolution and

6354

07:26:21,948 --> 07:26:19,920

um and uh Max M over Z calculations a

6355

07:26:26,150 --> 07:26:21,958

little bit uh

6356

07:26:27,590 --> 07:26:26,160

I guess more in detail uh about how that

6357

07:26:31,610 --> 07:26:27,600

connects to

6358

07:26:35,868 --> 07:26:31,620

um msms uh measurements is is this

6359

07:26:37,430 --> 07:26:35,878

um just with M over Z or okay yeah so um

6360

07:26:40,190 --> 07:26:37,440

yeah it's a great question so I'm not

6361

07:26:41,690 --> 07:26:40,200

assuming any fragmentation here

6362

07:26:42,948 --> 07:26:41,700

um mostly because we don't know exactly

6363

07:26:45,590 --> 07:26:42,958

what we're going to send or if it's an

6364

07:26:47,410 --> 07:26:45,600

ms1 or MS2 machine

6365

07:26:50,510 --> 07:26:47,420

um so I'm just assuming that there's a

6366

07:26:53,750 --> 07:26:50,520

there's a particular structure it's

6367

07:26:55,910 --> 07:26:53,760

ionized so I knock off a hydrogen and

6368

07:26:58,010 --> 07:26:55,920

then that's a single Peak that you get

6369

07:27:00,890 --> 07:26:58,020

what's the resolution to distinguish

6370

07:27:03,350 --> 07:27:00,900

those Peaks um which one thing is worst

6371

07:27:05,628 --> 07:27:03,360

case add fragmentation and add like a

6372

07:27:07,850 --> 07:27:05,638

really add a decent orbitrap and this

6373

07:27:08,990 --> 07:27:07,860

probably becomes a lot better but it's

6374

07:27:10,310 --> 07:27:09,000

hard to predict exactly what that

6375

07:27:12,110 --> 07:27:10,320

fragmentation is

6376

07:27:13,610 --> 07:27:12,120

um there's a team in Glasgow

6377

07:27:15,110 --> 07:27:13,620

um led by Emma chiric that's like trying

6378

07:27:15,830 --> 07:27:15,120

to figure that out right now

6379

07:27:17,690 --> 07:27:15,840

um

6380

07:27:19,010 --> 07:27:17,700

as you can imagine it's a difficult like

6381

07:27:20,208 --> 07:27:19,020

Mass specs are weird

6382

07:27:23,810 --> 07:27:20,218

um it's a difficult problem to predict

6383

07:27:26,090 --> 07:27:23,820

and extrapolate yeah because I guess I'm

6384

07:27:28,190 --> 07:27:26,100

wondering you know obviously

6385

07:27:30,288 --> 07:27:28,200

um ion neutral Mass spectrometer and

6386

07:27:34,250 --> 07:27:30,298

Cassini did not have nearly this

6387

07:27:36,048 --> 07:27:34,260

resolution uh but if the fragmentation

6388

07:27:38,448 --> 07:27:36,058

that you can assume happened when those

6389

07:27:40,368 --> 07:27:38,458

ice creams collided with it

6390

07:27:43,968 --> 07:27:40,378

um could be assumed to be an MS2 like

6391

07:27:45,830 --> 07:27:43,978

event then and if that you know if MS2

6392

07:27:47,750 --> 07:27:45,840

makes it that much better then maybe you

6393

07:27:50,868 --> 07:27:47,760

could look at it from this perspective

6394

07:27:52,850 --> 07:27:50,878

yeah no I didn't I think if we hadn't I

6395

07:27:54,830 --> 07:27:52,860

think I would love to see a number of

6396

07:27:57,230 --> 07:27:54,840

how much that correlates

6397

07:27:59,390 --> 07:27:57,240

um yeah I think that's the I think

6398

07:28:01,070 --> 07:27:59,400

that's probably the next step on where

6399

07:28:04,070 --> 07:28:01,080

to go with this yeah

6400

07:28:08,628 --> 07:28:06,708

okay uh we could probably take one more

6401  
07:28:10,610 --> 07:28:08,638  
question and you're the lucky man right

6402  
07:28:12,708 --> 07:28:10,620  
next to me

6403  
07:28:14,990 --> 07:28:12,718  
it's a very interesting talk uh you

6404  
07:28:17,448 --> 07:28:15,000  
talked about the lower limit on Ma is

6405  
07:28:19,788 --> 07:28:17,458  
there any upper limit on Ma

6406  
07:28:22,070 --> 07:28:19,798  
so like up a little bit of how far

6407  
07:28:23,390 --> 07:28:22,080  
biochemistry can go yeah

6408  
07:28:25,570 --> 07:28:23,400  
um it's a great question

6409  
07:28:31,250 --> 07:28:25,580  
so

6410  
07:28:33,288 --> 07:28:31,260  
small small molecules we're not using

6411  
07:28:35,390 --> 07:28:33,298  
this in peptides or anything mostly

6412  
07:28:37,250 --> 07:28:35,400  
because the base fragments that we're

6413  
07:28:39,048 --> 07:28:37,260

talking about in this case are elements

6414

07:28:41,868 --> 07:28:39,058

to bonds and we talked like something

6415

07:28:44,510 --> 07:28:41,878

like DNA molecule then Things become so

6416

07:28:46,910 --> 07:28:44,520

massive so massive that since it's an NP

6417

07:28:48,830 --> 07:28:46,920

complex NP complete problem if that'll

6418

07:28:49,968 --> 07:28:48,840

take forever to compute

6419

07:28:52,610 --> 07:28:49,978

um so I think like

6420

07:28:54,170 --> 07:28:52,620

It's Quickly depends on your definition

6421

07:28:55,788 --> 07:28:54,180

of a base fragment and what you want

6422

07:28:56,990 --> 07:28:55,798

your what you want those joining steps

6423

07:28:59,448 --> 07:28:57,000

to be

6424

07:29:02,810 --> 07:28:59,458

um it's essentially DNA I imagine would

6425

07:29:05,030 --> 07:29:02,820

be in tens of millions if not higher if

6426  
07:29:07,730 --> 07:29:05,040  
we're using this particular definition

6427  
07:29:09,650 --> 07:29:07,740  
for using amino acids or base pairs

6428  
07:29:11,448 --> 07:29:09,660  
Things become a little different

6429  
07:29:12,708 --> 07:29:11,458  
um I have some interesting results in

6430  
07:29:14,690 --> 07:29:12,718  
like patent chemistry that I'm happy to

6431  
07:29:15,890 --> 07:29:14,700  
share afterwards to show like we have a

6432  
07:29:17,810 --> 07:29:15,900  
little bit of upper limit of like what

6433  
07:29:19,968 --> 07:29:17,820  
chemistry can look like but um

6434  
07:29:21,350 --> 07:29:19,978  
I mean that's more of a computational

6435  
07:29:30,350 --> 07:29:21,360  
limit than anything

6436  
07:29:33,890 --> 07:29:32,030  
thank you John

6437  
07:29:35,030 --> 07:29:33,900  
um the extra guys go find him in the

6438  
07:29:38,208 --> 07:29:35,040

break because I know you have awesome

6439

07:29:40,968 --> 07:29:38,218

questions for him up next we have Macy

6440

07:29:47,448 --> 07:29:40,978

Houston she's coming from Penn State

6441

07:29:50,628 --> 07:29:48,530

hello

6442

07:29:52,850 --> 07:29:50,638

um my name is Macy Houston

6443

07:29:54,288 --> 07:29:52,860

um I'm sort of a fifth year grad student

6444

07:29:55,610 --> 07:29:54,298

at Penn State

6445

07:29:57,590 --> 07:29:55,620

um in astronomy as you may have guessed

6446

07:30:00,170 --> 07:29:57,600

from my background

6447

07:30:02,030 --> 07:30:00,180

um but I just successfully defended my

6448

07:30:08,930 --> 07:30:02,040

thesis last week so I've gone ahead and

6449

07:30:13,010 --> 07:30:11,030

I don't get my diploma and start my post

6450

07:30:15,530 --> 07:30:13,020

back until August but I'm still going to

6451

07:30:17,330 --> 07:30:15,540

call myself Dr Houston now

6452

07:30:19,548 --> 07:30:17,340

um so I'm going to be talking about

6453

07:30:20,930 --> 07:30:19,558

something that was not in my thesis so I

6454

07:30:22,368 --> 07:30:20,940

hadn't thought about too much for a

6455

07:30:23,208 --> 07:30:22,378

couple months but I'm getting back to it

6456

07:30:24,830 --> 07:30:23,218

now

6457

07:30:26,330 --> 07:30:24,840

um this is some work I'm doing as part

6458

07:30:29,090 --> 07:30:26,340

of the Penn State extraterrestrial

6459

07:30:31,310 --> 07:30:29,100

Intelligence Center and um this work is

6460

07:30:34,010 --> 07:30:31,320

actually being led by Dr Sophia shake at

6461

07:30:37,368 --> 07:30:34,020

The seti Institute

6462

07:30:38,810 --> 07:30:37,378

so um this project came out of a group a

6463

07:30:41,390 --> 07:30:38,820

collaboration called characterizing

6464

07:30:44,030 --> 07:30:41,400

atmospheric techno signatures uh or cats

6465

07:30:46,310 --> 07:30:44,040

which I'm very glad we found a good

6466

07:30:47,810 --> 07:30:46,320

abbreviation for and

6467

07:30:50,270 --> 07:30:47,820

um so what this group is doing is just

6468

07:30:51,770 --> 07:30:50,280

kind of creating a library of possible

6469

07:30:53,930 --> 07:30:51,780

techno signatures and especially

6470

07:30:56,750 --> 07:30:53,940

focusing on atmospheric techno

6471

07:30:58,490 --> 07:30:56,760

signatures as jwst launches and we're

6472

07:31:02,750 --> 07:30:58,500

making a lot of advances in our ability

6473

07:31:04,070 --> 07:31:02,760

to characterize exoplanet atmospheres

6474

07:31:05,570 --> 07:31:04,080

um but this project we're talking about

6475

07:31:07,490 --> 07:31:05,580

today actually goes a bit more abroad

6476  
07:31:09,110 --> 07:31:07,500  
than that and we're thinking of all the

6477  
07:31:10,128 --> 07:31:09,120  
Techno signatures that we produce here

6478  
07:31:11,570 --> 07:31:10,138  
on Earth

6479  
07:31:13,490 --> 07:31:11,580  
so the project we're calling Earth

6480  
07:31:16,430 --> 07:31:13,500  
detecting Earth is establishing

6481  
07:31:18,590 --> 07:31:16,440  
benchmarks for detectability based on

6482  
07:31:21,530 --> 07:31:18,600  
how strong our techno signatures we

6483  
07:31:22,788 --> 07:31:21,540  
produce here on Earth are and how a far

6484  
07:31:25,070 --> 07:31:22,798  
away

6485  
07:31:27,770 --> 07:31:25,080  
um we you would be able to use our

6486  
07:31:30,350 --> 07:31:27,780  
telescopes to successfully detect our

6487  
07:31:33,110 --> 07:31:30,360  
techno signatures

6488  
07:31:34,310 --> 07:31:33,120

so um this is a very preliminary version

6489

07:31:35,990 --> 07:31:34,320

of our plot here we're going to have

6490

07:31:38,150 --> 07:31:36,000

more techno signatures than this and we

6491

07:31:40,070 --> 07:31:38,160

still have to finish up a few

6492

07:31:41,690 --> 07:31:40,080

calculations to get all our distances

6493

07:31:42,948 --> 07:31:41,700

right but

6494

07:31:44,510 --> 07:31:42,958

um we're basically just trying to

6495

07:31:46,368 --> 07:31:44,520

calculate the detectable distance for

6496

07:31:48,530 --> 07:31:46,378

our telescopes to observe our techno

6497

07:31:50,510 --> 07:31:48,540

signatures for all of the Techno

6498

07:31:53,330 --> 07:31:50,520

signatures that we could think of that

6499

07:31:56,208 --> 07:31:54,708

so

6500

07:31:58,548 --> 07:31:56,218

um this is related to a similar concept

6501  
07:32:00,708 --> 07:31:58,558  
called the ignoscale which was proposed

6502  
07:32:03,410 --> 07:32:00,718  
by so cast novaro at all a couple years

6503  
07:32:05,510 --> 07:32:03,420  
ago this term is defined as these

6504  
07:32:07,490 --> 07:32:05,520  
relative size or intensity of a techno

6505  
07:32:09,288 --> 07:32:07,500  
signature in units of the same type no

6506  
07:32:10,810 --> 07:32:09,298  
signature as produced by Earth's

6507  
07:32:13,730 --> 07:32:10,820  
technology

6508  
07:32:16,190 --> 07:32:13,740  
so kind of the first step in our project

6509  
07:32:18,830 --> 07:32:16,200  
is to quantify the strength of Earth's

6510  
07:32:20,868 --> 07:32:18,840  
current day techno signatures and this

6511  
07:32:24,468 --> 07:32:20,878  
is kind of defining the power level that

6512  
07:32:26,330 --> 07:32:24,478  
is an ignoscale value of one

6513  
07:32:28,190 --> 07:32:26,340

and then we're going to determine what

6514

07:32:30,530 --> 07:32:28,200

distance we can use our technology to

6515

07:32:32,270 --> 07:32:30,540

detect those technical signatures and to

6516

07:32:33,670 --> 07:32:32,280

keep things kind of uniform among all

6517

07:32:37,250 --> 07:32:33,680

detective signatures we're looking at

6518

07:32:40,128 --> 07:32:37,260

we're adopting a signal noise ratio of

6519

07:32:41,930 --> 07:32:40,138

five but we're also going to talk a bit

6520

07:32:43,850 --> 07:32:41,940

about scaling relations you can use if

6521

07:32:45,910 --> 07:32:43,860

you want to get higher signal to noise

6522

07:32:49,250 --> 07:32:45,920

or something like that

6523

07:32:51,350 --> 07:32:49,260

so I'm just gonna gonna go through a few

6524

07:32:51,948 --> 07:32:51,360

of our calculations here

6525

07:32:54,590 --> 07:32:51,958

um

6526  
07:32:56,930 --> 07:32:54,600  
oh I don't know why it's covering my oh

6527  
07:32:58,128 --> 07:32:56,940  
well so uh the first kind of technical

6528  
07:33:00,410 --> 07:32:58,138  
signature I want to talk about is

6529  
07:33:02,448 --> 07:33:00,420  
intermittent celestially targeted radio

6530  
07:33:03,830 --> 07:33:02,458  
Transmissions

6531  
07:33:07,010 --> 07:33:03,840  
um so the types of signals that would

6532  
07:33:08,690 --> 07:33:07,020  
produce this are um Medi signals so

6533  
07:33:10,968 --> 07:33:08,700  
intentional messages that we have sent

6534  
07:33:12,468 --> 07:33:10,978  
out ostensibly to communicate with

6535  
07:33:15,590 --> 07:33:12,478  
extraterrestrial life but we don't

6536  
07:33:17,330 --> 07:33:15,600  
really do a lot of that so

6537  
07:33:20,570 --> 07:33:17,340  
um the more common types of signals we

6538  
07:33:24,468 --> 07:33:20,580

send out are powerful radio signals

6539

07:33:26,628 --> 07:33:24,478

targeted at planets and asteroids in the

6540

07:33:29,208 --> 07:33:26,638

solar system in order to characterize

6541

07:33:31,670 --> 07:33:29,218

them with radar

6542

07:33:34,070 --> 07:33:31,680

so for our calculation we are assuming

6543

07:33:36,708 --> 07:33:34,080

that our radar transmitter is Arecibo

6544

07:33:39,770 --> 07:33:36,718

Rip but

6545

07:33:41,628 --> 07:33:39,780

um our Observer for radio observations

6546

07:33:45,288 --> 07:33:41,638

we are using the currently under

6547

07:33:47,510 --> 07:33:45,298

construction square kilometer array if

6548

07:33:48,590 --> 07:33:47,520

we assume assume an observation time of

6549

07:33:50,390 --> 07:33:48,600

one hour

6550

07:33:52,850 --> 07:33:50,400

then we get our Earth detecting Earth

6551  
07:33:54,530 --> 07:33:52,860  
detectable distance of 12 000 light

6552  
07:33:55,850 --> 07:33:54,540  
years for our most powerful radio

6553  
07:33:58,788 --> 07:33:55,860  
signals

6554  
07:34:00,288 --> 07:33:58,798  
so this is the highest number that we're

6555  
07:34:02,030 --> 07:34:00,298  
going to see in terms of our distances

6556  
07:34:04,310 --> 07:34:02,040  
here but I wanted to start with it to

6557  
07:34:06,288 --> 07:34:04,320  
really emphasize that

6558  
07:34:07,788 --> 07:34:06,298  
um I see techno signatures as a really

6559  
07:34:09,830 --> 07:34:07,798  
important part of the search for

6560  
07:34:12,410 --> 07:34:09,840  
biosignatures because when you think

6561  
07:34:14,930 --> 07:34:12,420  
about all of the signs of life that we

6562  
07:34:16,548 --> 07:34:14,940  
produce here on Earth our radio signals

6563  
07:34:18,048 --> 07:34:16,558

are by far the most detectable thing

6564

07:34:21,288 --> 07:34:18,058

that we produce

6565

07:34:23,150 --> 07:34:21,298

so I really hope that the fields of

6566

07:34:25,368 --> 07:34:23,160

biosignatures detective signatures can

6567

07:34:26,690 --> 07:34:25,378

work closely together because I think we

6568

07:34:28,910 --> 07:34:26,700

want to take as many approaches as

6569

07:34:32,510 --> 07:34:28,920

possible to find any types of life we

6570

07:34:36,948 --> 07:34:34,670

so the next category of techno signature

6571

07:34:39,110 --> 07:34:36,958

is just another type of radio signal

6572

07:34:41,530 --> 07:34:39,120

intermittent celestially untargeted

6573

07:34:44,150 --> 07:34:41,540

leakage so these are

6574

07:34:46,250 --> 07:34:44,160

signals that we intentionally send into

6575

07:34:48,770 --> 07:34:46,260

the sky but not necessarily with the aim

6576  
07:34:52,310 --> 07:34:48,780  
of going to space so things like

6577  
07:34:54,170 --> 07:34:52,320  
Military and Commercial aircraft radar

6578  
07:34:56,690 --> 07:34:54,180  
we're just kind of assuming the standard

6579  
07:34:58,430 --> 07:34:56,700  
aircraft radar systems for a transmitter

6580  
07:35:00,650 --> 07:34:58,440  
and again observing with the square

6581  
07:35:02,448 --> 07:35:00,660  
kilometer array

6582  
07:35:06,048 --> 07:35:02,458  
and our Earth attacking earth distance

6583  
07:35:07,548 --> 07:35:06,058  
is a bit over 200 light years so this is

6584  
07:35:10,850 --> 07:35:07,558  
still a pretty big distance this

6585  
07:35:13,190 --> 07:35:10,860  
includes quite a number of stars

6586  
07:35:16,368 --> 07:35:13,200  
um if we're considering you know the

6587  
07:35:18,110 --> 07:35:16,378  
Stars within this distance range

6588  
07:35:20,208 --> 07:35:18,120

uh the next Technic signature I want to

6589

07:35:22,490 --> 07:35:20,218

talk about is persistent omnidirectional

6590

07:35:25,548 --> 07:35:22,500

radio leakage so there was some early

6591

07:35:28,968 --> 07:35:25,558

work done on this topic actually in 1989

6592

07:35:30,110 --> 07:35:28,978

where um Sullivan at all simulated

6593

07:35:32,750 --> 07:35:30,120

um

6594

07:35:34,368 --> 07:35:32,760

the output of Earth's television Tower

6595

07:35:35,990 --> 07:35:34,378

Transmissions as you might be able to

6596

07:35:39,530 --> 07:35:36,000

observe them from space

6597

07:35:41,150 --> 07:35:39,540

and concluded that it's possible that

6598

07:35:43,190 --> 07:35:41,160

other life out in the universe knows

6599

07:35:45,410 --> 07:35:43,200

that we're here

6600

07:35:48,170 --> 07:35:45,420

um our TV signals aren't quite as

6601  
07:35:51,048 --> 07:35:48,180  
powerful now as they were in the peak

6602  
07:35:53,350 --> 07:35:51,058  
a time but we've got all kinds of mobile

6603  
07:35:55,850 --> 07:35:53,360  
cell phone towers all over the world now

6604  
07:35:57,830 --> 07:35:55,860  
so there's a really great paper that

6605  
07:35:59,330 --> 07:35:57,840  
just came out a few weeks ago by Mira

6606  
07:36:01,368 --> 07:35:59,340  
Sade at all

6607  
07:36:03,530 --> 07:36:01,378  
um that kind of does a similar

6608  
07:36:05,750 --> 07:36:03,540  
calculation to the Sullivan paper but

6609  
07:36:08,390 --> 07:36:05,760  
using mobile phone towers instead of

6610  
07:36:14,330 --> 07:36:11,448  
so we adopted their value of a

6611  
07:36:16,310 --> 07:36:14,340  
transmitter strength of four gigawatts

6612  
07:36:19,490 --> 07:36:16,320  
and again using the square kilometer

6613  
07:36:21,530 --> 07:36:19,500

array as our radio detector and we got a

6614

07:36:22,670 --> 07:36:21,540

detectable distance of just under a

6615

07:36:24,890 --> 07:36:22,680

light year

6616

07:36:27,948 --> 07:36:24,900

so this is a little bit too short of a

6617

07:36:29,990 --> 07:36:27,958

distance to reach any nearby stars

6618

07:36:31,850 --> 07:36:30,000

um but it's getting pretty close and as

6619

07:36:33,830 --> 07:36:31,860

radio technology improves this kind of

6620

07:36:36,530 --> 07:36:33,840

uh thing is going to become more

6621

07:36:40,250 --> 07:36:38,150

um the next techno signature I want to

6622

07:36:43,190 --> 07:36:40,260

talk about is intermittent targeted

6623

07:36:44,750 --> 07:36:43,200

laser leakage so these are laser signals

6624

07:36:45,968 --> 07:36:44,760

that we happen to be sending out into

6625

07:36:50,030 --> 07:36:45,978

space

6626  
07:36:50,990 --> 07:36:50,040  
so for the non astronomers in the room

6627  
07:36:53,270 --> 07:36:51,000  
um

6628  
07:36:56,270 --> 07:36:53,280  
the example that I want to use here is

6629  
07:36:58,910 --> 07:36:56,280  
Adaptive Optics lasers Adaptive Optics

6630  
07:37:01,430 --> 07:36:58,920  
is an astronomy technique where you take

6631  
07:37:03,650 --> 07:37:01,440  
ground-based telescopes and distort

6632  
07:37:05,628 --> 07:37:03,660  
their mirrors and in order to account

6633  
07:37:07,990 --> 07:37:05,638  
for the effects of the atmosphere on the

6634  
07:37:10,910 --> 07:37:08,000  
light that we observed from space

6635  
07:37:12,708 --> 07:37:10,920  
and uh there are kind of a lot of

6636  
07:37:14,570 --> 07:37:12,718  
factors that goes into that but one

6637  
07:37:16,968 --> 07:37:14,580  
thing is that sometimes we need to

6638  
07:37:19,910 --> 07:37:16,978

create an artificial guide star to

6639

07:37:22,368 --> 07:37:19,920

calibrate these and so what we do is

6640

07:37:24,468 --> 07:37:22,378

send really powerful lasers shooting

6641

07:37:25,910 --> 07:37:24,478

into the atmosphere so that's some

6642

07:37:28,070 --> 07:37:25,920

amount of that laser power hits the

6643

07:37:30,288 --> 07:37:28,080

atmosphere and bounces back for us to

6644

07:37:32,570 --> 07:37:30,298

observe while a lot of that laser power

6645

07:37:34,610 --> 07:37:32,580

just happens to go out into space

6646

07:37:38,810 --> 07:37:34,620

wherever it's headed

6647

07:37:40,910 --> 07:37:38,820

so um for our calculation for laser

6648

07:37:43,490 --> 07:37:40,920

leakage we use the Keck 10 meter

6649

07:37:44,510 --> 07:37:43,500

telescope and it's of Adaptive Optics

6650

07:37:46,490 --> 07:37:44,520

system

6651  
07:37:49,070 --> 07:37:46,500  
and we get a detectable distance of

6652  
07:37:51,590 --> 07:37:49,080  
about 10 layers so this distance does

6653  
07:37:53,868 --> 07:37:51,600  
include a few nearby stars but it's

6654  
07:37:55,788 --> 07:37:53,878  
important to note that we're not

6655  
07:37:57,948 --> 07:37:55,798  
actually directing these lasers at any

6656  
07:38:00,770 --> 07:37:57,958  
nearby stars because you only need to

6657  
07:38:02,448 --> 07:38:00,780  
use Adaptive Optics um the laser

6658  
07:38:05,208 --> 07:38:02,458  
artificial guide star if you don't have

6659  
07:38:08,208 --> 07:38:05,218  
a real well-known bright star you can

6660  
07:38:10,548 --> 07:38:08,218  
look at so we're never really doing that

6661  
07:38:14,150 --> 07:38:10,558  
right at nearby Stars which would be

6662  
07:38:18,110 --> 07:38:15,830  
so the next category of techno

6663  
07:38:20,448 --> 07:38:18,120

signatures I want to get into are

6664

07:38:22,788 --> 07:38:20,458

um exoplanetary techno signatures that

6665

07:38:26,048 --> 07:38:22,798

you might detect for example in our in

6666

07:38:28,610 --> 07:38:26,058

the atmosphere of a planet

6667

07:38:30,708 --> 07:38:28,620

so we've got an example here of one

6668

07:38:33,170 --> 07:38:30,718

possible atmospheric pollutant which is

6669

07:38:35,270 --> 07:38:33,180

nitrogen dioxide and this is based on

6670

07:38:37,190 --> 07:38:35,280

work done by kaparapu at all a couple

6671

07:38:40,070 --> 07:38:37,200

years ago

6672

07:38:42,590 --> 07:38:40,080

so this simulation was performed using

6673

07:38:46,190 --> 07:38:42,600

the planetary Spectrum generator and

6674

07:38:47,750 --> 07:38:46,200

assuming that our Observer is a luvex

6675

07:38:49,968 --> 07:38:47,760

which I guess is now called habitable

6676

07:38:52,910 --> 07:38:49,978

worlds Observatory

6677

07:38:55,430 --> 07:38:52,920

um which is a space mission that's under

6678

07:38:57,890 --> 07:38:55,440

development but is the combination of

6679

07:39:00,230 --> 07:38:57,900

luvar and have exhibition Concepts that

6680

07:39:03,948 --> 07:39:00,240

was for a few months called lubex but

6681

07:39:06,350 --> 07:39:03,958

now this is already out of date so

6682

07:39:08,570 --> 07:39:06,360

um our detectable distance here is a

6683

07:39:11,030 --> 07:39:08,580

little over three light years so this

6684

07:39:11,628 --> 07:39:11,040

includes some nearby stars

6685

07:39:13,850 --> 07:39:11,638

um

6686

07:39:16,250 --> 07:39:13,860

but it's important to know that NO<sub>2</sub> can

6687

07:39:17,810 --> 07:39:16,260

also be created through natural means so

6688

07:39:20,030 --> 07:39:17,820

there's a lot of complicated chemistry

6689

07:39:21,590 --> 07:39:20,040

at play here to determine whether it's

6690

07:39:24,708 --> 07:39:21,600

actually artificial

6691

07:39:26,448 --> 07:39:24,718

but a really important thing about the

6692

07:39:29,510 --> 07:39:26,458

Cathedral at spheric pollution

6693

07:39:31,368 --> 07:39:29,520

signatures is that you can use the same

6694

07:39:33,650 --> 07:39:31,378

observations to search for techno

6695

07:39:35,690 --> 07:39:33,660

signatures and biosignatures when you're

6696

07:39:36,708 --> 07:39:35,700

looking at the Spectra so I think it's a

6697

07:39:40,850 --> 07:39:36,718

really great way that these two

6698

07:39:45,230 --> 07:39:42,288

um and then the last techno signature

6699

07:39:48,230 --> 07:39:45,240

I'm going to talk about is City Lights

6700

07:39:50,690 --> 07:39:48,240

so I'm showing a picture here of Earth

6701  
07:39:51,468 --> 07:39:50,700  
as each part of the world appears at

6702  
07:39:55,010 --> 07:39:51,478  
night

6703  
07:39:57,110 --> 07:39:55,020  
with City Lights so for this calculation

6704  
07:39:59,570 --> 07:39:57,120  
we're using some work done by Thomas

6705  
07:40:01,610 --> 07:39:59,580  
Beatty where he assumes that our lights

6706  
07:40:03,590 --> 07:40:01,620  
are primarily from high pressure sodium

6707  
07:40:05,810 --> 07:40:03,600  
lamps

6708  
07:40:07,968 --> 07:40:05,820  
in this simulation our Observer is

6709  
07:40:10,010 --> 07:40:07,978  
luvre a so a slightly earlier version

6710  
07:40:12,530 --> 07:40:10,020  
of the lubex I talked about last time

6711  
07:40:15,708 --> 07:40:12,540  
Lou Barre was an earlier Mission concept

6712  
07:40:17,208 --> 07:40:15,718  
concept for that so this exact design is

6713  
07:40:19,670 --> 07:40:17,218

not going to be launched in space but

6714

07:40:22,510 --> 07:40:19,680

we're going to have something similar

6715

07:40:26,030 --> 07:40:22,520

and our distance for this one is only

6716

07:40:28,250 --> 07:40:26,040

0.075 light years so this means

6717

07:40:30,530 --> 07:40:28,260

um you that we could only use something

6718

07:40:32,030 --> 07:40:30,540

like luvor to detect our city lights if

6719

07:40:33,650 --> 07:40:32,040

we're in the Oort cloud which is just

6720

07:40:35,330 --> 07:40:33,660

kind of the outer regions of the solar

6721

07:40:36,830 --> 07:40:35,340

system

6722

07:40:38,510 --> 07:40:36,840

um so if you want to detect this kind of

6723

07:40:41,448 --> 07:40:38,520

thing you're going to have to

6724

07:40:44,570 --> 07:40:41,458

uh have a planet that has a lot more

6725

07:40:48,830 --> 07:40:46,850

and so um I'll just kind of leave up my

6726

07:40:51,468 --> 07:40:48,840

summary slide here as the list of the

6727

07:40:53,030 --> 07:40:51,478

Techno signatures that we're looking at

6728

07:40:55,250 --> 07:40:53,040

um the first few on the list here are

6729

07:40:57,230 --> 07:40:55,260

the ones that we quickly went over I've

6730

07:40:58,730 --> 07:40:57,240

got a few more highlighted in yellow and

6731

07:40:59,930 --> 07:40:58,740

for those our calculations are still

6732

07:41:03,170 --> 07:40:59,940

underway

6733

07:41:04,310 --> 07:41:03,180

and then we've crossed a few out

6734

07:41:06,948 --> 07:41:04,320

um that turned out to be techno

6735

07:41:10,010 --> 07:41:06,958

signatures we've crossed off of um

6736

07:41:12,230 --> 07:41:10,020

consideration for various reasons mostly

6737

07:41:13,788 --> 07:41:12,240

because it's just not feasible to

6738

07:41:14,990 --> 07:41:13,798

observe them from space at all we'd be

6739

07:41:16,910 --> 07:41:15,000

talking about still in Earth's

6740

07:41:18,288 --> 07:41:16,920

atmosphere for our distance

6741

07:41:19,250 --> 07:41:18,298

or because

6742

07:41:20,990 --> 07:41:19,260

um

6743

07:41:23,150 --> 07:41:21,000

another possible techno signature is

6744

07:41:25,628 --> 07:41:23,160

observing the contents of Earth's

6745

07:41:28,310 --> 07:41:25,638

atmosphere over time and how it changes

6746

07:41:30,110 --> 07:41:28,320

but we decided for this project that

6747

07:41:32,628 --> 07:41:30,120

we're not going to get into things that

6748

07:41:35,690 --> 07:41:32,638

are based on changes over time because

6749

07:41:37,190 --> 07:41:35,700

uh this is already a really big paper as

6750

07:41:39,110 --> 07:41:37,200

is

6751  
07:41:48,288 --> 07:41:39,120  
um so yeah I can take questions I also

6752  
07:41:52,310 --> 07:41:50,868  
all right thank you Macy our new doctor

6753  
07:41:53,690 --> 07:41:52,320  
Houston

6754  
07:41:55,190 --> 07:41:53,700  
um unfortunately we only have time for

6755  
07:41:58,670 --> 07:41:55,200  
one question so I want to see some real

6756  
07:42:02,628 --> 07:42:00,948  
hi um thank you so much for your talk I

6757  
07:42:04,190 --> 07:42:02,638  
definitely agree with you that take my

6758  
07:42:06,590 --> 07:42:04,200  
signature and my signature scientists

6759  
07:42:08,628 --> 07:42:06,600  
need to work more closely together

6760  
07:42:10,788 --> 07:42:08,638  
um I was wondering I know the paper is

6761  
07:42:12,650 --> 07:42:10,798  
already super cool as it is but as a

6762  
07:42:14,810 --> 07:42:12,660  
sort of follow-up

6763  
07:42:16,788 --> 07:42:14,820

um would it be possible to estimate what

6764

07:42:18,948 --> 07:42:16,798

sort of techno signal like how those

6765

07:42:20,570 --> 07:42:18,958

techno signatures would evolve

6766

07:42:22,070 --> 07:42:20,580

um in the future and if there's one

6767

07:42:25,610 --> 07:42:22,080

that's going to shoot up and at what

6768

07:42:28,610 --> 07:42:25,620

point in our future uh would we be

6769

07:42:30,850 --> 07:42:28,620

detectable to most terrestrial planets

6770

07:42:33,288 --> 07:42:30,860

in our galaxy

6771

07:42:34,548 --> 07:42:33,298

yeah we'll talk a little bit about that

6772

07:42:36,048 --> 07:42:34,558

in the discussion but we're not going to

6773

07:42:38,208 --> 07:42:36,058

get too quantitative

6774

07:42:41,330 --> 07:42:38,218

um but that is something that comes up

6775

07:42:43,310 --> 07:42:41,340

as in you know uh one of the main things

6776  
07:42:46,070 --> 07:42:43,320  
you hear people talk about this in is is

6777  
07:42:47,750 --> 07:42:46,080  
like radio leakage because like

6778  
07:42:49,548 --> 07:42:47,760  
if our cell phone towers were more

6779  
07:42:51,708 --> 07:42:49,558  
directed you know down at the Earth they

6780  
07:42:53,570 --> 07:42:51,718  
could be more efficient and maybe more

6781  
07:42:55,610 --> 07:42:53,580  
advanced technology has less leakage

6782  
07:42:57,770 --> 07:42:55,620  
into space just because

6783  
07:42:59,150 --> 07:42:57,780  
it's a waste of energy

6784  
07:43:01,010 --> 07:42:59,160  
um so yeah these are things we think

6785  
07:43:02,690 --> 07:43:01,020  
about I don't have any definitive

6786  
07:43:08,710 --> 07:43:02,700  
answers right now

6787  
07:43:18,770 --> 07:43:14,628  
[Applause]

6788  
07:43:22,190 --> 07:43:18,780

okay our final speaker no pressure is

6789

07:43:27,708 --> 07:43:22,200

Evan Smith come on up Evan is coming

6790

07:43:27,718 --> 07:43:53,290

thank you good afternoon uh

6791

07:45:06,468 --> 07:43:58,548

[Music]

6792

07:45:14,970 --> 07:45:09,830

foreign

6793

07:45:37,310 --> 07:45:28,370

[Music]

6794

07:45:46,180 --> 07:45:40,210

foreign

6795

07:47:36,110 --> 07:45:56,850

[Music]

6796

07:47:36,120 --> 07:47:41,360

foreign

6797

07:48:23,810 --> 07:47:58,840

[Music]

6798

07:48:38,430 --> 07:48:25,070

foreign

6799

07:48:38,440 --> 07:48:49,490

[Music]

6800

07:48:57,740 --> 07:48:50,300

foreign

6801  
07:49:38,628 --> 07:49:16,420  
[Music]

6802  
07:49:38,638 --> 07:49:54,380  
thank you

6803  
07:51:03,650 --> 07:50:04,070  
[Music]

6804  
07:51:03,660 --> 07:51:07,010  
foreign

6805  
07:51:07,020 --> 07:51:19,850  
[Music]

6806  
07:51:19,860 --> 07:51:24,370  
foreign

6807  
07:52:32,610 --> 07:51:30,860  
[Music]

6808  
07:52:41,870 --> 07:52:32,620  
foreign

6809  
07:53:27,110 --> 07:52:53,940  
[Music]

6810  
07:53:35,020 --> 07:53:28,090  
thank you

6811  
07:53:35,030 --> 07:53:40,910  
[Music]

6812  
07:53:40,920 --> 07:53:44,500  
foreign

6813  
07:54:57,048 --> 07:54:02,720

[Music]

6814

07:54:57,058 --> 07:55:03,290

me

6815

07:55:03,300 --> 07:55:13,930

[Music]

6816

07:55:30,980 --> 07:55:16,250

thank you

6817

07:56:02,430 --> 07:56:00,888

[Music]

6818

07:56:08,208 --> 07:56:02,440

thank you

6819

07:56:08,218 --> 07:56:14,180

foreign

6820

07:57:22,190 --> 07:56:35,470

[Music]

6821

07:57:29,370 --> 07:57:23,220

foreign

6822

07:58:14,690 --> 07:57:43,550

[Music]

6823

07:58:25,310 --> 07:58:16,400

thank you

6824

07:58:41,680 --> 07:58:26,620

foreign

6825

07:59:04,960 --> 07:58:50,200

[Music]

6826  
07:59:13,750 --> 07:59:04,970  
thank you

6827  
07:59:37,310 --> 07:59:23,380  
[Music]

6828  
07:59:55,310 --> 07:59:37,320  
foreign

6829  
08:01:25,010 --> 08:00:07,670  
[Music]

6830  
08:01:48,720 --> 08:01:25,910  
thank you

6831  
08:01:48,730 --> 08:01:59,930  
[Music]

6832  
08:01:59,940 --> 08:02:03,780  
foreign

6833  
08:02:38,048 --> 08:02:26,530  
[Music]

6834  
08:02:38,058 --> 08:02:45,500  
thank you

6835  
08:04:36,468 --> 08:02:53,150  
[Music]

6836  
08:04:50,250 --> 08:04:37,570  
foreign

6837  
08:05:35,930 --> 08:05:29,310  
[Music]

6838  
08:05:35,940 --> 08:05:39,400

thank you

6839

08:07:03,888 --> 08:05:50,550

[Music]

6840

08:07:03,898 --> 08:07:09,100

foreign

6841

08:08:02,388 --> 08:07:20,950

[Music]

6842

08:08:02,398 --> 08:08:07,170

thank you

6843

08:08:18,290 --> 08:08:13,850

[Music]

6844

08:08:37,600 --> 08:08:18,300

foreign

6845

08:09:30,110 --> 08:08:50,060

[Music]

6846

08:09:30,120 --> 08:10:30,880

foreign

6847

08:10:30,890 --> 08:10:37,910

[Music]

6848

08:10:44,150 --> 08:10:38,880

thank you

6849

08:10:44,160 --> 08:10:59,740

foreign

6850

08:11:54,948 --> 08:11:42,870

[Music]

6851  
08:11:54,958 --> 08:12:05,590  
foreign

6852  
08:13:09,830 --> 08:12:19,730  
[Music]

6853  
08:13:09,840 --> 08:13:27,870  
foreign

6854  
08:14:13,850 --> 08:13:39,730  
[Music]

6855  
08:14:13,860 --> 08:14:38,880  
foreign

6856  
08:15:27,130 --> 08:14:52,130  
[Music]

6857  
08:15:46,990 --> 08:15:27,140  
foreign

6858  
08:17:31,430 --> 08:15:52,820  
[Music]

6859  
08:17:31,440 --> 08:17:35,140  
foreign

6860  
08:18:36,888 --> 08:17:48,690  
[Music]

6861  
08:18:36,898 --> 08:18:44,060  
thank you

6862  
08:19:06,830 --> 08:18:59,810  
[Music]

6863  
08:19:06,840 --> 08:19:13,130

foreign

6864

08:19:49,010 --> 08:19:25,650

[Music]

6865

08:19:49,020 --> 08:19:57,420

foreign

6866

08:20:19,368 --> 08:20:06,580

[Music]

6867

08:20:32,510 --> 08:20:21,100

foreign

6868

08:20:56,208 --> 08:20:37,790

[Music]

6869

08:21:14,700 --> 08:20:57,410

foreign

6870

08:21:14,710 --> 08:21:26,448

[Music]

6871

08:21:26,458 --> 08:21:32,690

thank you

6872

08:21:32,700 --> 08:21:46,770

foreign

6873

08:23:23,560 --> 08:21:55,910

[Music]

6874

08:23:44,170 --> 08:23:23,570

foreign

6875

08:23:44,180 --> 08:24:01,090

[Music]

6876  
08:24:26,230 --> 08:24:03,590  
thank you

6877  
08:24:53,750 --> 08:24:33,700  
[Music]

6878  
08:24:53,760 --> 08:24:58,880  
foreign

6879  
08:25:34,250 --> 08:25:22,630  
[Music]

6880  
08:25:34,260 --> 08:25:40,510  
foreign

6881  
08:26:04,910 --> 08:25:56,530  
[Music]

6882  
08:26:13,730 --> 08:26:06,170  
foreign

6883  
08:27:22,250 --> 08:26:23,150  
[Music]

6884  
08:27:22,260 --> 08:27:31,190  
foreign

6885  
08:27:52,968 --> 08:27:46,970  
[Music]

6886  
08:27:52,978 --> 08:27:57,000  
foreign

6887  
08:28:46,968 --> 08:28:11,370  
[Music]

6888  
08:28:51,350 --> 08:28:48,760

sweet

6889

08:29:06,708 --> 08:28:51,360

[Music]

6890

08:29:06,718 --> 08:29:11,860

foreign

6891

08:29:45,210 --> 08:29:34,490

[Music]

6892

08:30:18,350 --> 08:29:45,220

thank you

6893

08:30:18,360 --> 08:30:21,950

foreign

6894

08:31:08,090 --> 08:30:27,990

[Music]

6895

08:31:38,440 --> 08:31:09,560

foreign

6896

08:31:38,450 --> 08:32:07,490

[Music]

6897

08:33:14,060 --> 08:32:08,620

foreign

6898

08:33:14,070 --> 08:33:20,208

[Music]

6899

08:33:41,750 --> 08:33:21,660

foreign

6900

08:33:55,430 --> 08:33:48,200

[Music]

6901  
08:34:20,120 --> 08:33:56,870  
foreign

6902  
08:34:20,130 --> 08:34:35,030  
[Music]

6903  
08:34:35,040 --> 08:34:39,000  
thank you

6904  
08:34:39,010 --> 08:35:09,708  
[Music]

6905  
08:35:09,718 --> 08:35:14,220  
foreign

6906  
08:36:01,690 --> 08:35:27,440  
[Music]

6907  
08:36:01,700 --> 08:36:08,700  
thank you

6908  
08:37:10,310 --> 08:36:19,490  
[Music]

6909  
08:37:40,720 --> 08:37:12,700  
foreign

6910  
08:40:06,888 --> 08:38:32,700  
[Music]

6911  
08:40:15,530 --> 08:40:08,700  
foreign

6912  
08:40:18,350 --> 08:40:15,540  
[Music]

6913  
08:40:20,750 --> 08:40:18,360

we're going to get started uh our second

6914

08:40:22,010 --> 08:40:20,760

keynote speaker of the conference holds

6915

08:40:23,810 --> 08:40:22,020

the Chancellor's distinguished

6916

08:40:26,690 --> 08:40:23,820

profession professorship in physics at

6917

08:40:28,490 --> 08:40:26,700

UCSD he's a theoretical physicist whose

6918

08:40:31,010 --> 08:40:28,500

work is wide-ranging and whose Twitter

6919

08:40:33,048 --> 08:40:31,020

bio says I'm interested in everything

6920

08:40:34,150 --> 08:40:33,058

before joining UCSD he was at the

6921

08:40:36,468 --> 08:40:34,160

University of Illinois at

6922

08:40:39,110 --> 08:40:36,478

Urbana-Champaign for over 30 years where

6923

08:40:40,968 --> 08:40:39,120

he led the bio complexity group within

6924

08:40:41,930 --> 08:40:40,978

the Carl Roes Institute for genomic

6925

08:40:43,968 --> 08:40:41,940

biology

6926  
08:40:45,770 --> 08:40:43,978  
and where he both founded and directed

6927  
08:40:48,048 --> 08:40:45,780  
the NASA astrobiology Institute for

6928  
08:40:50,090 --> 08:40:48,058  
Universal biology his research has been

6929  
08:40:51,948 --> 08:40:50,100  
highly multidisciplinary ranging from

6930  
08:40:53,208 --> 08:40:51,958  
condensed matter and hydrodynamics to

6931  
08:40:55,788 --> 08:40:53,218  
the ecology and evolution of living

6932  
08:40:58,250 --> 08:40:55,798  
systems among his many accolades Nigel

6933  
08:41:00,410 --> 08:40:58,260  
received the 2020 leap kadenoff prize

6934  
08:41:02,270 --> 08:41:00,420  
from the American physical Society for

6935  
08:41:03,948 --> 08:41:02,280  
quote profound contributions to the

6936  
08:41:05,570 --> 08:41:03,958  
fields of superconductivity fluid

6937  
08:41:07,368 --> 08:41:05,580  
turbulence and dynamical pattern

6938  
08:41:08,810 --> 08:41:07,378

formation it's been a pleasure to have

6939

08:41:10,548 --> 08:41:08,820

him as a professor and it's a pleasure

6940

08:41:15,888 --> 08:41:10,558

to have him with us here today please

6941

08:41:15,898 --> 08:41:22,270

foreign

6942

08:41:27,770 --> 08:41:26,030

invitation to speak at the at Brad Khan

6943

08:41:29,990 --> 08:41:27,780

um I love this conference I've sent my

6944

08:41:31,310 --> 08:41:30,000

students to it I've been in it before I

6945

08:41:33,830 --> 08:41:31,320

think it's absolutely wonderful and I

6946

08:41:36,708 --> 08:41:33,840

was really thrilled to see that NASA is

6947

08:41:39,888 --> 08:41:36,718

still supporting it and even to uh to uh

6948

08:41:42,410 --> 08:41:39,898

to catch up with an old friend in class

6949

08:41:45,410 --> 08:41:42,420

and acquaintance for my days at the NASA

6950

08:41:47,510 --> 08:41:45,420

astrobiology Institute hi Mike so I'm

6951  
08:41:51,530 --> 08:41:47,520  
going to talk about something that that

6952  
08:41:53,690 --> 08:41:51,540  
by all right shouldn't exist and I don't

6953  
08:41:56,570 --> 08:41:53,700  
mean life itself

6954  
08:41:58,788 --> 08:41:56,580  
um I mean uh Universal aspects of living

6955  
08:42:01,368 --> 08:41:58,798  
systems I'm a physicist as you heard

6956  
08:42:04,368 --> 08:42:01,378  
from the introduction and so my approach

6957  
08:42:07,368 --> 08:42:04,378  
to anything is is ridiculously as simple

6958  
08:42:10,610 --> 08:42:07,378  
and is almost surely destined for

6959  
08:42:12,350 --> 08:42:10,620  
failure but we try to fail in a in a

6960  
08:42:15,048 --> 08:42:12,360  
grand way and at least see what we can

6961  
08:42:17,628 --> 08:42:15,058  
learn from our attempts to understand uh

6962  
08:42:19,368 --> 08:42:17,638  
the physical principles that govern uh

6963  
08:42:21,468 --> 08:42:19,378

life so I'm going to talk about

6964

08:42:23,510 --> 08:42:21,478

Universal biology the genetic code in

6965

08:42:28,368 --> 08:42:23,520

the first billion years of life on Earth

6966

08:42:30,288 --> 08:42:28,378

and I have uh collaborators my first

6967

08:42:32,388 --> 08:42:30,298

collaborate I want to mention is uh Carl

6968

08:42:34,368 --> 08:42:32,398

woes who will feature in this story and

6969

08:42:37,010 --> 08:42:34,378

many of you may know Carl was he

6970

08:42:39,048 --> 08:42:37,020

discovered the Arca he was a very famous

6971

08:42:41,270 --> 08:42:39,058

evolutionary biologist and he was my

6972

08:42:44,530 --> 08:42:41,280

mentor when I started doing biology

6973

08:42:47,628 --> 08:42:44,540

about 20 years ago

6974

08:42:50,750 --> 08:42:47,638

I was one of my graduate students who

6975

08:42:52,910 --> 08:42:50,760

did a fantastic work on the generic code

6976

08:42:56,208 --> 08:42:52,920

and was in fact also at the uh

6977

08:42:58,548 --> 08:42:56,218

University of Wisconsin where Alex was

6978

08:43:02,208 --> 08:42:58,558

as a as a student before

6979

08:43:03,910 --> 08:43:02,218

um uh Apache Jaffa Paul is now uh as a

6980

08:43:07,730 --> 08:43:03,920

in in the Netherlands and tomato

6981

08:43:09,708 --> 08:43:07,740

bianchalani is now working in a genotech

6982

08:43:10,910 --> 08:43:09,718

here in California all right so I'm

6983

08:43:15,468 --> 08:43:10,920

going to tell you about work that was

6984

08:43:16,930 --> 08:43:15,478

done uh over the last uh 10 or 10 or 15

6985

08:43:19,430 --> 08:43:16,940

years or so

6986

08:43:21,230 --> 08:43:19,440

through the NASA astrobiology Institute

6987

08:43:23,570 --> 08:43:21,240

and I hope you're going to find it

6988

08:43:26,750 --> 08:43:23,580

interesting if you have any questions

6989

08:43:28,128 --> 08:43:26,760

feel free to interrupt during the during

6990

08:43:30,350 --> 08:43:28,138

the talk especially if it's a

6991

08:43:32,810 --> 08:43:30,360

clarification and I'll be of course be

6992

08:43:35,208 --> 08:43:32,820

happy to take questions as as we go

6993

08:43:37,250 --> 08:43:35,218

through to the end so the thing I want

6994

08:43:39,468 --> 08:43:37,260

to understand is what are the sorts of

6995

08:43:41,750 --> 08:43:39,478

evolutionary transitions that life must

6996

08:43:45,650 --> 08:43:41,760

inevitably pass through this is part of

6997

08:43:48,530 --> 08:43:45,660

a program that the NASA uh discussed in

6998

08:43:50,448 --> 08:43:48,540

The Marvelous astrobiology road map from

6999

08:43:52,730 --> 08:43:50,458

about 15 years ago

7000

08:43:55,010 --> 08:43:52,740

trying to understand a universal biology

7001  
08:43:57,650 --> 08:43:55,020  
and look for Universal characteristics

7002  
08:43:59,330 --> 08:43:57,660  
of life and the idea is if we can

7003  
08:44:02,030 --> 08:43:59,340  
understand what features of life on

7004  
08:44:03,230 --> 08:44:02,040  
Earth are not idiosyncratic but actually

7005  
08:44:05,330 --> 08:44:03,240  
just something that we should expect

7006  
08:44:07,310 --> 08:44:05,340  
from another planet and understanding

7007  
08:44:09,650 --> 08:44:07,320  
these processes understanding these

7008  
08:44:12,410 --> 08:44:09,660  
transitions may help us to come up with

7009  
08:44:15,230 --> 08:44:12,420  
uh biosignatures and we'll see that in

7010  
08:44:18,048 --> 08:44:15,240  
fact there are some prospects for that

7011  
08:44:19,490 --> 08:44:18,058  
so I want to understand basically can we

7012  
08:44:22,310 --> 08:44:19,500  
understand some features of Life

7013  
08:44:24,230 --> 08:44:22,320

Universal features which you may say may

7014

08:44:26,750 --> 08:44:24,240

not exist but we'll see we'll see it's

7015

08:44:28,788 --> 08:44:26,760

the country and can we understand from

7016

08:44:30,468 --> 08:44:28,798

general dynamical principles without

7017

08:44:32,090 --> 08:44:30,478

necessarily having to worry about all

7018

08:44:34,368 --> 08:44:32,100

the chemical details

7019

08:44:36,708 --> 08:44:34,378

so I'm going to talk about two things in

7020

08:44:38,930 --> 08:44:36,718

this talk I'm going to talk about uh the

7021

08:44:42,110 --> 08:44:38,940

canonical genetic code and that's going

7022

08:44:44,030 --> 08:44:42,120

to be most the most of my talk I will

7023

08:44:46,250 --> 08:44:44,040

talk about biological homochoality

7024

08:44:48,948 --> 08:44:46,260

because it is important as a as a

7025

08:44:52,128 --> 08:44:48,958

biosignature it's been assumed to be a

7026

08:44:54,410 --> 08:44:52,138

biosignature but um but actually we'll

7027

08:44:56,410 --> 08:44:54,420

see in this talk that actually there are

7028

08:44:59,510 --> 08:44:56,420

dynamical reasons for thinking that

7029

08:45:01,548 --> 08:44:59,520

homoclicity isn't inevitable outcome of

7030

08:45:04,128 --> 08:45:01,558

living systems

7031

08:45:06,170 --> 08:45:04,138

so I want to first start off though by

7032

08:45:08,868 --> 08:45:06,180

talking about are there any universal

7033

08:45:10,968 --> 08:45:08,878

features in biology and and how should

7034

08:45:12,530 --> 08:45:10,978

we think about them so I'm a physicist

7035

08:45:14,868 --> 08:45:12,540

so I start off by asking is there

7036

08:45:18,110 --> 08:45:14,878

universality in physics so here's an

7037

08:45:20,930 --> 08:45:18,120

example this is thermal conductivity or

7038

08:45:23,510 --> 08:45:20,940

various uh glassy materials this is raw

7039

08:45:25,610 --> 08:45:23,520

data and then when we process it in a

7040

08:45:28,128 --> 08:45:25,620

certain way the data from different

7041

08:45:29,868 --> 08:45:28,138

materials all collapse onto one uh

7042

08:45:31,670 --> 08:45:29,878

Universal curve except for this regime

7043

08:45:33,350 --> 08:45:31,680

over here and so that's something that

7044

08:45:34,150 --> 08:45:33,360

we try to understand if we want to

7045

08:45:37,548 --> 08:45:34,160

understand

7046

08:45:40,070 --> 08:45:37,558

glassy materials here's another example

7047

08:45:43,070 --> 08:45:40,080

which is a much better one this example

7048

08:45:45,350 --> 08:45:43,080

is looking at the magnetic field or the

7049

08:45:47,690 --> 08:45:45,360

magnetization in a magnet exposed to an

7050

08:45:51,170 --> 08:45:47,700

external magnetic field  $H$  at temperature

7051

08:45:52,850 --> 08:45:51,180

t as you go through the ferromagnetic

7052

08:45:54,948 --> 08:45:52,860

phase transition the transition that

7053

08:45:57,110 --> 08:45:54,958

makes stuff be magnetic at low

7054

08:45:59,930 --> 08:45:57,120

temperatures and not magnetic at high

7055

08:46:02,690 --> 08:45:59,940

temperatures and you the data you take

7056

08:46:05,750 --> 08:46:02,700

from a different external magnetic

7057

08:46:07,610 --> 08:46:05,760

fields different uh temperatures and

7058

08:46:09,770 --> 08:46:07,620

then if you process the data in the

7059

08:46:11,270 --> 08:46:09,780

right way all these data from five

7060

08:46:13,670 --> 08:46:11,280

different materials none of which are

7061

08:46:16,968 --> 08:46:13,680

look anything alike all fall onto one

7062

08:46:19,310 --> 08:46:16,978

universal curve and the prediction for

7063

08:46:22,250 --> 08:46:19,320

that curve is the solid line which goes

7064

08:46:24,830 --> 08:46:22,260

embarrassingly close to all the data and

7065

08:46:27,948 --> 08:46:24,840

it has no adjustable parameters

7066

08:46:30,410 --> 08:46:27,958

so that's another example of of scaling

7067

08:46:31,730 --> 08:46:30,420

and universality in physics and you

7068

08:46:33,830 --> 08:46:31,740

might say well this is this is really

7069

08:46:36,048 --> 08:46:33,840

great because what did the physicists do

7070

08:46:38,330 --> 08:46:36,058

they made a model of a magnetic system

7071

08:46:40,010 --> 08:46:38,340

and then they took that model worked out

7072

08:46:42,048 --> 08:46:40,020

its consequences did some calculations

7073

08:46:43,788 --> 08:46:42,058

and then showed that it gave a precise

7074

08:46:46,010 --> 08:46:43,798

prediction in agreement with experiments

7075

08:46:47,810 --> 08:46:46,020

that's what physicists usually do in

7076

08:46:49,250 --> 08:46:47,820

fact it's nothing like that at all well

7077

08:46:51,468 --> 08:46:49,260

actually it is it's a model of a model

7078

08:46:54,170 --> 08:46:51,478

of a model of a model of a model and

7079

08:46:55,850 --> 08:46:54,180

that that does all the work the first

7080

08:46:57,590 --> 08:46:55,860

model is a model of quantum chemistry

7081

08:46:59,510 --> 08:46:57,600

then there's a model of electronic

7082

08:47:01,368 --> 08:46:59,520

structure then there's a model of the

7083

08:47:03,830 --> 08:47:01,378

dipole moment on the electronic spins

7084

08:47:05,930 --> 08:47:03,840

that uses quantum mechanics and then you

7085

08:47:08,090 --> 08:47:05,940

say well quantum mechanics is too hard

7086

08:47:09,888 --> 08:47:08,100

so let's get rid of quantum mechanics so

7087

08:47:11,388 --> 08:47:09,898

then you have a classical and you still

7088

08:47:13,548 --> 08:47:11,398

can't do it and then you make some sort

7089

08:47:16,788 --> 08:47:13,558

of approximation that physics to call

7090

08:47:18,708 --> 08:47:16,798

Landau Theory and then you you get the

7091

08:47:20,448 --> 08:47:18,718

results that I showed you

7092

08:47:22,388 --> 08:47:20,458

and the thing you want I want you to

7093

08:47:24,468 --> 08:47:22,398

understand the reason why I'm uh

7094

08:47:27,048 --> 08:47:24,478

tormenting you with this physics stuff

7095

08:47:30,170 --> 08:47:27,058

is because every step along the way here

7096

08:47:31,968 --> 08:47:30,180

is a non-systematic approximation you

7097

08:47:34,490 --> 08:47:31,978

cannot justify these approximations

7098

08:47:36,288 --> 08:47:34,500

starting from first principles from the

7099

08:47:39,590 --> 08:47:36,298

Schrodinger equation or whatever else it

7100

08:47:42,830 --> 08:47:39,600

is so the point is here is an example of

7101

08:47:45,650 --> 08:47:42,840

how a ludicrously simple model that has

7102

08:47:48,830 --> 08:47:45,660

no right to actually be able to describe

7103

08:47:50,990 --> 08:47:48,840

reality actually describes it precisely

7104

08:47:52,548 --> 08:47:51,000

and we know in this case why it works it

7105

08:47:54,170 --> 08:47:52,558

works in this case because of a thing

7106

08:47:56,090 --> 08:47:54,180

called renormalization group Theory

7107

08:47:58,548 --> 08:47:56,100

which Ken Wilson won the Nobel Prize for

7108

08:48:00,590 --> 08:47:58,558

inventing in the 1980s and so we

7109

08:48:02,868 --> 08:48:00,600

understand how all these approximations

7110

08:48:04,250 --> 08:48:02,878

that we made throw away stuff that

7111

08:48:06,230 --> 08:48:04,260

really doesn't matter for the thing that

7112

08:48:08,628 --> 08:48:06,240

we were trying to calculate

7113

08:48:11,150 --> 08:48:08,638

so that's the uh so that that tells you

7114

08:48:13,968 --> 08:48:11,160

that it is not impossible to make

7115

08:48:16,730 --> 08:48:13,978

ludicrously simple models and still have

7116

08:48:18,888 --> 08:48:16,740

some understanding of how the system

7117

08:48:20,750 --> 08:48:18,898

actually behaves

7118

08:48:23,690 --> 08:48:20,760

okay so but we're going to of course

7119

08:48:26,990 --> 08:48:23,700

apply that type of modeling philosophy

7120

08:48:30,170 --> 08:48:27,000

to biology but first of all let's ask

7121

08:48:31,788 --> 08:48:30,180

another question so for me as a

7122

08:48:34,548 --> 08:48:31,798

physicist I want to know do we learn new

7123

08:48:36,410 --> 08:48:34,558

physics when we study biology or is it

7124

08:48:38,930 --> 08:48:36,420

just insanely complicated Material

7125

08:48:40,910 --> 08:48:38,940

Science are they Universal phenomena do

7126  
08:48:42,288 --> 08:48:40,920  
they reveal anything important and what

7127  
08:48:44,448 --> 08:48:42,298  
do we miss by not understanding

7128  
08:48:45,888 --> 08:48:44,458  
Universal phenomena okay I'm going to

7129  
08:48:47,810 --> 08:48:45,898  
show you that there are Universal and

7130  
08:48:49,670 --> 08:48:47,820  
some of you will be very surprised at

7131  
08:48:51,468 --> 08:48:49,680  
the examples I'm going to show you I'm

7132  
08:48:53,750 --> 08:48:51,478  
also going to show you that if we don't

7133  
08:48:55,430 --> 08:48:53,760  
understand these Universal phenomena not

7134  
08:48:58,190 --> 08:48:55,440  
only can we not understand how life

7135  
08:48:59,690 --> 08:48:58,200  
started at all and how it evolved we

7136  
08:49:03,590 --> 08:48:59,700  
certainly can't understand how to do

7137  
08:49:05,990 --> 08:49:03,600  
things like respond to a pandemic or

7138  
08:49:09,048 --> 08:49:06,000

deal with antibiotic resistance or

7139

08:49:11,570 --> 08:49:09,058

herbicide doesn't or Cancer all of these

7140

08:49:14,510 --> 08:49:11,580

things depend on understanding Evolution

7141

08:49:16,548 --> 08:49:14,520

and these Universal properties

7142

08:49:19,250 --> 08:49:16,558

okay so let's talk about Universal

7143

08:49:21,288 --> 08:49:19,260

biology so so uh let me give you an

7144

08:49:24,170 --> 08:49:21,298

example here

7145

08:49:26,990 --> 08:49:24,180

so this was a this was a headline on the

7146

08:49:29,330 --> 08:49:27,000

NASA website at some point uh 2013 about

7147

08:49:32,628 --> 08:49:29,340

10 years ago mystery of the missing

7148

08:49:35,690 --> 08:49:32,638

waves on Titan so basically people knew

7149

08:49:38,570 --> 08:49:35,700

that from looking at the uh at uh the

7150

08:49:41,330 --> 08:49:38,580

flow mechanics and and the atmosphere of

7151  
08:49:43,968 --> 08:49:41,340  
Tito that there should be uh waves on on

7152  
08:49:46,610 --> 08:49:43,978  
the surface of Titan

7153  
08:49:48,170 --> 08:49:46,620  
um and uh and uh so there was a mystery

7154  
08:49:50,990 --> 08:49:48,180  
they weren't there we couldn't see them

7155  
08:49:53,930 --> 08:49:51,000  
nobody knew why and then about a year

7156  
08:49:58,128 --> 08:49:53,940  
later uh Cassini Spies The wind-rippled

7157  
08:49:59,868 --> 08:49:58,138  
Waves uh on Titan so so suddenly side of

7158  
08:50:02,388 --> 08:49:59,878  
relief thank goodness you you can sleep

7159  
08:50:05,090 --> 08:50:02,398  
at night we found the waves on the

7160  
08:50:08,270 --> 08:50:05,100  
surface of the oceans of Titan okay so

7161  
08:50:11,330 --> 08:50:08,280  
that's a real real headline okay here's

7162  
08:50:13,490 --> 08:50:11,340  
what here's one that you oh okay so I

7163  
08:50:14,750 --> 08:50:13,500

forget I forgot this we know the waves

7164

08:50:16,310 --> 08:50:14,760

on the ocean of Titan are missing

7165

08:50:18,288 --> 08:50:16,320

because there's a general theory of

7166

08:50:19,730 --> 08:50:18,298

two-phase fluid flow interfaces but

7167

08:50:21,888 --> 08:50:19,740

predict waves and the dispersion

7168

08:50:24,530 --> 08:50:21,898

characteristics so we knew what to look

7169

08:50:26,030 --> 08:50:24,540

for okay here's a headline that you

7170

08:50:28,910 --> 08:50:26,040

didn't see

7171

08:50:30,468 --> 08:50:28,920

mystery of the missing life on Titan and

7172

08:50:32,628 --> 08:50:30,478

then definitely not this one Cassini

7173

08:50:35,090 --> 08:50:32,638

Spies The Long sort life on Titan okay

7174

08:50:37,368 --> 08:50:35,100

anybody seen that headline it never

7175

08:50:39,770 --> 08:50:37,378

occurred okay and it's a joke right

7176  
08:50:40,788 --> 08:50:39,780  
because it's a joke because we don't

7177  
08:50:42,888 --> 08:50:40,798  
know if there's a missing life because

7178  
08:50:44,030 --> 08:50:42,898  
we don't have a theory that predicts the

7179  
08:50:46,310 --> 08:50:44,040  
existence of Life as a physical

7180  
08:50:48,530 --> 08:50:46,320  
phenomena so that's the first thing why

7181  
08:50:49,968 --> 08:50:48,540  
does life as a phenomenon exist and we

7182  
08:50:51,830 --> 08:50:49,978  
certainly don't understand what sort of

7183  
08:50:53,150 --> 08:50:51,840  
Life can exist in different uh

7184  
08:50:57,530 --> 08:50:53,160  
environments

7185  
08:51:00,410 --> 08:50:57,540  
so so um so so so actually going back to

7186  
08:51:02,270 --> 08:51:00,420  
going back to Cassini Cassini May indeed

7187  
08:51:04,010 --> 08:51:02,280  
have actually seen life

7188  
08:51:06,190 --> 08:51:04,020

but not on Titan

7189

08:51:08,750 --> 08:51:06,200

it may have seen life

7190

08:51:10,850 --> 08:51:08,760

okay so how many people here know about

7191

08:51:13,788 --> 08:51:10,860

encelados

7192

08:51:15,530 --> 08:51:13,798

great a lot more a lot more people than

7193

08:51:18,410 --> 08:51:15,540

would as a typical physics colloquium

7194

08:51:21,650 --> 08:51:18,420

right so so good so so as you know

7195

08:51:23,690 --> 08:51:21,660

insolidos is a is an isolated World

7196

08:51:27,308 --> 08:51:23,700

orbiting Saturn

7197

08:51:29,868 --> 08:51:27,318

um it has a global ocean of liquid water

7198

08:51:32,270 --> 08:51:29,878

underneath the ice and we know that

7199

08:51:34,070 --> 08:51:32,280

because we can see how it wobbles and

7200

08:51:36,110 --> 08:51:34,080

because of the way it wobbles we can

7201  
08:51:38,510 --> 08:51:36,120  
detect there must be life underneath but

7202  
08:51:41,510 --> 08:51:38,520  
there must be water underneath and it

7203  
08:51:43,788 --> 08:51:41,520  
also obligingly has a crack in the ice

7204  
08:51:45,530 --> 08:51:43,798  
lots of cracks and so water squirts out

7205  
08:51:47,150 --> 08:51:45,540  
through the cracks and so you've got a

7206  
08:51:49,250 --> 08:51:47,160  
fountain a huge fountain and you can fly

7207  
08:51:52,010 --> 08:51:49,260  
satellites through the fountain and you

7208  
08:51:53,448 --> 08:51:52,020  
can look at the water that you uh that

7209  
08:51:55,968 --> 08:51:53,458  
you pick up

7210  
08:51:58,010 --> 08:51:55,978  
and that water you can analyze it's

7211  
08:51:59,868 --> 08:51:58,020  
chemistry and its chemistry looks very

7212  
08:52:02,270 --> 08:51:59,878  
similar to what we might see as an

7213  
08:52:05,510 --> 08:52:02,280

alkaline hydrothermal vent here on Earth

7214

08:52:08,270 --> 08:52:05,520

so we Cassini wasn't instrumented for

7215

08:52:11,150 --> 08:52:08,280

looking at life but we may have seen

7216

08:52:13,670 --> 08:52:11,160

some signatures of life through that

7217

08:52:16,368 --> 08:52:13,680

experiment

7218

08:52:19,128 --> 08:52:16,378

so what is universal biology well

7219

08:52:20,990 --> 08:52:19,138

Universal biology is the idea that we

7220

08:52:23,150 --> 08:52:21,000

are interested in general principles and

7221

08:52:25,430 --> 08:52:23,160

not specific carbon chemistry details

7222

08:52:27,048 --> 08:52:25,440

and so we want to develop a theory of

7223

08:52:29,388 --> 08:52:27,058

universal biology divorced from

7224

08:52:31,730 --> 08:52:29,398

idiosyncratic details of the actual

7225

08:52:34,628 --> 08:52:31,740

chemistry and the and the geological

7226

08:52:37,850 --> 08:52:34,638

context and so on and this will involve

7227

08:52:40,308 --> 08:52:37,860

abstractions and and we use abstractions

7228

08:52:43,070 --> 08:52:40,318

all the time in in biology and we'll

7229

08:52:45,530 --> 08:52:43,080

talk about one of those in a minute

7230

08:52:47,510 --> 08:52:45,540

so in this slide is pretty much all we

7231

08:52:50,388 --> 08:52:47,520

know about Universal biology

7232

08:52:53,510 --> 08:52:50,398

so are you looking at it carefully

7233

08:52:55,788 --> 08:52:53,520

there's not much there so let's talk

7234

08:52:58,070 --> 08:52:55,798

instead about something where we do have

7235

08:52:59,270 --> 08:52:58,080

an understanding and that is universal

7236

08:53:01,308 --> 08:52:59,280

computation

7237

08:53:03,650 --> 08:53:01,318

so I wanted to tell you now about what

7238

08:53:05,868 --> 08:53:03,660

we what a universal biology would look

7239

08:53:09,708 --> 08:53:05,878

like if we could do it and we use as a

7240

08:53:11,208 --> 08:53:09,718

Model A computer so here's a picture of

7241

08:53:12,288 --> 08:53:11,218

my computer or something close to my

7242

08:53:17,570 --> 08:53:12,298

computer

7243

08:53:19,128 --> 08:53:17,580

see a few hundred miles up the road at

7244

08:53:21,770 --> 08:53:19,138

the Museum of computation in Mountain

7245

08:53:23,868 --> 08:53:21,780

View or in my case I saw it at the

7246

08:53:25,670 --> 08:53:23,878

science museum in London this is a

7247

08:53:28,250 --> 08:53:25,680

computer made out of COG wheels and

7248

08:53:31,070 --> 08:53:28,260

springs designed and partially built by

7249

08:53:35,090 --> 08:53:31,080

George Babbage in the 1900s it is the

7250

08:53:37,190 --> 08:53:35,100

authentic steampunk artifact

7251

08:53:40,128 --> 08:53:37,200

these two things are the same

7252

08:53:43,070 --> 08:53:40,138

they're the same algorithmically this

7253

08:53:45,468 --> 08:53:43,080

thing over here the left hand side is a

7254

08:53:48,170 --> 08:53:45,478

computer and you know that it's uh not

7255

08:53:50,388 --> 08:53:48,180

uh just a shiny chunk of glass plastic

7256

08:53:51,530 --> 08:53:50,398

and silicon it's actually a universal

7257

08:53:53,808 --> 08:53:51,540

turing machine

7258

08:53:55,430 --> 08:53:53,818

the thing on the right is also a turing

7259

08:53:57,650 --> 08:53:55,440

machine because it has conditional

7260

08:53:59,090 --> 08:53:57,660

branching in its instruction set and so

7261

08:54:02,030 --> 08:53:59,100

it can be shown that it can be mapped

7262

08:54:03,308 --> 08:54:02,040

onto a universal turing machine so in

7263

08:54:05,510 --> 08:54:03,318

fact the two things are the same

7264

08:54:07,070 --> 08:54:05,520

although one of them is at many times

7265

08:54:08,628 --> 08:54:07,080

faster than the other

7266

08:54:10,968 --> 08:54:08,638

so a turing machine with an online

7267

08:54:13,330 --> 08:54:10,978

architecture is really what a computer

7268

08:54:16,910 --> 08:54:13,340

is and we have Hardware to instantiate

7269

08:54:19,548 --> 08:54:16,920

that that algorithm so the medium is not

7270

08:54:21,708 --> 08:54:19,558

the message here is a John Von Neumann

7271

08:54:23,690 --> 08:54:21,718

standing in front of another computer

7272

08:54:26,090 --> 08:54:23,700

that he built at The Institute for

7273

08:54:27,948 --> 08:54:26,100

advanced study in the 1950s in this

7274

08:54:31,250 --> 08:54:27,958

computer it's built out of thermionic

7275

08:54:33,888 --> 08:54:31,260

valves it's built out of relays and

7276

08:54:35,448 --> 08:54:33,898

switches so neither this nor this we're

7277

08:54:38,448 --> 08:54:35,458

seeing here the evolution of

7278

08:54:40,250 --> 08:54:38,458

computational Hardware but in all of

7279

08:54:41,750 --> 08:54:40,260

these machines they all do the same

7280

08:54:43,788 --> 08:54:41,760

thing they're all Universal Turing

7281

08:54:45,830 --> 08:54:43,798

machines and so we're looking at life we

7282

08:54:48,590 --> 08:54:45,840

should be thinking about life as making

7283

08:54:51,590 --> 08:54:48,600

a progression as you see over here but

7284

08:54:53,150 --> 08:54:51,600

executing the same sort of algorithmic

7285

08:54:55,850 --> 08:54:53,160

processes

7286

08:54:58,670 --> 08:54:55,860

now there's a new physical laws in in

7287

08:54:59,990 --> 08:54:58,680

biology well schrodinger and Dell Brooke

7288

08:55:02,448 --> 08:55:00,000

were the first physicists to work in

7289

08:55:04,250 --> 08:55:02,458

biology and their partial motivation was

7290

08:55:05,990 --> 08:55:04,260

to find new physical laws they were

7291

08:55:08,628 --> 08:55:06,000

thinking about quantum mechanics in the

7292

08:55:10,190 --> 08:55:08,638

1930s as they might see some deviations

7293

08:55:14,388 --> 08:55:10,200

from quantum mechanics or something like

7294

08:55:15,770 --> 08:55:14,398

that but today we not many people well

7295

08:55:18,830 --> 08:55:15,780

some people think that could be still

7296

08:55:20,690 --> 08:55:18,840

true but most of us think that uh the

7297

08:55:22,308 --> 08:55:20,700

real big question is trying to

7298

08:55:24,708 --> 08:55:22,318

understand emergence and the existence

7299

08:55:27,650 --> 08:55:24,718

of life itself how is it that matter

7300

08:55:30,350 --> 08:55:27,660

that molecules and atoms are

7301

08:55:33,468 --> 08:55:30,360

self-organize hierarchically create

7302

08:55:35,750 --> 08:55:33,478

replicating and evolvable structures we

7303

08:55:38,208 --> 08:55:35,760

don't have a clue about how that happens

7304

08:55:40,070 --> 08:55:38,218

how do molecules come to life

7305

08:55:41,270 --> 08:55:40,080

so if you want to understand biology in

7306

08:55:43,490 --> 08:55:41,280

the same way that we understand physical

7307

08:55:45,468 --> 08:55:43,500

phenomena we need to understand the

7308

08:55:49,070 --> 08:55:45,478

existence and not just the specific

7309

08:55:50,750 --> 08:55:49,080

realization of of living systems

7310

08:55:53,388 --> 08:55:50,760

and I'm going to take the perspective

7311

08:55:55,670 --> 08:55:53,398

here that living systems are dynamical

7312

08:55:56,808 --> 08:55:55,680

systems that are able to reprogram

7313

08:55:58,610 --> 08:55:56,818

themselves

7314

08:56:01,070 --> 08:55:58,620

so let's think about that

7315

08:56:03,350 --> 08:56:01,080

so here is the uh here is the fortune

7316

08:56:05,690 --> 08:56:03,360

cookie the program is the data the data

7317

08:56:08,510 --> 08:56:05,700

is the program okay this is Niels

7318

08:56:10,968 --> 08:56:08,520

barricelli who was uh the first person

7319

08:56:13,548 --> 08:56:10,978

to write a computer virus he was working

7320

08:56:15,650 --> 08:56:13,558

at The Institute for advanced study and

7321

08:56:17,510 --> 08:56:15,660

in the day while John Von Neumann was

7322

08:56:20,330 --> 08:56:17,520

using the computer one of the first

7323

08:56:23,330 --> 08:56:20,340

computers to solve the equations of

7324

08:56:26,448 --> 08:56:23,340

hydrodynamics to design hydrogen bombs

7325

08:56:28,030 --> 08:56:26,458

uh Niels bandicelli went in at night and

7326  
08:56:30,708 --> 08:56:28,040  
made a

7327  
08:56:33,590 --> 08:56:30,718  
computer viruses and then had them

7328  
08:56:36,288 --> 08:56:33,600  
compete and and evolve with each other

7329  
08:56:38,808 --> 08:56:36,298  
inside a fixed ecosystem which was the

7330  
08:56:41,570 --> 08:56:38,818  
memory of the of the computer

7331  
08:56:44,510 --> 08:56:41,580  
and he he understood what he was seeing

7332  
08:56:47,030 --> 08:56:44,520  
here uh was uh was actually meaning of

7333  
08:56:49,850 --> 08:56:47,040  
the phenomena that we see in evolving uh

7334  
08:56:52,190 --> 08:56:49,860  
evolvable ecosystems

7335  
08:56:54,288 --> 08:56:52,200  
so what do self programming systems uh

7336  
08:56:56,930 --> 08:56:54,298  
can do well living systems have the

7337  
08:56:59,510 --> 08:56:56,940  
capacity to evolve and evolving systems

7338  
08:57:01,850 --> 08:56:59,520

can reprogram themselves so they're able

7339

08:57:04,490 --> 08:57:01,860

to respond to perturbations by creating

7340

08:57:06,888 --> 08:57:04,500

new functionality that is the defining

7341

08:57:08,150 --> 08:57:06,898

characteristic of living systems and

7342

08:57:10,368 --> 08:57:08,160

this is very different from physical

7343

08:57:13,010 --> 08:57:10,378

systems or engineered systems which are

7344

08:57:16,010 --> 08:57:13,020

by a fixed or predetermined uh equation

7345

08:57:17,930 --> 08:57:16,020

of motion or or behavior so the future

7346

08:57:21,048 --> 08:57:17,940

state of an evolvable system is

7347

08:57:23,150 --> 08:57:21,058

inherently unpredictable and maybe good

7348

08:57:26,208 --> 08:57:23,160

undecidable don't worry about that and

7349

08:57:27,968 --> 08:57:26,218

so this this uh this this feature means

7350

08:57:30,350 --> 08:57:27,978

that it's very difficult to control

7351  
08:57:32,388 --> 08:57:30,360  
evolving systems and we'll come to that

7352  
08:57:33,770 --> 08:57:32,398  
we'll turn to that at the end of The

7353  
08:57:36,830 --> 08:57:33,780  
Talk

7354  
08:57:40,010 --> 08:57:36,840  
now what do most biologists do well most

7355  
08:57:41,690 --> 08:57:40,020  
biologists do something rather strange

7356  
08:57:44,570 --> 08:57:41,700  
you could call it the inverse problem

7357  
08:57:46,968 --> 08:57:44,580  
imagine that you came down from Mars and

7358  
08:57:49,128 --> 08:57:46,978  
I gave you my computer and you had no

7359  
08:57:52,548 --> 08:57:49,138  
idea what this thing was what would you

7360  
08:57:54,770 --> 08:57:52,558  
be able to do to figure out that this

7361  
08:57:56,628 --> 08:57:54,780  
thing is not just an expensive door stop

7362  
08:57:58,670 --> 08:57:56,638  
but actually as a universal turing

7363  
08:58:00,650 --> 08:57:58,680

machine with a Von Wyman architecture it

7364

08:58:03,410 --> 08:58:00,660

will be very very different very very

7365

08:58:05,628 --> 08:58:03,420

difficult to figure out from the

7366

08:58:07,730 --> 08:58:05,638

electronic circuits and the hardware and

7367

08:58:10,670 --> 08:58:07,740

so on but that's what the thing actually

7368

08:58:12,770 --> 08:58:10,680

did and so what we want to do in biology

7369

08:58:14,930 --> 08:58:12,780

is we have the inverse problem the

7370

08:58:16,368 --> 08:58:14,940

biology is already created and we want

7371

08:58:19,010 --> 08:58:16,378

to understand what is the abstract

7372

08:58:21,110 --> 08:58:19,020

theory of which it is an instantiation

7373

08:58:22,788 --> 08:58:21,120

and that abstract Theory would underline

7374

08:58:24,948 --> 08:58:22,798

all systems that exhibit the

7375

08:58:26,990 --> 08:58:24,958

characteristics of life so could you

7376

08:58:28,368 --> 08:58:27,000

could you if you didn't know about the

7377

08:58:31,128 --> 08:58:28,378

universal Turing machines with a Von

7378

08:58:33,410 --> 08:58:31,138

Wyman architecture could you deduce a

7379

08:58:37,788 --> 08:58:33,420

theoretical framework just by somebody

7380

08:58:39,948 --> 08:58:37,798

giving you a highly evolved computer

7381

08:58:41,808 --> 08:58:39,958

okay we've talked about abstraction so

7382

08:58:44,150 --> 08:58:41,818

now let's get down to a real abstraction

7383

08:58:47,090 --> 08:58:44,160

so I want to talk about the genetic code

7384

08:58:49,610 --> 08:58:47,100

and I figuratively find that people uh

7385

08:58:51,468 --> 08:58:49,620

from various wide-ranging audiences

7386

08:58:53,388 --> 08:58:51,478

don't quite know what I mean when I talk

7387

08:58:56,150 --> 08:58:53,398

about the genetic code so let's just

7388

08:58:59,330 --> 08:58:56,160

take a pause uh to uh to go through that

7389

08:59:03,230 --> 08:58:59,340

so in the modern world as you know uh

7390

08:59:06,770 --> 08:59:03,240

DNA contains our genome the DNA is built

7391

08:59:09,730 --> 08:59:06,780

from four nucleotide bases RNA

7392

08:59:13,250 --> 08:59:09,740

polymerase reads uh the the gene coding

7393

08:59:15,468 --> 08:59:13,260

segments some spits out uh mRNA that's

7394

08:59:18,410 --> 08:59:15,478

also built from four nucleotide bases

7395

08:59:21,288 --> 08:59:18,420

and then the ribosomes go along the MRNA

7396

08:59:23,750 --> 08:59:21,298

and they spit out the proteins and they

7397

08:59:26,990 --> 08:59:23,760

choose which proteins should go into the

7398

08:59:29,090 --> 08:59:27,000

protein sorry if you choose which amino

7399

08:59:31,308 --> 08:59:29,100

acids should go into the proteins from

7400

08:59:33,770 --> 08:59:31,318

the code that they're reading from the

7401  
08:59:37,788 --> 08:59:33,780  
from the mRNA and the way they read that

7402  
08:59:41,090 --> 08:59:37,798  
code is they read it in triplets so aug

7403  
08:59:43,510 --> 08:59:41,100  
ACA ggt and so on these are codon

7404  
08:59:46,968 --> 08:59:43,520  
Triplets of of

7405  
08:59:48,650 --> 08:59:46,978  
nucleotide bases and the genetic code it

7406  
08:59:53,330 --> 08:59:48,660  
tells you if you read this thing here

7407  
08:59:55,430 --> 08:59:53,340  
what amino acid is going to go into the

7408  
08:59:57,830 --> 08:59:55,440  
into the protein that you're building

7409  
09:00:00,048 --> 08:59:57,840  
and so this is a sort of cartoon here of

7410  
09:00:01,808 --> 09:00:00,058  
the whole translation process and you're

7411  
09:00:04,170 --> 09:00:01,818  
supposed to think of this huge machine

7412  
09:00:05,270 --> 09:00:04,180  
moving along like so

7413  
09:00:07,670 --> 09:00:05,280

[Applause]

7414

09:00:10,070 --> 09:00:07,680

so just to summarize what the genetic

7415

09:00:11,808 --> 09:00:10,080

code is it's a map it's a map used by

7416

09:00:15,048 --> 09:00:11,818

the ribosome to translate the message

7417

09:00:18,048 --> 09:00:15,058

from A1A Triplets of four bases into the

7418

09:00:21,350 --> 09:00:18,058

20 amino acids of life and uh and and

7419

09:00:25,128 --> 09:00:21,360

we're going to discuss uh how that code

7420

09:00:27,830 --> 09:00:25,138

evolved now this is Carl Rose sitting uh

7421

09:00:29,690 --> 09:00:27,840

in his office on and on the New York

7422

09:00:34,490 --> 09:00:29,700

Times front page Thursday November the

7423

09:00:36,410 --> 09:00:34,500

3rd 1977. why is he there well it says

7424

09:00:39,288 --> 09:00:36,420

here scientists discover a form of life

7425

09:00:41,510 --> 09:00:39,298

that predates higher organisms

7426

09:00:43,968 --> 09:00:41,520

um I guess uh fake news is not just a

7427

09:00:45,708 --> 09:00:43,978

new invention it happened uh it happened

7428

09:00:48,590 --> 09:00:45,718

back in the 70s as well this is

7429

09:00:50,808 --> 09:00:48,600

partially true not not not not quite

7430

09:00:54,590 --> 09:00:50,818

true but in any case he had discovered

7431

09:00:57,230 --> 09:00:54,600

uh the uh the archaea so let me just

7432

09:00:59,628 --> 09:00:57,240

tell you uh what he had discovered so

7433

09:01:02,808 --> 09:00:59,638

this is the tree of life this is from a

7434

09:01:04,910 --> 09:01:02,818

paper by Norm Pace in 97

7435

09:01:08,208 --> 09:01:04,920

now you can see here there are three

7436

09:01:11,388 --> 09:01:08,218

domains the bacteria the archaea and the

7437

09:01:13,368 --> 09:01:11,398

eukaryotes you are over here but

7438

09:01:15,968 --> 09:01:13,378

actually everything else here is is

7439

09:01:18,708 --> 09:01:15,978

microbial and uh the and this this this

7440

09:01:21,288 --> 09:01:18,718

phylogenetic tree is a kind of map it's

7441

09:01:23,690 --> 09:01:21,298

built it's been elaborated on by now and

7442

09:01:25,610 --> 09:01:23,700

there's there's uh it's it's out of date

7443

09:01:27,590 --> 09:01:25,620

and there's uh some debates about

7444

09:01:29,448 --> 09:01:27,600

whether there's two domains or three

7445

09:01:31,548 --> 09:01:29,458

domains and so on and so forth but

7446

09:01:34,010 --> 09:01:31,558

fundamentally this is what uh what he

7447

09:01:36,468 --> 09:01:34,020

discovered now how did he uh how did he

7448

09:01:39,288 --> 09:01:36,478

discover this well what he did was

7449

09:01:42,288 --> 09:01:39,298

looked for patterns in uh in in

7450

09:01:44,868 --> 09:01:42,298

molecular sequences from parts of the

7451

09:01:46,610 --> 09:01:44,878

ribosome the 16s small subunit of the

7452

09:01:49,250 --> 09:01:46,620

ribosome and by looking at those

7453

09:01:51,530 --> 09:01:49,260

sequences was able to look at do the

7454

09:01:53,930 --> 09:01:51,540

what what today would call comparative

7455

09:01:55,430 --> 09:01:53,940

genomics and map out uh the the this

7456

09:01:57,948 --> 09:01:55,440

tree of life

7457

09:02:00,110 --> 09:01:57,958

and some around here is uh the last

7458

09:02:03,170 --> 09:02:00,120

Universal common ancestor or the last

7459

09:02:04,910 --> 09:02:03,180

Universal common ancestral community

7460

09:02:09,048 --> 09:02:04,920

so this is the paper that they wrote in

7461

09:02:11,150 --> 09:02:09,058

in 1977 and uh the the mystery that this

7462

09:02:14,150 --> 09:02:11,160

uh this this work

7463

09:02:16,430 --> 09:02:14,160

um uh left us with is the following we

7464

09:02:18,048 --> 09:02:16,440

know that the planet is about 4.6

7465

09:02:21,230 --> 09:02:18,058

billion years old

7466

09:02:24,530 --> 09:02:21,240

we know that the the last Universal

7467

09:02:26,388 --> 09:02:24,540

common ancestor even then was uh was

7468

09:02:28,968 --> 09:02:26,398

dated to at least three billion years

7469

09:02:31,010 --> 09:02:28,978

today we think it's about 3.6 3.8

7470

09:02:34,490 --> 09:02:31,020

billion years depending on who you're

7471

09:02:35,150 --> 09:02:34,500

talking to based on uh static

7472

09:02:44,330 --> 09:02:35,160

um

7473

09:02:47,090 --> 09:02:44,340

you know if they're various geological

7474

09:02:47,930 --> 09:02:47,100

evidence and and so on for matalites and

7475

09:02:50,208 --> 09:02:47,940

so on

7476

09:02:53,270 --> 09:02:50,218

um so so basically but something like

7477

09:02:56,090 --> 09:02:53,280

this but but the point that that woes

7478

09:02:58,250 --> 09:02:56,100

and fox were making is that a lot of the

7479

09:03:00,170 --> 09:02:58,260

of the time the planet was inhospitable

7480

09:03:03,650 --> 09:03:00,180

to life you had less than a billion

7481

09:03:05,330 --> 09:03:03,660

years in which life could evolve and it

7482

09:03:07,910 --> 09:03:05,340

evolved the complexity of something like

7483

09:03:09,948 --> 09:03:07,920

the modern cell in less than the billion

7484

09:03:11,690 --> 09:03:09,958

years and then after that there wasn't

7485

09:03:13,850 --> 09:03:11,700

very much cellular Evolution maybe

7486

09:03:15,288 --> 09:03:13,860

dinosaurs and multicellularity and

7487

09:03:17,208 --> 09:03:15,298

things like that but from a point of

7488

09:03:18,830 --> 09:03:17,218

view of the architecture of the cell uh

7489

09:03:22,610 --> 09:03:18,840

very little

7490

09:03:24,288 --> 09:03:22,620

so so what uh What uh uh woes and fox uh

7491

09:03:27,170 --> 09:03:24,298

here's some pictures of them doing their

7492

09:03:30,708 --> 09:03:27,180

work at the time uh what they what they

7493

09:03:33,590 --> 09:03:30,718

uh what they wrote was that uh that it

7494

09:03:35,990 --> 09:03:33,600

wasn't that the evolution speeded up at

7495

09:03:38,448 --> 09:03:36,000

the beginning and then slowed down uh

7496

09:03:40,308 --> 09:03:38,458

the last Universal common ancestor what

7497

09:03:43,610 --> 09:03:40,318

they wrote was that actually maybe

7498

09:03:45,288 --> 09:03:43,620

Evolution had a different character

7499

09:03:47,628 --> 09:03:45,298

um in its early phases and we're going

7500

09:03:49,968 --> 09:03:47,638

to see that there is evidence for that

7501  
09:03:51,830 --> 09:03:49,978  
now what kind of different mode could

7502  
09:03:54,650 --> 09:03:51,840  
there be of evolution

7503  
09:03:56,930 --> 09:03:54,660  
well most of us when you think about

7504  
09:03:59,510 --> 09:03:56,940  
Evolution you think about what is really

7505  
09:04:01,788 --> 09:03:59,520  
called vertical Evolution that is you

7506  
09:04:03,350 --> 09:04:01,798  
have your genes you give your genes to

7507  
09:04:05,208 --> 09:04:03,360  
your children they give their genes to

7508  
09:04:08,030 --> 09:04:05,218  
their children and so on and so forth

7509  
09:04:10,670 --> 09:04:08,040  
and so there's a a transfer of genetic

7510  
09:04:12,530 --> 09:04:10,680  
material of genes through the

7511  
09:04:15,230 --> 09:04:12,540  
generations

7512  
09:04:17,570 --> 09:04:15,240  
horizontal Gene transfer is a is a

7513  
09:04:20,208 --> 09:04:17,580

different thing altogether horizontal

7514

09:04:22,730 --> 09:04:20,218

team transfer is the transfer of genes

7515

09:04:25,788 --> 09:04:22,740

from one organism to another that it is

7516

09:04:29,030 --> 09:04:25,798

not related to and I and this is uh this

7517

09:04:31,250 --> 09:04:29,040

is what happens uh in in bacteria

7518

09:04:34,010 --> 09:04:31,260

there's three ways that this can known

7519

09:04:36,048 --> 09:04:34,020

to happen here on Earth genes can be

7520

09:04:38,570 --> 09:04:36,058

transmitted through viruses through

7521

09:04:40,670 --> 09:04:38,580

direct contact or through uptake of free

7522

09:04:44,330 --> 09:04:40,680

DNA from the environment so the question

7523

09:04:46,788 --> 09:04:44,340

is what happens when all the all the

7524

09:04:49,250 --> 09:04:46,798

microbes in the world do this what

7525

09:04:52,128 --> 09:04:49,260

happens when all of early life is able

7526

09:04:54,048 --> 09:04:52,138

to uh to transfer genes

7527

09:04:57,490 --> 09:04:54,058

okay let me just give you two quick uh

7528

09:05:00,288 --> 09:04:57,500

anecdotes about that so this here is a

7529

09:05:03,170 --> 09:05:00,298

cyanophage it's a it's a phase that's in

7530

09:05:04,868 --> 09:05:03,180

in facts uh prochlorococcus one of the

7531

09:05:08,388 --> 09:05:04,878

most abundant organisms of the planet

7532

09:05:11,270 --> 09:05:08,398

and uh and and this here is a is a

7533

09:05:14,150 --> 09:05:11,280

phylogenetic tree of the of a gene that

7534

09:05:17,448 --> 09:05:14,160

is involved in the in photosystem too

7535

09:05:18,590 --> 09:05:17,458

and if you can read phylogenetic trees

7536

09:05:20,868 --> 09:05:18,600

it doesn't matter if you can't but if

7537

09:05:23,388 --> 09:05:20,878

you can read them what this shows you is

7538

09:05:26,208 --> 09:05:23,398

that this Gene was transferred back and

7539

09:05:30,590 --> 09:05:26,218

forth between a virus and the bacterial

7540

09:05:32,990 --> 09:05:30,600

host multiple times during evolution

7541

09:05:34,968 --> 09:05:33,000

and in fact the the the group that

7542

09:05:37,910 --> 09:05:34,978

discovered this sort of a little in

7543

09:05:40,610 --> 09:05:37,920

penitism's lab they wrote that to host

7544

09:05:42,230 --> 09:05:40,620

like genes acquired by phages undergo a

7545

09:05:44,690 --> 09:05:42,240

period of diversification and phase

7546

09:05:47,510 --> 09:05:44,700

genomes and serve as a genetic reservoir

7547

09:05:50,030 --> 09:05:47,520

for their hosts so the idea is I have a

7548

09:05:52,270 --> 09:05:50,040

gene that is a photosynthesis Gene that

7549

09:05:55,490 --> 09:05:52,280

that Gene helps her in photosynthesis

7550

09:05:57,530 --> 09:05:55,500

that Gene gets transferred by a viral

7551

09:06:01,070 --> 09:05:57,540

attack to phage

7552

09:06:04,128 --> 09:06:01,080

in phage that Gene can evolve much more

7553

09:06:05,690 --> 09:06:04,138

rapidly because there are less proof

7554

09:06:09,170 --> 09:06:05,700

readings and things like this that go on

7555

09:06:12,650 --> 09:06:09,180

in phage replication so as a result the

7556

09:06:14,630 --> 09:06:12,660

bacteria are get infected by new genes

7557

09:06:16,248 --> 09:06:14,640

from the phage but those genes have

7558

09:06:18,350 --> 09:06:16,258

evolved much more rapidly in the phase

7559

09:06:20,330 --> 09:06:18,360

than they would in the bacteria and so

7560

09:06:23,350 --> 09:06:20,340

there's a there's a mechanism by which

7561

09:06:26,568 --> 09:06:23,360

you could have rapid evolutionary change

7562

09:06:28,548 --> 09:06:26,578

mediated by phage or by other mechanisms

7563

09:06:30,408 --> 09:06:28,558

of horizontal Gene transfer and because

7564

09:06:32,928 --> 09:06:30,418

that is a network effect it's

7565

09:06:35,748 --> 09:06:32,938

extraordinarily efficient

7566

09:06:37,548 --> 09:06:35,758

and uh and um I'm not going to have time

7567

09:06:39,888 --> 09:06:37,558

to show you work that we did actually

7568

09:06:42,650 --> 09:06:39,898

modeling that that whole process

7569

09:06:44,990 --> 09:06:42,660

now this is the uh the uh with that

7570

09:06:47,088 --> 09:06:45,000

having said that and told you about an

7571

09:06:49,310 --> 09:06:47,098

other mode of transfer let me now tell

7572

09:06:51,708 --> 09:06:49,320

you about the genetic code so here is

7573

09:06:55,068 --> 09:06:51,718

the genetic code so the way you read it

7574

09:06:57,048 --> 09:06:55,078

is like this you you and then the First

7575

09:06:59,272 --> 09:06:57,058

Column up here so that brings you to

7576

09:07:00,650 --> 09:06:59,282

this cell that's phenylalanyl in and you

7577

09:07:03,588 --> 09:07:00,660

can do the same thing for all of these

7578

09:07:06,708 --> 09:07:03,598

of course it's a it's a it's a code of

7579

09:07:08,690 --> 09:07:06,718

triplets of for a nucleotide basis in

7580

09:07:10,190 --> 09:07:08,700

alphabet of four so in principle there

7581

09:07:12,588 --> 09:07:10,200

are 64 things you could code for but

7582

09:07:15,830 --> 09:07:12,598

there's only 20 amino acids so the code

7583

09:07:18,408 --> 09:07:15,840

is redundant and uh but it's not just

7584

09:07:19,908 --> 09:07:18,418

redundant it also has structure so if

7585

09:07:21,772 --> 09:07:19,918

you look here these are the most

7586

09:07:23,568 --> 09:07:21,782

hydrophobic amino acids these are the

7587

09:07:24,888 --> 09:07:23,578

most hydrophilic ones and you can see

7588

09:07:27,530 --> 09:07:24,898

that in the way that this code is

7589

09:07:32,088 --> 09:07:27,540

written there is structure here

7590

09:07:34,670 --> 09:07:32,098

the amino acids have are segmented in

7591

09:07:37,190 --> 09:07:34,680

this in this uh in this genetic code

7592

09:07:41,272 --> 09:07:37,200

table so one of the things that Carl was

7593

09:07:42,588 --> 09:07:41,282

did back in the 1960s was to measure a

7594

09:07:44,868 --> 09:07:42,598

quantity that he called polar

7595

09:07:46,368 --> 09:07:44,878

acquirement which measured this balance

7596

09:07:48,950 --> 09:07:46,378

between hydrophobicity and

7597

09:07:51,830 --> 09:07:48,960

hydrophilicity and gave a single number

7598

09:07:54,708 --> 09:07:51,840

which is small up over here and large

7599

09:07:58,248 --> 09:07:54,718

over here and and so he was able to

7600

09:08:01,030 --> 09:07:58,258

quantify that chemical difference

7601  
09:08:03,408 --> 09:08:01,040  
now you all know that the genetic code

7602  
09:08:04,670 --> 09:08:03,418  
is pretty much Universal it's not

7603  
09:08:06,408 --> 09:08:04,680  
exactly Universal there's small

7604  
09:08:08,388 --> 09:08:06,418  
variations and stop codons but it's

7605  
09:08:09,470 --> 09:08:08,398  
basically Universal but what I want to

7606  
09:08:11,088 --> 09:08:09,480  
tell you now is something that you may

7607  
09:08:14,272 --> 09:08:11,098  
not know about and that is that the

7608  
09:08:16,368 --> 09:08:14,282  
genetic code is pretty much optimal in

7609  
09:08:18,588 --> 09:08:16,378  
minimizing errors

7610  
09:08:21,048 --> 09:08:18,598  
okay so let's let's uh let's discuss

7611  
09:08:22,728 --> 09:08:21,058  
what we mean by that so let's suppose

7612  
09:08:25,310 --> 09:08:22,738  
that you were given the task of of

7613  
09:08:28,310 --> 09:08:25,320

Designing intelligently a genetic code

7614

09:08:30,530 --> 09:08:28,320

okay well you might say well translation

7615

09:08:32,330 --> 09:08:30,540

is fundamentally important to a cellular

7616

09:08:34,850 --> 09:08:32,340

operation so we want to make sure that

7617

09:08:38,450 --> 09:08:34,860

any any mistakes any mutations or any

7618

09:08:40,068 --> 09:08:38,460

misreadings give you an amino acid which

7619

09:08:42,228 --> 09:08:40,078

is pretty close in clinical properties

7620

09:08:43,728 --> 09:08:42,238

to the one that you should have got and

7621

09:08:46,490 --> 09:08:43,738

if you could design a code like that

7622

09:08:49,548 --> 09:08:46,500

then then that would be great okay it

7623

09:08:52,850 --> 09:08:49,558

would be robust to errors so the

7624

09:08:55,548 --> 09:08:52,860

question is is our genetic code like

7625

09:08:58,190 --> 09:08:55,558

that I'm going to show you that it is

7626

09:08:59,748 --> 09:08:58,200

so here's the actual genetic code so

7627

09:09:02,272 --> 09:08:59,758

what you can do is you can make in the

7628

09:09:04,728 --> 09:09:02,282

computer alternative genetic codes just

7629

09:09:06,588 --> 09:09:04,738

by permuting the labels so here I'm

7630

09:09:08,690 --> 09:09:06,598

permuting the label so I get new codes

7631

09:09:10,850 --> 09:09:08,700

I'll be it with the same pattern of

7632

09:09:13,490 --> 09:09:10,860

degeneracy there's 20 factorial which is

7633

09:09:15,530 --> 09:09:13,500

about 10 to the 18 possible genetic code

7634

09:09:17,690 --> 09:09:15,540

that you could have in the computer

7635

09:09:21,470 --> 09:09:17,700

okay so now I can say all right I've

7636

09:09:23,810 --> 09:09:21,480

made this whole Suite of genetic codes

7637

09:09:26,990 --> 09:09:23,820

how good are they at minimizing errors

7638

09:09:29,568 --> 09:09:27,000

and uh and there's a way that you can

7639

09:09:32,030 --> 09:09:29,578

you can compute that and I'm not going

7640

09:09:33,650 --> 09:09:32,040

to go into the exact metric that one

7641

09:09:35,810 --> 09:09:33,660

uses

7642

09:09:38,208 --> 09:09:35,820

so there's a way that one can do that so

7643

09:09:41,030 --> 09:09:38,218

then one can ask well what should be the

7644

09:09:42,428 --> 09:09:41,040

output if we take all our genetic codes

7645

09:09:44,810 --> 09:09:42,438

that we've constructed in the computer

7646

09:09:46,670 --> 09:09:44,820

measure how good they are at minimizing

7647

09:09:49,428 --> 09:09:46,680

hours and then plot the probability

7648

09:09:51,350 --> 09:09:49,438

distribution how many times we see a

7649

09:09:53,990 --> 09:09:51,360

particular code with a particular score

7650

09:09:56,208 --> 09:09:54,000

and minimizing errors and the smaller

7651  
09:09:58,248 --> 09:09:56,218  
the the number here is on the horizontal

7652  
09:09:59,748 --> 09:09:58,258  
axis the better the code is at

7653  
09:10:01,970 --> 09:09:59,758  
minimizing error

7654  
09:10:03,772 --> 09:10:01,980  
okay so one possibility that you could

7655  
09:10:06,350 --> 09:10:03,782  
have is something like this you've got

7656  
09:10:08,868 --> 09:10:06,360  
some you know Bells roughly bell-shaped

7657  
09:10:10,548 --> 09:10:08,878  
curve and uh and then you that's what

7658  
09:10:12,112 --> 09:10:10,558  
you would get for any random genetic

7659  
09:10:13,790 --> 09:10:12,122  
code and then you look at the actual

7660  
09:10:16,010 --> 09:10:13,800  
genetic code it happens to be here in

7661  
09:10:18,112 --> 09:10:16,020  
the middle in this in this sketch and so

7662  
09:10:20,928 --> 09:10:18,122  
you would say okay well if that's what

7663  
09:10:23,568 --> 09:10:20,938

happens then that means that the current

7664

09:10:27,888 --> 09:10:23,578

genetic code is just a frozen accident

7665

09:10:30,290 --> 09:10:27,898

there were some ancestral organism

7666

09:10:31,790 --> 09:10:30,300

it by accident it happens to be the one

7667

09:10:34,970 --> 09:10:31,800

that we're all descended from all life

7668

09:10:37,010 --> 09:10:34,980

on Earth it had some genetic code we all

7669

09:10:38,928 --> 09:10:37,020

have the same genetic code as it because

7670

09:10:42,888 --> 09:10:38,938

if we had a different genetic code then

7671

09:10:44,388 --> 09:10:42,898

we'd be mistranslating our genomes we'd

7672

09:10:45,950 --> 09:10:44,398

be getting the wrong amino acids and the

7673

09:10:49,130 --> 09:10:45,960

wrong proteins and so we wouldn't

7674

09:10:51,950 --> 09:10:49,140

survive and so the code must be what

7675

09:10:54,290 --> 09:10:51,960

Francis Crick in 1968 called a frozen

7676

09:10:56,088 --> 09:10:54,300

accident it's an accident because it

7677

09:10:58,248 --> 09:10:56,098

just comes from whatever was the last

7678

09:11:00,830 --> 09:10:58,258

Universal common ancestor and it's

7679

09:11:04,310 --> 09:11:00,840

frozen because if it evolves the changes

7680

09:11:07,428 --> 09:11:04,320

that it would happen would be deadly

7681

09:11:09,530 --> 09:11:07,438

well the other option is something like

7682

09:11:11,868 --> 09:11:09,540

this you've got a bell-shaped curve like

7683

09:11:14,088 --> 09:11:11,878

this and then the atrogenetic code is

7684

09:11:16,428 --> 09:11:14,098

somewhere down here in the Tails and if

7685

09:11:18,228 --> 09:11:16,438

that's true then that says heck the

7686

09:11:21,530 --> 09:11:18,238

genetic code that we have is not a

7687

09:11:24,112 --> 09:11:21,540

frozen accident it had to have evolved

7688

09:11:25,548 --> 09:11:24,122

so here are the data this was a these

7689

09:11:29,272 --> 09:11:25,558

are data taken from an experiment that

7690

09:11:31,790 --> 09:11:29,282

was done by freelance Hearst in 1998 so

7691

09:11:33,650 --> 09:11:31,800

they they generated 1 million genetic

7692

09:11:35,630 --> 09:11:33,660

codes and they scored them in a way

7693

09:11:37,548 --> 09:11:35,640

they're like I'm not going to go into in

7694

09:11:40,548 --> 09:11:37,558

detail and the actual genetic code is

7695

09:11:42,408 --> 09:11:40,558

way way down here in the tail so all

7696

09:11:44,748 --> 09:11:42,418

these random codes look nothing like

7697

09:11:47,748 --> 09:11:44,758

this actual universal genetic code the

7698

09:11:49,670 --> 09:11:47,758

canonical genetic code and so the title

7699

09:11:51,350 --> 09:11:49,680

of their paper was the genetic code is

7700

09:11:53,630 --> 09:11:51,360

one in a million

7701

09:11:56,510 --> 09:11:53,640

okay generate a million genetic codes

7702

09:11:58,908 --> 09:11:56,520

and and they're all worse than the one

7703

09:12:00,708 --> 09:11:58,918

that we actually have at minimizing

7704

09:12:02,150 --> 09:12:00,718

translation hours

7705

09:12:03,888 --> 09:12:02,160

actually we know that actually it's

7706

09:12:06,772 --> 09:12:03,898

actually more more like a hundred times

7707

09:12:08,928 --> 09:12:06,782

uh better than that

7708

09:12:11,568 --> 09:12:08,938

okay so now we have to ask the question

7709

09:12:13,190 --> 09:12:11,578

how did the genetic code get like this

7710

09:12:15,588 --> 09:12:13,200

how is it possible for the code to

7711

09:12:17,868 --> 09:12:15,598

evolve because Florence is quick already

7712

09:12:19,850 --> 09:12:17,878

told us that it can't evolve if you so

7713

09:12:21,408 --> 09:12:19,860

if you change the genetic code you're

7714

09:12:23,030 --> 09:12:21,418

going to start making the wrong amino

7715

09:12:25,010 --> 09:12:23,040

acids you make wrong amino acids you

7716

09:12:27,228 --> 09:12:25,020

make the wrong proteins everything dies

7717

09:12:31,130 --> 09:12:27,238

so we have to figure out how to do it

7718

09:12:33,530 --> 09:12:31,140

and and this is what we did in this

7719

09:12:35,388 --> 09:12:33,540

paper over here and I want to walk you

7720

09:12:37,908 --> 09:12:35,398

through not I'm not going to go into any

7721

09:12:40,190 --> 09:12:37,918

of the the modeling and the math and so

7722

09:12:42,650 --> 09:12:40,200

on I want to give you a feel of how we

7723

09:12:45,588 --> 09:12:42,660

can understand how it is possible for a

7724

09:12:46,908 --> 09:12:45,598

code to evolve

7725

09:12:48,530 --> 09:12:46,918

okay so we're going to do a thought

7726

09:12:51,588 --> 09:12:48,540

experiment and we're going to do the

7727

09:12:54,772 --> 09:12:51,598

thought experiment by involving in our

7728

09:13:00,650 --> 09:12:54,782

little story here the experts on codes

7729

09:13:06,670 --> 09:13:03,112

spies you're right

7730

09:13:12,530 --> 09:13:11,088

and possibly success 1960s TV shows

7731

09:13:15,048 --> 09:13:12,540

all right so we're going to do an

7732

09:13:17,150 --> 09:13:15,058

experiment which involves uh these spies

7733

09:13:19,068 --> 09:13:17,160

and we're going to imagine that the

7734

09:13:19,970 --> 09:13:19,078

spies of course have their secret code

7735

09:13:25,010 --> 09:13:19,980

book

7736

09:13:26,690 --> 09:13:25,020

are trying to communicate with uh one

7737

09:13:28,612 --> 09:13:26,700

disreputable member of their Community

7738

09:13:29,810 --> 09:13:28,622

shown here on the right and so we're

7739

09:13:32,330 --> 09:13:29,820

going to do a thought experiment about

7740

09:13:34,068 --> 09:13:32,340

what can happen when one spy tries to

7741

09:13:36,588 --> 09:13:34,078

talk to to the other

7742

09:13:39,170 --> 09:13:36,598

so let's start off with a with a message

7743

09:13:41,748 --> 09:13:39,180

which is emitted over here so this is

7744

09:13:45,112 --> 09:13:41,758

the message that she wants to send

7745

09:13:47,810 --> 09:13:45,122

that is a received by by uh the the

7746

09:13:51,650 --> 09:13:47,820

person on the right uses their code book

7747

09:13:54,830 --> 09:13:51,660

and they correctly decode it as as uh as

7748

09:13:57,350 --> 09:13:54,840

that sequence of uh of amino acids so so

7749

09:14:00,350 --> 09:13:57,360

far everything is good there's only a

7750

09:14:02,568 --> 09:14:00,360

single message that you can deduce from

7751

09:14:05,088 --> 09:14:02,578

this signal that you receive okay so

7752

09:14:07,728 --> 09:14:05,098

this is the standard operating procedure

7753

09:14:10,130 --> 09:14:07,738

for the person on the right was chosen

7754

09:14:11,748 --> 09:14:10,140

not just for their for their glamorous

7755

09:14:15,048 --> 09:14:11,758

sartorial Style

7756

09:14:17,510 --> 09:14:15,058

but for the fact that they're very uh

7757

09:14:19,790 --> 09:14:17,520

um incompetent and so I want you to

7758

09:14:21,588 --> 09:14:19,800

imagine that this person has lost half

7759

09:14:25,670 --> 09:14:21,598

the code book

7760

09:14:27,228 --> 09:14:25,680

and so the code has now been uh changed

7761

09:14:29,690 --> 09:14:27,238

because you've missed half the code

7762

09:14:31,130 --> 09:14:29,700

button so now he translates it as E

7763

09:14:33,170 --> 09:14:31,140

equals  $m c^2$  which means nothing

7764

09:14:35,030 --> 09:14:33,180

to him but it may mean something to to

7765

09:14:37,970 --> 09:14:35,040

you and so what we've learned from this

7766

09:14:39,830 --> 09:14:37,980

is that if you evolve or change the code

7767

09:14:42,708 --> 09:14:39,840

in this case by losing half the code

7768

09:14:45,650 --> 09:14:42,718

book the message gets garbled so so far

7769

09:14:47,450 --> 09:14:45,660

Crick was right

7770

09:14:50,388 --> 09:14:47,460

suppose however

7771

09:14:52,010 --> 09:14:50,398

that we have a statistical code book not

7772

09:14:54,290 --> 09:14:52,020

a code book that gives you one message

7773

09:14:55,670 --> 09:14:54,300

but a code book that gives you an

7774

09:14:57,772 --> 09:14:55,680

ensemble of messages

7775

09:14:59,568 --> 09:14:57,782

and from those messages you look at them

7776

09:15:00,970 --> 09:14:59,578

and you say that makes no sense that

7777

09:15:03,950 --> 09:15:00,980

makes no sense that makes it says oh

7778

09:15:05,990 --> 09:15:03,960

phenylalanolin okay great perfect this

7779

09:15:09,290 --> 09:15:06,000

must be what they what they meant if you

7780

09:15:10,908 --> 09:15:09,300

have a code plus it's context then if

7781

09:15:12,708 --> 09:15:10,918

you if you just have a probabilistic

7782

09:15:15,228 --> 09:15:12,718

code book you have a chance of being

7783

09:15:17,450 --> 09:15:15,238

able to interpret the message

7784

09:15:19,670 --> 09:15:17,460

so the idea then was that if you have a

7785

09:15:21,728 --> 09:15:19,680

probabilistic code book then that means

7786

09:15:24,470 --> 09:15:21,738

that you may you may need to have

7787

09:15:26,330 --> 09:15:24,480

statistical proteins a process of

7788

09:15:29,510 --> 09:15:26,340

translation that doesn't Just Produce

7789

09:15:31,428 --> 09:15:29,520

one protein but produces many

7790

09:15:34,310 --> 09:15:31,438

and this would make complete sense

7791

09:15:36,408 --> 09:15:34,320

because think about early life think

7792

09:15:39,470 --> 09:15:36,418

about early life which we know was uh

7793

09:15:41,630 --> 09:15:39,480

was dominated by endosymbiosis and all

7794

09:15:43,790 --> 09:15:41,640

sorts of events like that which of

7795

09:15:46,728 --> 09:15:43,800

course led to many of the structures

7796

09:15:49,248 --> 09:15:46,738

that we see in in modern cells uh like

7797

09:15:52,190 --> 09:15:49,258

mitochondria and chloroplasts and so on

7798

09:15:55,368 --> 09:15:52,200

so we can imagine that early life was a

7799

09:15:57,888 --> 09:15:55,378

bit like early automobiles okay remember

7800

09:15:59,530 --> 09:15:57,898

how early automobiles were they 100

7801

09:16:01,428 --> 09:15:59,540

years ago a bit more than that

7802

09:16:04,068 --> 09:16:01,438

automobiles did not look like they do

7803

09:16:05,568 --> 09:16:04,078

today they were rickety old things they

7804

09:16:07,850 --> 09:16:05,578

were sort of held together by strings

7805

09:16:10,612 --> 09:16:07,860

ceiling wax and if I drove over to one

7806

09:16:12,530 --> 09:16:10,622

of my friends in my car and uh and then

7807

09:16:14,450 --> 09:16:12,540

the wheel fell off

7808

09:16:16,190 --> 09:16:14,460

you know she would just say well no

7809

09:16:17,868 --> 09:16:16,200

problem I've got an old bicycle in the

7810

09:16:19,970 --> 09:16:17,878

garage here we'll just screw on the

7811

09:16:23,030 --> 09:16:19,980

wheel of that old bicycle onto your car

7812

09:16:24,830 --> 09:16:23,040

and you'll go you're good to go

7813

09:16:26,568 --> 09:16:24,840

thought you could do you could mix and

7814

09:16:29,272 --> 09:16:26,578

match parts

7815

09:16:30,290 --> 09:16:29,282

100 years ago 120 years ago in the early

7816

09:16:33,228 --> 09:16:30,300

class

7817

09:16:35,990 --> 09:16:33,238

try to try doing that today to a to a

7818

09:16:37,612 --> 09:16:36,000

Toyota Corolla right to taking a bicycle

7819

09:16:39,350 --> 09:16:37,622

wheel and sticking it on when you've got

7820

09:16:41,630 --> 09:16:39,360

a flat tire now it's not going to work

7821

09:16:44,030 --> 09:16:41,640

at all modern cars are more highly

7822

09:16:46,908 --> 09:16:44,040

evolved and so they're very intolerant

7823

09:16:49,310 --> 09:16:46,918

of anything it is not exactly right

7824

09:16:52,670 --> 09:16:49,320

and so we get the idea that evolved

7825

09:16:56,030 --> 09:16:52,680

systems become very intolerant of any

7826

09:16:57,888 --> 09:16:56,040

kind of ambiguity in what's present but

7827

09:17:00,650 --> 09:16:57,898

systems that are very early on are very

7828

09:17:03,950 --> 09:17:00,660

simple are able to tolerate ambiguity

7829

09:17:06,470 --> 09:17:03,960

and uh and and and so uh you can have

7830

09:17:08,088 --> 09:17:06,480

this idea that the codes are floppy that

7831

09:17:10,248 --> 09:17:08,098

the statistical proteins that aren't

7832

09:17:13,670 --> 09:17:10,258

made are not always the same proteins

7833

09:17:16,190 --> 09:17:13,680

and then somehow the messages uh can can

7834

09:17:18,950 --> 09:17:16,200

be interpreted so in other words what

7835

09:17:22,428 --> 09:17:18,960

I'm saying is that the code book and the

7836

09:17:25,068 --> 09:17:22,438

message can co-evolve as the organisms

7837

09:17:27,650 --> 09:17:25,078

become more and more complex you get a

7838

09:17:29,990 --> 09:17:27,660

probability distribution of codes that

7839

09:17:31,310 --> 09:17:30,000

can be the outcome of translation and as

7840

09:17:34,010 --> 09:17:31,320

the organisms become more and more

7841

09:17:36,950 --> 09:17:34,020

complex that distribution gets narrower

7842

09:17:38,810 --> 09:17:36,960

and narrower and very intolerant of any

7843

09:17:41,388 --> 09:17:38,820

kind of element

7844

09:17:43,612 --> 09:17:41,398

now you might ask yourself well wait

7845

09:17:44,690 --> 09:17:43,622

this doesn't make any sense selection

7846

09:17:48,470 --> 09:17:44,700

pressure

7847

09:17:49,670 --> 09:17:48,480

acts on the phenotype it doesn't act on

7848

09:17:51,350 --> 09:17:49,680

the code

7849

09:17:53,810 --> 09:17:51,360

I want to show you that it acts on the

7850

09:17:55,850 --> 09:17:53,820

code too okay so here is a thought

7851  
09:17:58,130 --> 09:17:55,860  
experiment but for me it was an actual

7852  
09:17:59,630 --> 09:17:58,140  
experiment so I'm a physicist so I like

7853  
09:18:02,330 --> 09:17:59,640  
to write papers with mathematical

7854  
09:18:05,690 --> 09:18:02,340  
equations and so when I write a paper or

7855  
09:18:08,450 --> 09:18:05,700  
a grant proposal I write it in a Thing

7856  
09:18:10,790 --> 09:18:08,460  
Called Tech a type setting program that

7857  
09:18:13,790 --> 09:18:10,800  
enables you to write equations my

7858  
09:18:21,048 --> 09:18:13,800  
biological colleagues uh of course use a

7859  
09:18:27,530 --> 09:18:23,568  
I guess the age of satire is not over

7860  
09:18:29,450 --> 09:18:27,540  
yet and so uh so you can imagine the

7861  
09:18:31,010 --> 09:18:29,460  
situation where I have sitting with my

7862  
09:18:32,690 --> 09:18:31,020  
friends and the institute for genomic

7863  
09:18:35,208 --> 09:18:32,700

biology and I'm saying hey let's write

7864

09:18:36,612 --> 09:18:35,218

this proposal together and they say sure

7865

09:18:39,588 --> 09:18:36,622

about so we're going to write it in in

7866

09:18:41,810 --> 09:18:39,598

word and the heist and my stuff in Tech

7867

09:18:44,388 --> 09:18:41,820

and of course you know it's it's a

7868

09:18:46,790 --> 09:18:44,398

complete disaster and uh and uh and what

7869

09:18:48,708 --> 09:18:46,800

happens is the uh our proposal never

7870

09:18:50,588 --> 09:18:48,718

actually gets written it never gets

7871

09:18:53,272 --> 09:18:50,598

submitted and so it never gets funded

7872

09:18:55,490 --> 09:18:53,282

meanwhile down the corridor another

7873

09:18:59,272 --> 09:18:55,500

person is collaborating with their

7874

09:19:00,950 --> 09:18:59,282

co-workers they just write it in word no

7875

09:19:03,830 --> 09:19:00,960

problems and even if their proposal was

7876

09:19:05,810 --> 09:19:03,840

less good than ours it's still uh it

7877

09:19:09,170 --> 09:19:05,820

still has a chance of being funded so

7878

09:19:11,568 --> 09:19:09,180

the code actually uh does matter

7879

09:19:13,670 --> 09:19:11,578

now what is the basic way that the

7880

09:19:14,690 --> 09:19:13,680

genetic code evolves in terms of its

7881

09:19:18,170 --> 09:19:14,700

context

7882

09:19:20,690 --> 09:19:18,180

so here's our here's a an interesting uh

7883

09:19:23,510 --> 09:19:20,700

factoid and this this slide is now quite

7884

09:19:25,310 --> 09:19:23,520

old but uh this is uh this you may not

7885

09:19:28,070 --> 09:19:25,320

recognize this person this is Bill Gates

7886

09:19:30,350 --> 09:19:28,080

uh this is the late uh Steve Jobs both

7887

09:19:33,290 --> 09:19:30,360

of them with examples of their of their

7888

09:19:35,570 --> 09:19:33,300

of their companies or computers and uh

7889

09:19:38,086 --> 09:19:35,580

actually uh my computer is a Windows

7890

09:19:40,246 --> 09:19:38,096

computer but many people like uh like

7891

09:19:41,630 --> 09:19:40,256

the Apple computers and and the reason

7892

09:19:44,450 --> 09:19:41,640

that um

7893

09:19:45,950 --> 09:19:44,460

you know the the reason I use a Windows

7894

09:19:48,370 --> 09:19:45,960

computer well I mean everybody does

7895

09:19:50,870 --> 09:19:48,380

right like 96 of all the world's

7896

09:19:54,230 --> 09:19:50,880

computers run their windows in a very

7897

09:19:56,086 --> 09:19:54,240

small fashion run uh the the Mac

7898

09:19:58,190 --> 09:19:56,096

operating system and the reason is that

7899

09:19:59,870 --> 09:19:58,200

the Windows operating system is much

7900

09:20:04,370 --> 09:19:59,880

better than

7901

09:20:09,586 --> 09:20:07,130

well that's a very inopportune time to

7902

09:20:12,290 --> 09:20:09,596

have a blue screen of death

7903

09:20:16,190 --> 09:20:12,300

the Windows operating system is to put

7904

09:20:19,310 --> 09:20:16,200

it mildly uh rubbish it has all sorts of

7905

09:20:20,630 --> 09:20:19,320

things like this but the reason why it

7906

09:20:22,550 --> 09:20:20,640

is so popular

7907

09:20:26,746 --> 09:20:22,560

is not because it is the best computer

7908

09:20:30,050 --> 09:20:26,756

system it's because any program that you

7909

09:20:32,030 --> 09:20:30,060

want to run you can find it on Windows

7910

09:20:34,670 --> 09:20:32,040

but you may not be able to find it on

7911

09:20:37,070 --> 09:20:34,680

the Macos that may not be so true today

7912

09:20:39,110 --> 09:20:37,080

but it was certainly true uh suddenly 10

7913

09:20:41,390 --> 09:20:39,120

10 years ago and so what you learn from

7914

09:20:43,330 --> 09:20:41,400

this is that the community with access

7915

09:20:45,710 --> 09:20:43,340

to the broadest range of Innovations

7916

09:20:47,746 --> 09:20:45,720

hasn't evolutionary Advantage anything

7917

09:20:49,730 --> 09:20:47,756

that you want to do you can find a

7918

09:20:52,130 --> 09:20:49,740

gadget in that operating system that

7919

09:20:54,470 --> 09:20:52,140

does it and so what's important for

7920

09:20:56,630 --> 09:20:54,480

platforms for operating systems for

7921

09:20:59,810 --> 09:20:56,640

processes that are fundamental to cells

7922

09:21:02,990 --> 09:20:59,820

like the like translation is that is

7923

09:21:05,630 --> 09:21:03,000

that you have the broadest reach

7924

09:21:07,190 --> 09:21:05,640

so what we did in our in our

7925

09:21:09,230 --> 09:21:07,200

mathematical model which I'm not going

7926

09:21:11,926 --> 09:21:09,240

to go into in detail was we we

7927

09:21:14,150 --> 09:21:11,936

considered a simulation a digital life

7928

09:21:15,770 --> 09:21:14,160

simulation just like the computer virus

7929

09:21:17,330 --> 09:21:15,780

once that I showed you at the beginning

7930

09:21:20,030 --> 09:21:17,340

of the call at the beginning of the uh

7931

09:21:21,710 --> 09:21:20,040

of the of the talk the ones uh run by

7932

09:21:23,990 --> 09:21:21,720

Niels Barry Charlie at The Institute for

7933

09:21:25,790 --> 09:21:24,000

advanced study so we have an asexual

7934

09:21:28,190 --> 09:21:25,800

population of evolving reproducing

7935

09:21:30,950 --> 09:21:28,200

digital organisms like computer viruses

7936

09:21:34,550 --> 09:21:30,960

they're phenotype is a function of their

7937

09:21:36,586 --> 09:21:34,560

proteins and the proteins are obtained

7938

09:21:38,746 --> 09:21:36,596

by translating the genome with a code

7939

09:21:40,246 --> 09:21:38,756

but with uh with errors the individual

7940

09:21:42,230 --> 09:21:40,256

reproduction rate is a function of

7941

09:21:45,406 --> 09:21:42,240

fitness and the messages change are

7942

09:21:48,830 --> 09:21:45,416

faster than codes and so forth and so

7943

09:21:51,770 --> 09:21:48,840

everything that's in this system allows

7944

09:21:53,870 --> 09:21:51,780

codes to evolve due to selection of the

7945

09:21:55,370 --> 09:21:53,880

phenotype through the mechanism that I

7946

09:21:56,990 --> 09:21:55,380

was showing you so now what we're doing

7947

09:21:58,610 --> 09:21:57,000

is simulating a whole population of

7948

09:22:01,490 --> 09:21:58,620

different organisms which have different

7949

09:22:03,770 --> 09:22:01,500

codes another question is which code is

7950

09:22:05,570 --> 09:22:03,780

the one that wins

7951  
09:22:07,426 --> 09:22:05,580  
all right so let's imagine that we've

7952  
09:22:09,170 --> 09:22:07,436  
done this experiment

7953  
09:22:10,246 --> 09:22:09,180  
so I started with a bunch of organisms

7954  
09:22:12,170 --> 09:22:10,256  
all of which have slightly different

7955  
09:22:13,850 --> 09:22:12,180  
genetic codes and they all co-evolve and

7956  
09:22:16,010 --> 09:22:13,860  
they're trying to deal with the

7957  
09:22:19,370 --> 09:22:16,020  
environment that they are they're in and

7958  
09:22:22,190 --> 09:22:19,380  
we watch how they evolve in time now we

7959  
09:22:23,690 --> 09:22:22,200  
did two experiments here I'm going to

7960  
09:22:25,130 --> 09:22:23,700  
show you this graph and I'm going to

7961  
09:22:27,650 --> 09:22:25,140  
show another one similar to it in the

7962  
09:22:30,110 --> 09:22:27,660  
next slide this on the vertical axis is

7963  
09:22:32,406 --> 09:22:30,120

the quality of the code it's how good

7964

09:22:35,630 --> 09:22:32,416

the genetic code is of those organisms

7965

09:22:38,390 --> 09:22:35,640

minimizing ever and this is time over

7966

09:22:40,426 --> 09:22:38,400

here and here's what happens when you do

7967

09:22:42,350 --> 09:22:40,436

this with regular vertical darwinian

7968

09:22:44,630 --> 09:22:42,360

Evolution that you're used to and you

7969

09:22:47,570 --> 09:22:44,640

can see that what happens is that is as

7970

09:22:50,630 --> 09:22:47,580

I as I evolve the system

7971

09:22:53,210 --> 09:22:50,640

the uh the um the codes get better

7972

09:22:55,130 --> 09:22:53,220

smaller is better and then eventually it

7973

09:22:57,170 --> 09:22:55,140

stops and it just stays constant in time

7974

09:22:58,970 --> 09:22:57,180

and maybe if we waited like a hundred

7975

09:23:00,530 --> 09:22:58,980

times longer maybe there'd be some other

7976

09:23:02,266 --> 09:23:00,540

change down here or something like this

7977

09:23:04,070 --> 09:23:02,276

and you run it again and for this one

7978

09:23:07,070 --> 09:23:04,080

you get something like this and you run

7979

09:23:09,230 --> 09:23:07,080

it again you get something like this

7980

09:23:12,230 --> 09:23:09,240

and if you ask

7981

09:23:13,670 --> 09:23:12,240

I've got a whole distribution

7982

09:23:15,290 --> 09:23:13,680

codes here

7983

09:23:17,086 --> 09:23:15,300

um what would I have got at random when

7984

09:23:18,650 --> 09:23:17,096

you can work that out and it would be

7985

09:23:21,170 --> 09:23:18,660

something like this and so what I've

7986

09:23:23,570 --> 09:23:21,180

learned is that without uh in this

7987

09:23:27,290 --> 09:23:23,580

experiment with vertical Evolution only

7988

09:23:29,630 --> 09:23:27,300

I evolve organisms that have codes that

7989

09:23:31,610 --> 09:23:29,640

are indistinguishable from random codes

7990

09:23:32,990 --> 09:23:31,620

and they're not unique and they're

7991

09:23:35,086 --> 09:23:33,000

certainly not optimal

7992

09:23:37,550 --> 09:23:35,096

but if I switch on horizontal Gene

7993

09:23:40,730 --> 09:23:37,560

transfer then what happens is the codes

7994

09:23:43,610 --> 09:23:40,740

follow this blue trajectory here as you

7995

09:23:47,086 --> 09:23:43,620

can see end up uh with uh with a very

7996

09:23:49,850 --> 09:23:47,096

optimal code and one which is very far

7997

09:23:51,586 --> 09:23:49,860

from what you would get at random and so

7998

09:23:53,330 --> 09:23:51,596

what you've learned from this is that

7999

09:23:55,630 --> 09:23:53,340

the process of horizontal Gene to

8000

09:23:58,790 --> 09:23:55,640

transfer as an evolutionary process

8001

09:24:00,530 --> 09:23:58,800

leads to optimality of the of the

8002

09:24:03,710 --> 09:24:00,540

genetic code

8003

09:24:06,290 --> 09:24:03,720

now if we look at uh at uh how many

8004

09:24:08,810 --> 09:24:06,300

codes we have in our system and that's

8005

09:24:11,450 --> 09:24:08,820

shown shown here and again the same

8006

09:24:14,390 --> 09:24:11,460

thing is true that if you just use a

8007

09:24:17,150 --> 09:24:14,400

vertical Evolution uh you have you don't

8008

09:24:18,650 --> 09:24:17,160

get much uh selection of the of the

8009

09:24:20,510 --> 09:24:18,660

genetic codes as we saw on the previous

8010

09:24:22,906 --> 09:24:20,520

slide and but if you switch on

8011

09:24:25,490 --> 09:24:22,916

horizontal Gene transfer you get a

8012

09:24:27,830 --> 09:24:25,500

universal genetic code and so what we've

8013

09:24:30,890 --> 09:24:27,840

learned from this is that the the the

8014

09:24:32,870 --> 09:24:30,900

phase diagram of Life must have looked

8015

09:24:35,050 --> 09:24:32,880

something like this so we're somewhere

8016

09:24:37,150 --> 09:24:35,060

up here where in that blob over here

8017

09:24:41,330 --> 09:24:37,160

early on

8018

09:24:44,266 --> 09:24:41,340

the evolution was a network process

8019

09:24:46,610 --> 09:24:44,276

shown schematically over here

8020

09:24:48,290 --> 09:24:46,620

rapid Evolution and then over here we

8021

09:24:51,110 --> 09:24:48,300

have the vertical Evolution which we saw

8022

09:24:53,330 --> 09:24:51,120

was incredibly slow and that's the

8023

09:24:55,670 --> 09:24:53,340

process that we are in today and the

8024

09:24:57,470 --> 09:24:55,680

summary over here was a transition that

8025

09:24:59,690 --> 09:24:57,480

uh that Carl was like to call the

8026

09:25:02,450 --> 09:24:59,700

darwinian transition I claimed of a

8027

09:25:04,670 --> 09:25:02,460

phase transition uh between a collective

8028

09:25:08,266 --> 09:25:04,680

Network phase of life and a transition

8029

09:25:11,810 --> 09:25:08,276

to a life where organismal identity and

8030

09:25:17,690 --> 09:25:11,820

individuality becomes more important

8031

09:25:19,970 --> 09:25:17,700

all right so so I I I'm going to skip my

8032

09:25:22,310 --> 09:25:19,980

section on homework of housing so I'm

8033

09:25:24,710 --> 09:25:22,320

just going to skip through that and uh

8034

09:25:26,266 --> 09:25:24,720

and I wanted to tell you about some of

8035

09:25:28,850 --> 09:25:26,276

the things that are Universal in biology

8036

09:25:30,890 --> 09:25:28,860

so anyway the bottom line of this is

8037

09:25:34,810 --> 09:25:30,900

that uh we made a mathematical model of

8038

09:25:37,670 --> 09:25:34,820

the evolution of of of of of Kyle

8039

09:25:40,010 --> 09:25:37,680

autocatalytic self-replicators and we

8040

09:25:44,030 --> 09:25:40,020

could show that uh you ultimately end up

8041

09:25:46,490 --> 09:25:44,040

with with broken 100 are broken uh

8042

09:25:48,830 --> 09:25:46,500

chirality not just you get sun

8043

09:25:50,746 --> 09:25:48,840

right-handed or some left-handed but 100

8044

09:25:52,850 --> 09:25:50,756

effect and that's the thing that we

8045

09:25:55,730 --> 09:25:52,860

observe in biology and that's the thing

8046

09:25:58,246 --> 09:25:55,740

that was difficult to explain and and we

8047

09:26:01,070 --> 09:25:58,256

have made a theory for that

8048

09:26:01,906 --> 09:26:01,080

okay so um let me just very quickly show

8049

09:26:05,210 --> 09:26:01,916

you

8050

09:26:07,246 --> 09:26:05,220

um some examples of universality in

8051  
09:26:09,110 --> 09:26:07,256  
Modern Biology even today there are

8052  
09:26:10,850 --> 09:26:09,120  
things that are Universal not just the

8053  
09:26:12,050 --> 09:26:10,860  
evolutionary processes of say the

8054  
09:26:14,450 --> 09:26:12,060  
genetic code which may have happened

8055  
09:26:17,390 --> 09:26:14,460  
billions of years ago but other things

8056  
09:26:19,730 --> 09:26:17,400  
too so one example of this is the

8057  
09:26:21,890 --> 09:26:19,740  
universal statistics routine expression

8058  
09:26:24,710 --> 09:26:21,900  
so if I have a genetically identical

8059  
09:26:26,450 --> 09:26:24,720  
cells they can exhibit different protein

8060  
09:26:28,310 --> 09:26:26,460  
copy numbers that's something that we've

8061  
09:26:30,470 --> 09:26:28,320  
known for about 20 years that's called

8062  
09:26:32,810 --> 09:26:30,480  
stochastic gene expression the whole

8063  
09:26:35,570 --> 09:26:32,820

process of of expressing genes is a

8064

09:26:38,266 --> 09:26:35,580

random process and so the protein copy

8065

09:26:40,670 --> 09:26:38,276

numbers are not thermodynamically large

8066

09:26:43,370 --> 09:26:40,680

and so what happens is you have large

8067

09:26:45,950 --> 09:26:43,380

fluctuations in protein copy numbers in

8068

09:26:48,170 --> 09:26:45,960

in cells and here are experimental data

8069

09:26:51,710 --> 09:26:48,180

are showing you for a variety of

8070

09:26:53,210 --> 09:26:51,720

different uh or different uh cells here

8071

09:26:55,246 --> 09:26:53,220

I'm looking to go through the through

8072

09:26:58,310 --> 09:26:55,256

the details showing you that there's a

8073

09:27:00,586 --> 09:26:58,320

universal distribution for the protein

8074

09:27:02,450 --> 09:27:00,596

copy number now which is all these data

8075

09:27:05,030 --> 09:27:02,460

are collapsing onto one universal curve

8076

09:27:07,670 --> 09:27:05,040

which can be predicted this is very much

8077

09:27:09,290 --> 09:27:07,680

like the universality I showed you in

8078

09:27:11,570 --> 09:27:09,300

the magnetic system at the beginning of

8079

09:27:12,890 --> 09:27:11,580

the talk

8080

09:27:15,290 --> 09:27:12,900

um here's another one which is

8081

09:27:17,450 --> 09:27:15,300

absolutely fantastic and is still not

8082

09:27:20,210 --> 09:27:17,460

understood and that is universal

8083

09:27:22,190 --> 09:27:20,220

metabolism so here's the experiment so

8084

09:27:24,290 --> 09:27:22,200

what you do is you go into the lab and

8085

09:27:26,030 --> 09:27:24,300

uh you get some paper and some mud and

8086

09:27:28,370 --> 09:27:26,040

bits of egg and water and stuff like

8087

09:27:29,810 --> 09:27:28,380

this and you throw in some microbes and

8088

09:27:31,550 --> 09:27:29,820

then you make a bioreactor and the

8089

09:27:34,370 --> 09:27:31,560

bioreactor is producing that same

8090

09:27:38,450 --> 09:27:34,380

methane okay and so you get this thing

8091

09:27:41,030 --> 09:27:38,460

running and the bioreactor is uh your

8092

09:27:43,550 --> 09:27:41,040

measuring is producing a fixed rate of

8093

09:27:46,190 --> 09:27:43,560

methane coming out if you're feeding the

8094

09:27:48,950 --> 09:27:46,200

bioreactor and the rate of uh methane

8095

09:27:51,650 --> 09:27:48,960

coming out is a constant so you say well

8096

09:27:53,630 --> 09:27:51,660

that's great I wonder what's in my

8097

09:27:56,926 --> 09:27:53,640

bioreactor what's in my chemostat

8098

09:28:00,950 --> 09:27:56,936

so you go and do a Melody genomic survey

8099

09:28:03,530 --> 09:28:00,960

and and what you find is that even

8100

09:28:04,906 --> 09:28:03,540

though the methane that is coming out is

8101  
09:28:07,550 --> 09:28:04,916  
constant

8102  
09:28:09,530 --> 09:28:07,560  
when you look at the community structure

8103  
09:28:11,630 --> 09:28:09,540  
that you see and here I'm showing you

8104  
09:28:14,690 --> 09:28:11,640  
examples where these are real data from

8105  
09:28:17,030 --> 09:28:14,700  
from different uh from from a reactor

8106  
09:28:20,510 --> 09:28:17,040  
what do you find is that you know let's

8107  
09:28:23,030 --> 09:28:20,520  
say day 900 you go and draw a pie chart

8108  
09:28:25,426 --> 09:28:23,040  
showing you the different uh uh uh

8109  
09:28:27,290 --> 09:28:25,436  
operational taxonomic units that are

8110  
09:28:29,746 --> 09:28:27,300  
present in your system and you say now

8111  
09:28:32,030 --> 09:28:29,756  
until I'm done and then you know your

8112  
09:28:34,070 --> 09:28:32,040  
advisor says aha you're not done wait

8113  
09:28:35,266 --> 09:28:34,080

two years and do the experiment again so

8114

09:28:36,950 --> 09:28:35,276

you've treated your thumb for two years

8115

09:28:38,450 --> 09:28:36,960

and do the experiment again and then

8116

09:28:41,870 --> 09:28:38,460

what you find is a completely different

8117

09:28:43,906 --> 09:28:41,880

uh set of organisms that are in the back

8118

09:28:46,490 --> 09:28:43,916

in the bioreactor but it's still

8119

09:28:47,870 --> 09:28:46,500

producing methane at exactly the rate

8120

09:28:50,086 --> 09:28:47,880

that it was before

8121

09:28:54,710 --> 09:28:50,096

this experiment was actually done by

8122

09:28:57,950 --> 09:28:54,720

Anna Fernandez and uh and in 1999 and

8123

09:29:01,190 --> 09:28:57,960

her advisor basically served this can't

8124

09:29:02,746 --> 09:29:01,200

be true we can't publish this the the we

8125

09:29:05,266 --> 09:29:02,756

can't publish these data but they

8126

09:29:08,510 --> 09:29:05,276

publish it in any case and and this has

8127

09:29:10,190 --> 09:29:08,520

been replicated many times since so what

8128

09:29:13,370 --> 09:29:10,200

we've learned then is that the

8129

09:29:16,310 --> 09:29:13,380

functional properties of a community are

8130

09:29:19,190 --> 09:29:16,320

insensitive to taxonomic fluctuations

8131

09:29:24,530 --> 09:29:19,200

here's a here's another example this is

8132

09:29:27,710 --> 09:29:24,540

from uh Luca and and durably uh and uh

8133

09:29:29,926 --> 09:29:27,720

partly uh this is decoupling function

8134

09:29:32,330 --> 09:29:29,936

and taxonomy in the global ocean

8135

09:29:34,870 --> 09:29:32,340

microbiome and basically the same the

8136

09:29:37,070 --> 09:29:34,880

same story that despite the constant

8137

09:29:40,130 --> 09:29:37,080

metabolic function of the ocean

8138

09:29:42,170 --> 09:29:40,140

microbiome there were large taxonomic

8139

09:29:45,170 --> 09:29:42,180

fluctuations and we don't have any idea

8140

09:29:47,450 --> 09:29:45,180

well why this is happening

8141

09:29:49,190 --> 09:29:47,460

okay so these are examples of universal

8142

09:29:50,810 --> 09:29:49,200

things that are going on right now and

8143

09:29:51,766 --> 09:29:50,820

they need to be understood and they're

8144

09:29:53,690 --> 09:29:51,776

telling us something about the

8145

09:29:55,790 --> 09:29:53,700

collective properties of microbial

8146

09:29:57,950 --> 09:29:55,800

communities now

8147

09:30:00,470 --> 09:29:57,960

if the NASA astrobiology Institute was

8148

09:30:02,390 --> 09:30:00,480

still still a thing in existence and I

8149

09:30:03,890 --> 09:30:02,400

hadn't moved from Illinois to hear and

8150

09:30:05,630 --> 09:30:03,900

so on one of the things that I would be

8151

09:30:08,150 --> 09:30:05,640

thinking about doing is exploiting this

8152

09:30:10,010 --> 09:30:08,160

for example suppose I want to know what

8153

09:30:14,030 --> 09:30:10,020

are going to be the bio signatures of

8154

09:30:16,190 --> 09:30:14,040

say life that lives under the uh the ice

8155

09:30:18,950 --> 09:30:16,200

of ensalidos

8156

09:30:20,690 --> 09:30:18,960

well it turns out

8157

09:30:22,670 --> 09:30:20,700

that the metabolic output of microbial

8158

09:30:25,130 --> 09:30:22,680

communities doesn't depend sensitively

8159

09:30:27,586 --> 09:30:25,140

on what organisms are there so if I have

8160

09:30:30,350 --> 09:30:27,596

some knowledge of the geochemistry I can

8161

09:30:32,210 --> 09:30:30,360

then exploit this this uh this

8162

09:30:35,290 --> 09:30:32,220

functional redundancy to be able to make

8163

09:30:37,906 --> 09:30:35,300

predictions about what a metabolic

8164

09:30:40,246 --> 09:30:37,916

biosignatures I might find

8165

09:30:42,890 --> 09:30:40,256

okay so let's end with a discussing

8166

09:30:49,490 --> 09:30:42,900

about whether or not a universality is

8167

09:30:53,690 --> 09:30:52,370

so here is an example of another uh

8168

09:31:02,030 --> 09:30:53,700

scaling law

8169

09:31:05,086 --> 09:31:02,040

been known since the 1850s in England uh

8170

09:31:07,190 --> 09:31:05,096

these are data taken from bird

8171

09:31:09,850 --> 09:31:07,200

lovers actually not bird lovers these

8172

09:31:12,950 --> 09:31:09,860

are plants never mind these are plants

8173

09:31:15,470 --> 09:31:12,960

people in England like two things or

8174

09:31:17,810 --> 09:31:15,480

actually three things they like plants

8175

09:31:19,310 --> 09:31:17,820

they're like birds and they like beer or

8176

09:31:20,810 --> 09:31:19,320

like stink any pie or they're like

8177

09:31:22,490 --> 09:31:20,820

football or whatever you want but they

8178

09:31:24,050 --> 09:31:22,500

like plants and they're like and they

8179

09:31:28,490 --> 09:31:24,060

like birds and so there's a lot of data

8180

09:31:30,230 --> 09:31:28,500

going back uh you know 150 years uh um

8181

09:31:33,470 --> 09:31:30,240

and and here is showing you the number

8182

09:31:36,290 --> 09:31:33,480

of species as a function of the area of

8183

09:31:38,450 --> 09:31:36,300

the of the of the habitat and what you

8184

09:31:40,790 --> 09:31:38,460

can see from these data is that the

8185

09:31:42,766 --> 09:31:40,800

number of species uh scales like the

8186

09:31:45,170 --> 09:31:42,776

area to the one quarter power

8187

09:31:47,266 --> 09:31:45,180

so you might say here's a field count

8188

09:31:48,650 --> 09:31:47,276

all the bugs in the field count all the

8189

09:31:50,990 --> 09:31:48,660

plants in the field

8190

09:31:52,790 --> 09:31:51,000

double the size of the field count how

8191

09:31:54,170 --> 09:31:52,800

many they're in there then you might say

8192

09:31:56,926 --> 09:31:54,180

okay remember species are going to

8193

09:31:59,810 --> 09:31:56,936

double not true it goes like roughly

8194

09:32:02,630 --> 09:31:59,820

like the area to the one quarter power

8195

09:32:05,810 --> 09:32:02,640

not not the area itself so this is a

8196

09:32:08,926 --> 09:32:05,820

very important law because we can use it

8197

09:32:11,746 --> 09:32:08,936

to make extrapolations for example if we

8198

09:32:14,570 --> 09:32:11,756

know how much deforestation happened

8199

09:32:16,070 --> 09:32:14,580

today in the Amazon let's say then we

8200

09:32:19,426 --> 09:32:16,080

can figure out how many species might

8201  
09:32:22,730 --> 09:32:19,436  
have got affected by that

8202  
09:32:24,586 --> 09:32:22,740  
so that says these universal laws are

8203  
09:32:26,390 --> 09:32:24,596  
useful here's an argument that says

8204  
09:32:28,190 --> 09:32:26,400  
they're not useful

8205  
09:32:29,926 --> 09:32:28,200  
so here's an experiment that was

8206  
09:32:31,450 --> 09:32:29,936  
actually done this is Battle at Colorado

8207  
09:32:35,450 --> 09:32:31,460  
Island

8208  
09:32:37,790 --> 09:32:35,460  
in Panama and this is a an island which

8209  
09:32:40,426 --> 09:32:37,800  
is beloved by ecologists because it has

8210  
09:32:42,050 --> 09:32:40,436  
lots of trees and plants and we know

8211  
09:32:44,630 --> 09:32:42,060  
every single tree and every plant on

8212  
09:32:46,426 --> 09:32:44,640  
that island it's heavily studded okay

8213  
09:32:49,310 --> 09:32:46,436

so you might ask yourself the following

8214

09:32:51,230 --> 09:32:49,320

question on this island what is the

8215

09:32:53,630 --> 09:32:51,240

number of species fraction of species

8216

09:32:56,150 --> 09:32:53,640

with a given number of individuals okay

8217

09:32:57,710 --> 09:32:56,160

how many species have 100 individuals

8218

09:32:59,210 --> 09:32:57,720

how many species have a thousand

8219

09:33:01,670 --> 09:32:59,220

individuals how many species have four

8220

09:33:05,926 --> 09:33:01,680

individuals in salt okay so you can

8221

09:33:08,810 --> 09:33:05,936

produce a species abundance curve and

8222

09:33:10,190 --> 09:33:08,820

and then you and you get data that looks

8223

09:33:12,110 --> 09:33:10,200

like one of these curves here I don't

8224

09:33:14,450 --> 09:33:12,120

even remember which one it is so that

8225

09:33:16,190 --> 09:33:14,460

would be uh that would be a measurement

8226

09:33:18,050 --> 09:33:16,200

and you could make a theory for that

8227

09:33:20,030 --> 09:33:18,060

because you could say well we have to

8228

09:33:21,290 --> 09:33:20,040

look at the soil we have to look at the

8229

09:33:22,906 --> 09:33:21,300

weather we have to look at the

8230

09:33:25,010 --> 09:33:22,916

interactions between the trees the

8231

09:33:27,170 --> 09:33:25,020

canopy and so on and so forth and if we

8232

09:33:30,890 --> 09:33:27,180

had a detailed model we could probably

8233

09:33:32,390 --> 09:33:30,900

predict uh this this this curve

8234

09:33:34,610 --> 09:33:32,400

but there's another way to think about

8235

09:33:36,050 --> 09:33:34,620

it which is just to say well this is

8236

09:33:38,030 --> 09:33:36,060

close it's just a random process

8237

09:33:40,670 --> 09:33:38,040

something has to be the most abundant

8238

09:33:43,246 --> 09:33:40,680

organism okay so what I've read is

8239

09:33:44,746 --> 09:33:43,256

that's it what its name is then

8240

09:33:46,730 --> 09:33:44,756

something else has to be the next most

8241

09:33:48,406 --> 09:33:46,740

abundant and you can work out a theory

8242

09:33:50,746 --> 09:33:48,416

that looks like the general statistics

8243

09:33:52,790 --> 09:33:50,756

but you would expect for abundance just

8244

09:33:54,230 --> 09:33:52,800

like the central limit theorem in in

8245

09:33:57,110 --> 09:33:54,240

statistics

8246

09:33:58,610 --> 09:33:57,120

and so in in a neutral Theory the

8247

09:34:00,766 --> 09:33:58,620

species are functionally equivalent

8248

09:34:03,170 --> 09:34:00,776

they're not different they don't occupy

8249

09:34:05,510 --> 09:34:03,180

different uh geochemical or biological

8250

09:34:08,510 --> 09:34:05,520

niches metabolic niches so you've got

8251

09:34:10,850 --> 09:34:08,520

these two completely different theories

8252

09:34:12,350 --> 09:34:10,860

and one of them gives the black curve

8253

09:34:14,690 --> 09:34:12,360

one of them gives the green curve they

8254

09:34:17,150 --> 09:34:14,700

both explain the data equally well

8255

09:34:19,850 --> 09:34:17,160

so this is uh again

8256

09:34:22,010 --> 09:34:19,860

not not helpful so the upside of

8257

09:34:23,630 --> 09:34:22,020

universality is that you can make

8258

09:34:25,190 --> 09:34:23,640

predictions based on the normal model

8259

09:34:27,766 --> 09:34:25,200

and that's a good thing

8260

09:34:29,990 --> 09:34:27,776

like trying to predict the metabolic

8261

09:34:33,110 --> 09:34:30,000

signature or putative life under the

8262

09:34:35,390 --> 09:34:33,120

under the ice cap of encels the downside

8263

09:34:37,426 --> 09:34:35,400

of universality is that statistically

8264

09:34:39,406 --> 09:34:37,436

similar results can be obtained from

8265

09:34:41,150 --> 09:34:39,416

microscopic models that are completely

8266

09:34:43,010 --> 09:34:41,160

different in their assumptions

8267

09:34:45,290 --> 09:34:43,020

and so if you have something Universal

8268

09:34:46,970 --> 09:34:45,300

at a high level of description that

8269

09:34:49,670 --> 09:34:46,980

means you can't understand the actual

8270

09:34:51,950 --> 09:34:49,680

processes that went on that caused the

8271

09:34:55,370 --> 09:34:51,960

thing in the first place

8272

09:34:57,470 --> 09:34:55,380

okay I want to end by asking what do we

8273

09:35:00,530 --> 09:34:57,480

miss if we don't understand Universal

8274

09:35:03,350 --> 09:35:00,540

phenomena and I'm going to talk about an

8275

09:35:05,630 --> 09:35:03,360

example uh that that may not be

8276

09:35:07,790 --> 09:35:05,640

meaningful to to some of you or many of

8277

09:35:10,610 --> 09:35:07,800

you even but it doesn't matter I want

8278

09:35:12,110 --> 09:35:10,620

you to just understand the the point so

8279

09:35:14,990 --> 09:35:12,120

this is about something in in

8280

09:35:17,266 --> 09:35:15,000

superconductivity and uh and there's a

8281

09:35:19,070 --> 09:35:17,276

couple of students here from my class on

8282

09:35:21,230 --> 09:35:19,080

emerging states of matter so they'll be

8283

09:35:23,810 --> 09:35:21,240

familiar with these examples so what is

8284

09:35:26,690 --> 09:35:23,820

superconductivity it's the it's the fact

8285

09:35:28,370 --> 09:35:26,700

that you can have a current flowing

8286

09:35:30,290 --> 09:35:28,380

through a material and there is no

8287

09:35:32,510 --> 09:35:30,300

electrical resistance and no heat that

8288

09:35:34,610 --> 09:35:32,520

comes out so that's that's the that's

8289

09:35:36,530 --> 09:35:34,620

the idea of superconductivity it's just

8290

09:35:39,406 --> 09:35:36,540

superconductor if you have it you can

8291

09:35:41,746 --> 09:35:39,416

make levitating trains and and transmit

8292

09:35:43,730 --> 09:35:41,756

power over long distances and solve all

8293

09:35:46,450 --> 09:35:43,740

the world's problems

8294

09:35:50,450 --> 09:35:46,460

that was discovered in 1911

8295

09:35:52,670 --> 09:35:50,460

1903 1933 it was also discovered that

8296

09:35:55,426 --> 09:35:52,680

superconductors don't just have a a

8297

09:35:56,990 --> 09:35:55,436

current that don't last forever and also

8298

09:35:59,330 --> 09:35:57,000

go round and round Forever by petrol

8299

09:36:02,746 --> 09:35:59,340

motion they also expel magnetic fields

8300

09:36:05,150 --> 09:36:02,756

okay don't ask why it doesn't matter

8301

09:36:06,586 --> 09:36:05,160

20 years later after that it was

8302

09:36:08,150 --> 09:36:06,596

discovered that actually nope it's not

8303

09:36:10,610 --> 09:36:08,160

true they don't expel magnetic fields

8304

09:36:12,890 --> 09:36:10,620

well some do but some don't some allow

8305

09:36:15,650 --> 09:36:12,900

magnetic fields to penetrate a

8306

09:36:17,990 --> 09:36:15,660

superconductor but in a lattice of

8307

09:36:20,210 --> 09:36:18,000

so-called vortices or flux tubes in a

8308

09:36:21,650 --> 09:36:20,220

way that is you know I'm not going to

8309

09:36:24,766 --> 09:36:21,660

I'm not going to go into but that that

8310

09:36:27,890 --> 09:36:24,776

can happen and then finally oops wrong

8311

09:36:30,050 --> 09:36:27,900

thing then finally uh about 10 years or

8312

09:36:32,450 --> 09:36:30,060

so after that something called the

8313

09:36:34,370 --> 09:36:32,460

Judaism effect was discovered the idea

8314

09:36:37,426 --> 09:36:34,380

that I can have

8315

09:36:40,850 --> 09:36:37,436

um a current uh flowing

8316

09:36:43,010 --> 09:36:40,860

um which which will will be uh um

8317

09:36:46,070 --> 09:36:43,020

oscillating with a frequency that is

8318

09:36:47,746 --> 09:36:46,080

just determined by quantum mechanics and

8319

09:36:49,610 --> 09:36:47,756

doesn't depend on the material or

8320

09:36:52,850 --> 09:36:49,620

anything like that so you can use this

8321

09:36:55,310 --> 09:36:52,860

to create a universal standard of

8322

09:36:57,530 --> 09:36:55,320

voltage and and of time okay so this

8323

09:37:00,406 --> 09:36:57,540

this is a complicated quantum mechanical

8324

09:37:03,110 --> 09:37:00,416

effect and it took 50 years and and most

8325

09:37:04,490 --> 09:37:03,120

of the people on on this who discovered

8326

09:37:06,230 --> 09:37:04,500

these things ends up getting Nobel

8327

09:37:08,450 --> 09:37:06,240

prizes these were very important things

8328

09:37:10,730 --> 09:37:08,460

scientifically and technically and the

8329

09:37:12,110 --> 09:37:10,740

question is why did it take so long to

8330

09:37:15,170 --> 09:37:12,120

make these discoveries are physicists

8331

09:37:17,210 --> 09:37:15,180

stupid well maybe but uh but the thing

8332

09:37:19,670 --> 09:37:17,220

is this it's even worse because in my

8333

09:37:21,830 --> 09:37:19,680

class I derive all of these things in

8334

09:37:24,530 --> 09:37:21,840

basically one lecture in a few lines of

8335

09:37:27,830 --> 09:37:24,540

algebra from some mumbo jumbo that's

8336

09:37:29,690 --> 09:37:27,840

written down here okay so what was going

8337

09:37:32,690 --> 09:37:29,700

wrong what was going wrong was that

8338

09:37:35,450 --> 09:37:32,700

people were focusing on the wrong level

8339

09:37:37,426 --> 09:37:35,460

of description and I want to explain to

8340

09:37:40,790 --> 09:37:37,436

you what I mean by that

8341

09:37:42,830 --> 09:37:40,800

okay so in world of superconductivity

8342

09:37:44,266 --> 09:37:42,840

you have to make a superconductor so

8343

09:37:46,490 --> 09:37:44,276

that's a problem in quantum chemistry

8344

09:37:49,490 --> 09:37:46,500

and Material Science there's a theory

8345

09:37:51,830 --> 09:37:49,500

that applies to at least the classic

8346

09:37:53,330 --> 09:37:51,840

superconductors but not the ones that

8347

09:37:55,070 --> 09:37:53,340

everybody is excited about for the last

8348

09:37:57,230 --> 09:37:55,080

30 years the high temperature

8349

09:37:59,086 --> 09:37:57,240

superconductors so there's a theory of

8350

09:38:00,950 --> 09:37:59,096

that which is which is very nice and so

8351

09:38:03,170 --> 09:38:00,960

on and then lastly there's a theory

8352

09:38:05,630 --> 09:38:03,180

which I which I've given but this name

8353

09:38:08,570 --> 09:38:05,640

here is basically a theory that looks at

8354

09:38:10,790 --> 09:38:08,580

the quantum mechanical symmetries of of

8355

09:38:14,086 --> 09:38:10,800

Superman actors now when we talk about

8356

09:38:17,086 --> 09:38:14,096

biology we have another set of levels of

8357

09:38:19,130 --> 09:38:17,096

description so so this level is quantum

8358

09:38:21,170 --> 09:38:19,140

chemistry this is electrons moving

8359

09:38:24,530 --> 09:38:21,180

around and this is looking at Symmetry

8360

09:38:26,330 --> 09:38:24,540

and and wave functions all right here in

8361

09:38:27,890 --> 09:38:26,340

biology we start off with the lowest

8362

09:38:28,906 --> 09:38:27,900

level of description with atoms and

8363

09:38:30,406 --> 09:38:28,916

molecules

8364

09:38:32,330 --> 09:38:30,416

there's an intermediate level of

8365

09:38:34,010 --> 09:38:32,340

description where we you know we talked

8366

09:38:36,290 --> 09:38:34,020

about with translation we look at our

8367

09:38:38,210 --> 09:38:36,300

DNA we look at how elastic it is and how

8368

09:38:40,010 --> 09:38:38,220

proteins fold and things like this we

8369

09:38:41,926 --> 09:38:40,020

look at a liquid liquid intracellular

8370

09:38:43,010 --> 09:38:41,936

complexes and things like that in cell

8371

09:38:45,350 --> 09:38:43,020

biology

8372

09:38:48,350 --> 09:38:45,360

and then finally on the LA on the larger

8373

09:38:50,330 --> 09:38:48,360

scale I talked about the Dynamics of how

8374

09:38:52,670 --> 09:38:50,340

systems evolved the Dynamics of evolving

8375

09:38:54,710 --> 09:38:52,680

systems like the genetic code

8376

09:38:57,110 --> 09:38:54,720

so those are levels of description

8377

09:38:59,450 --> 09:38:57,120

these levels of description answer

8378

09:39:02,510 --> 09:38:59,460

different questions so in

8379

09:39:04,730 --> 09:39:02,520

superconductivity well quantum chemistry

8380

09:39:06,890 --> 09:39:04,740

and Material Science says how do you

8381

09:39:09,110 --> 09:39:06,900

make a stuff what's the specific recipe

8382

09:39:10,190 --> 09:39:09,120

of putting the atoms together in such a

8383

09:39:11,810 --> 09:39:10,200

way that you make a particular

8384

09:39:14,630 --> 09:39:11,820

superconductor

8385

09:39:17,330 --> 09:39:14,640

this uh this uh this intermediate level

8386

09:39:20,330 --> 09:39:17,340

of description tells you about what is

8387

09:39:21,950 --> 09:39:20,340

the basic mechanism by which uh you know

8388

09:39:23,690 --> 09:39:21,960

electrons form what's called a Cooper

8389

09:39:25,190 --> 09:39:23,700

pair a composite boson inside a

8390

09:39:27,350 --> 09:39:25,200

superconductor and then do something

8391

09:39:29,990 --> 09:39:27,360

called Bose condensation so this is a

8392

09:39:31,850 --> 09:39:30,000

sort of more detailed uh description

8393

09:39:34,246 --> 09:39:31,860

that applies to um to many different

8394

09:39:36,710 --> 09:39:34,256

superconductors and this level of

8395

09:39:39,530 --> 09:39:36,720

description this symmetry wave function

8396

09:39:40,970 --> 09:39:39,540

quantum mechanical Theory describes why

8397

09:39:43,246 --> 09:39:40,980

the phenomenon of superconductivity

8398

09:39:45,406 --> 09:39:43,256

exists at all how you can get all the

8399

09:39:47,330 --> 09:39:45,416

phenomena of superconductivity just from

8400

09:39:48,830 --> 09:39:47,340

one very simple and mathematical

8401

09:39:52,070 --> 09:39:48,840

description

8402

09:39:53,926 --> 09:39:52,080

now in the in the world of biology atoms

8403

09:39:57,470 --> 09:39:53,936

and molecules tells us something about

8404

09:39:59,570 --> 09:39:57,480

how specific biopolymers interact and

8405

09:40:01,370 --> 09:39:59,580

fold undergo template directed synthesis

8406

09:40:03,110 --> 09:40:01,380

and so on and so forth if you want to

8407

09:40:04,730 --> 09:40:03,120

understand those questions you have to

8408

09:40:05,926 --> 09:40:04,740

deal with atoms and molecules there's no

8409

09:40:08,266 --> 09:40:05,936

way around it

8410

09:40:10,190 --> 09:40:08,276

if you want to understand

8411

09:40:12,406 --> 09:40:10,200

um the you know the basic functional

8412

09:40:14,690 --> 09:40:12,416

cellular processes you don't need to

8413

09:40:17,330 --> 09:40:14,700

have such a detailed description you can

8414

09:40:19,850 --> 09:40:17,340

just think about uh you know face

8415

09:40:21,830 --> 09:40:19,860

separation inside cells and and sort of

8416

09:40:23,926 --> 09:40:21,840

bending rigidity of cell membranes and

8417

09:40:26,030 --> 09:40:23,936

DNA and so on and so forth

8418

09:40:28,310 --> 09:40:26,040

and if you want to understand why the

8419

09:40:30,170 --> 09:40:28,320

phenomenon of Life exists at all well

8420

09:40:32,390 --> 09:40:30,180

that's surely a question that would be

8421

09:40:35,210 --> 09:40:32,400

answered if we understood more about the

8422

09:40:38,266 --> 09:40:35,220

Dynamics of evolving systems

8423

09:40:41,030 --> 09:40:38,276

different levels of description apply to

8424

09:40:43,490 --> 09:40:41,040

different levels of universality so if I

8425

09:40:45,290 --> 09:40:43,500

look in in the quantum chemistry of

8426  
09:40:46,970 --> 09:40:45,300  
material science that tells us something

8427  
09:40:48,830 --> 09:40:46,980  
about very specific materials like

8428  
09:40:51,230 --> 09:40:48,840  
Atrium barium copper oxide or something

8429  
09:40:53,086 --> 09:40:51,240  
like this if I want to look at this

8430  
09:40:54,830 --> 09:40:53,096  
level of description it tells us

8431  
09:40:57,170 --> 09:40:54,840  
something about what are called weak

8432  
09:40:59,810 --> 09:40:57,180  
coupling superconductors and finally

8433  
09:41:02,150 --> 09:40:59,820  
this level of description uh this

8434  
09:41:04,070 --> 09:41:02,160  
symmetry wave function Theory tells us

8435  
09:41:05,990 --> 09:41:04,080  
about all superconductors whether

8436  
09:41:08,330 --> 09:41:06,000  
they're made in a material science lab

8437  
09:41:11,746 --> 09:41:08,340  
or whether they occur in the in the

8438  
09:41:14,650 --> 09:41:11,756

heart of a of a neutron star

8439

09:41:18,110 --> 09:41:14,660

in biology this level of description

8440

09:41:19,850 --> 09:41:18,120

applies effort to uh very specific

8441

09:41:22,310 --> 09:41:19,860

biopolymers you know this chemical

8442

09:41:23,890 --> 09:41:22,320

structure of RNA or DNA or some

8443

09:41:27,830 --> 09:41:23,900

particular protein

8444

09:41:29,630 --> 09:41:27,840

the elasticity theory for DNA and so on

8445

09:41:33,050 --> 09:41:29,640

and so forth tells you about the physics

8446

09:41:34,670 --> 09:41:33,060

of subcellular components and the

8447

09:41:37,010 --> 09:41:34,680

Dynamics of evolving systems would have

8448

09:41:39,350 --> 09:41:37,020

would be applying to all life and just

8449

09:41:40,906 --> 09:41:39,360

in the same way that a universal turing

8450

09:41:42,890 --> 09:41:40,916

machine with a Von Neumann architecture

8451

09:41:44,990 --> 09:41:42,900

applies to all things that we call

8452

09:41:47,510 --> 09:41:45,000

computers

8453

09:41:50,690 --> 09:41:47,520

now why do we need this Universal level

8454

09:41:53,926 --> 09:41:50,700

this top level description of of of of

8455

09:41:56,990 --> 09:41:53,936

stuff well if I have a superconductor

8456

09:41:59,030 --> 09:41:57,000

and I want to understand uh this level

8457

09:42:01,190 --> 09:41:59,040

of description not only does it tell me

8458

09:42:02,390 --> 09:42:01,200

that superconductors exist but it also

8459

09:42:04,610 --> 09:42:02,400

tells me everything that a

8460

09:42:06,350 --> 09:42:04,620

superconductor can do it tells me the

8461

09:42:08,990 --> 09:42:06,360

myosin effect the vortex lattice the

8462

09:42:10,310 --> 09:42:09,000

josen effects it tells me how a

8463

09:42:12,950 --> 09:42:10,320

superconductor responds to

8464

09:42:14,630 --> 09:42:12,960

electromagnetic fields so if I don't

8465

09:42:16,790 --> 09:42:14,640

have this

8466

09:42:18,650 --> 09:42:16,800

I can't predict how a superconductive

8467

09:42:21,370 --> 09:42:18,660

responds to an electromagnetic field and

8468

09:42:25,850 --> 09:42:23,870

by regarding superconductors as

8469

09:42:28,190 --> 09:42:25,860

collections of atoms

8470

09:42:30,230 --> 09:42:28,200

we are missing the emergent laws that

8471

09:42:32,086 --> 09:42:30,240

act at the system scale and govern the

8472

09:42:35,150 --> 09:42:32,096

large-scale response to electromagnetic

8473

09:42:37,850 --> 09:42:35,160

fields just like uh

8474

09:42:40,850 --> 09:42:37,860

when we were looking at our bioreactor

8475

09:42:44,150 --> 09:42:40,860

it produces methane at a constant rate

8476

09:42:46,010 --> 09:42:44,160

if we just focus on the on the on the uh

8477

09:42:47,870 --> 09:42:46,020

on the bacteria that are in there we

8478

09:42:49,610 --> 09:42:47,880

won't be able to understand that we need

8479

09:42:52,610 --> 09:42:49,620

to understand how metabolism can be

8480

09:42:54,470 --> 09:42:52,620

emergent in a community this problem we

8481

09:42:56,510 --> 09:42:54,480

know how to solve it took us 50 years to

8482

09:42:59,170 --> 09:42:56,520

do it and we had to re-jigger the way we

8483

09:43:01,610 --> 09:42:59,180

think about physics for living systems

8484

09:43:03,950 --> 09:43:01,620

we know that this level of description

8485

09:43:06,586 --> 09:43:03,960

would apply to all of life and what

8486

09:43:08,390 --> 09:43:06,596

happens if we don't have it we can't

8487

09:43:10,906 --> 09:43:08,400

predict the response of living systems

8488

09:43:13,070 --> 09:43:10,916

to selective perturbations we can't tell

8489

09:43:15,470 --> 09:43:13,080

what happens when you play antibiotics

8490

09:43:17,210 --> 09:43:15,480

or herbicides or insecticides or

8491

09:43:20,390 --> 09:43:17,220

chemotherapy to somebody with cancer

8492

09:43:22,310 --> 09:43:20,400

okay and and we know what happens in the

8493

09:43:24,470 --> 09:43:22,320

real world whenever we do these

8494

09:43:26,510 --> 09:43:24,480

interventions and treat living systems

8495

09:43:28,850 --> 09:43:26,520

as engineered systems

8496

09:43:31,426 --> 09:43:28,860

what happens is they fight back they

8497

09:43:33,170 --> 09:43:31,436

evolve the cancer tumor evolves and you

8498

09:43:35,870 --> 09:43:33,180

and you and you and the chemotherapy

8499

09:43:37,390 --> 09:43:35,880

stops being effective Roundup stops

8500

09:43:39,530 --> 09:43:37,400

being effective against weeds

8501  
09:43:41,746 --> 09:43:39,540  
antibiotics stop being effective against

8502  
09:43:43,130 --> 09:43:41,756  
bacterial infections and so on and so

8503  
09:43:45,170 --> 09:43:43,140  
forth

8504  
09:43:47,390 --> 09:43:45,180  
by regarding biology as complicated

8505  
09:43:48,766 --> 09:43:47,400  
physical systems we are missing the

8506  
09:43:50,746 --> 09:43:48,776  
emergent laws that act on the system

8507  
09:43:53,086 --> 09:43:50,756  
scale and govern the large-scale

8508  
09:43:57,586 --> 09:43:53,096  
response to control perturbations and we

8509  
09:44:00,950 --> 09:43:59,510  
otherwise if you if you want to read

8510  
09:44:03,190 --> 09:44:00,960  
about any of these things that I've been

8511  
09:44:06,586 --> 09:44:03,200  
talking about there is a article I wrote

8512  
09:44:09,050 --> 09:44:06,596  
uh called life is physics with uh with

8513  
09:44:11,086 --> 09:44:09,060

Carl Rose and another one on the

8514

09:44:13,426 --> 09:44:11,096

statistical mechanics of early life uh

8515

09:44:15,050 --> 09:44:13,436

in in Phil Transit

8516

09:44:17,150 --> 09:44:15,060

um this one was called life is physics

8517

09:44:18,766 --> 09:44:17,160

for the following reason

8518

09:44:21,230 --> 09:44:18,776

well I used to go to astrobiology

8519

09:44:23,086 --> 09:44:21,240

conferences on the first day somebody

8520

09:44:25,730 --> 09:44:23,096

would get up and show some extremely

8521

09:44:27,830 --> 09:44:25,740

complicated chemical pathway that they

8522

09:44:29,990 --> 09:44:27,840

thought might have existed in the RNA

8523

09:44:32,150 --> 09:44:30,000

world or the sugar world or lipid world

8524

09:44:33,950 --> 09:44:32,160

or whatever was the was the fad of the

8525

09:44:35,266 --> 09:44:33,960

time and they would say life is

8526

09:44:39,710 --> 09:44:35,276

chemistry

8527

09:44:40,850 --> 09:44:39,720

doesn't it doesn't matter it does matter

8528

09:44:42,766 --> 09:44:40,860

you can't build a superconductor without

8529

09:44:44,510 --> 09:44:42,776

atoms and molecules but you have to

8530

09:44:47,150 --> 09:44:44,520

understand the emergent physical laws as

8531

09:44:49,130 --> 09:44:47,160

well the dynamical processes that go on

8532

09:44:51,290 --> 09:44:49,140

and so that's why we talk about this as

8533

09:44:53,266 --> 09:44:51,300

life is physics

8534

09:44:55,246 --> 09:44:53,276

all right so did we learn new physics

8535

09:44:58,490 --> 09:44:55,256

when we studied biological biological

8536

09:44:59,810 --> 09:44:58,500

systems uh yes we do we we realize that

8537

09:45:02,210 --> 09:44:59,820

they actually do things that physical

8538

09:45:04,990 --> 09:45:02,220

systems don't are they Universal

8539

09:45:07,370 --> 09:45:05,000

phenomena in biology yes genetic code

8540

09:45:09,890 --> 09:45:07,380

gene expression distribution of species

8541

09:45:12,230 --> 09:45:09,900

metabolism and so on do they reveal

8542

09:45:14,390 --> 09:45:12,240

things that are important well yes they

8543

09:45:16,130 --> 09:45:14,400

tell us about the phase diagram of Life

8544

09:45:18,350 --> 09:45:16,140

they tell us about cell structure and

8545

09:45:19,670 --> 09:45:18,360

principles of how things evolve and what

8546

09:45:22,010 --> 09:45:19,680

do we miss by not understanding

8547

09:45:24,470 --> 09:45:22,020

Universal phenomena we've we don't

8548

09:45:26,390 --> 09:45:24,480

understand why life exists at all and we

8549

09:45:29,870 --> 09:45:26,400

don't understand how to how biological

8550

09:45:33,110 --> 09:45:29,880

systems respond to control perturbations

8551

09:45:35,086 --> 09:45:33,120

so so here is uh here's the the history

8552

09:45:37,426 --> 09:45:35,096

of life we know that some around here

8553

09:45:39,586 --> 09:45:37,436

was a homocylbal transition in the

8554

09:45:42,290 --> 09:45:39,596

genetic code the darwinian transition

8555

09:45:44,630 --> 09:45:42,300

and finally 3.8 billion years ago last

8556

09:45:46,426 --> 09:45:44,640

Universal common ancestor all of this

8557

09:45:49,670 --> 09:45:46,436

happens super fast because it was

8558

09:45:51,950 --> 09:45:49,680

dominated by Network effects and while

8559

09:45:54,730 --> 09:45:51,960

and what I didn't tell you about this in

8560

09:45:57,470 --> 09:45:54,740

detail or the catalysis leads to 100

8561

09:45:59,690 --> 09:45:57,480

homicorality horizontal Gene transfer

8562

09:46:01,670 --> 09:45:59,700

networks Drive the evolution of the

8563

09:46:03,290 --> 09:46:01,680

unique optimal genetic code and

8564

09:46:05,330 --> 09:46:03,300

horizontal Gene transfer eventually

8565

09:46:07,906 --> 09:46:05,340

becomes ineffective compared to Vertical

8566

09:46:09,950 --> 09:46:07,916

selection and you get this transition to

8567

09:46:12,110 --> 09:46:09,960

the vertical phase of life that we are

8568

09:46:15,110 --> 09:46:12,120

in today

8569

09:46:17,990 --> 09:46:15,120

I want to end with a quote uh since I'm

8570

09:46:20,330 --> 09:46:18,000

a physicist I studied biology I'm not

8571

09:46:22,906 --> 09:46:20,340

because I love biology I have a sort of

8572

09:46:25,730 --> 09:46:22,916

love hate relationship with Biology but

8573

09:46:28,190 --> 09:46:25,740

but because it teaches me things that

8574

09:46:30,170 --> 09:46:28,200

are that expands the scope of physics so

8575

09:46:32,510 --> 09:46:30,180

ask not what physics can do for biology

8576  
09:46:34,550 --> 09:46:32,520  
build you a better microscope build your

8577  
09:46:37,926 --> 09:46:34,560  
build a computer simulation understand

8578  
09:46:40,130 --> 09:46:37,936  
the uh the structure of some protein

8579  
09:46:41,870 --> 09:46:40,140  
asking instead what biology can do for

8580  
09:46:42,810 --> 09:46:41,880  
physics it can teach us wonderful things

8581  
09:46:44,010 --> 09:46:42,820  
thank you very much

8582  
09:46:46,060 --> 09:46:44,020  
[Applause]

8583  
09:46:47,690 --> 09:46:46,070  
[Music]

8584  
09:46:57,470 --> 09:46:47,700  
[Applause]

8585  
09:46:57,480 --> 09:47:02,390  
thank you

8586  
09:47:07,490 --> 09:47:05,150  
so I'm very recently coming to

8587  
09:47:09,290 --> 09:47:07,500  
appreciate this the importance of this

8588  
09:47:11,766 --> 09:47:09,300

horizontal Gene transfer but

8589

09:47:14,870 --> 09:47:11,776

mechanistically I don't understand

8590

09:47:17,330 --> 09:47:14,880

how like why this trade-off is tied to

8591

09:47:18,730 --> 09:47:17,340

optimizing the genetic code what you

8592

09:47:21,246 --> 09:47:18,740

don't understand why what

8593

09:47:24,050 --> 09:47:21,256

mechanistically I don't understand why

8594

09:47:28,570 --> 09:47:24,060

it's massive Advantage is tied to having

8595

09:47:35,510 --> 09:47:31,970

the the horizontal so the question is uh

8596

09:47:38,690 --> 09:47:35,520

why why why is if I understand why why

8597

09:47:41,210 --> 09:47:38,700

is horizontal Gene transfer

8598

09:47:42,530 --> 09:47:41,220

um important in in evolving the genetic

8599

09:47:45,530 --> 09:47:42,540

code is that what you're asking yeah

8600

09:47:47,266 --> 09:47:45,540

yeah yeah so so so the fundamental

8601  
09:47:49,070 --> 09:47:47,276  
reason is this well I showed you in the

8602  
09:47:51,050 --> 09:47:49,080  
in the simulations

8603  
09:47:54,050 --> 09:47:51,060  
um was that if you if you just have

8604  
09:47:55,246 --> 09:47:54,060  
vertical Evolution which I explained to

8605  
09:47:56,630 --> 09:47:55,256  
you what it is

8606  
09:47:58,070 --> 09:47:56,640  
um you kind of get trapped in local

8607  
09:48:00,650 --> 09:47:58,080  
Minima

8608  
09:48:02,870 --> 09:48:00,660  
okay so horizontal Gene transfer is a

8609  
09:48:04,310 --> 09:48:02,880  
very non-local shuffling of genes that

8610  
09:48:06,586 --> 09:48:04,320  
wouldn't otherwise happen

8611  
09:48:09,110 --> 09:48:06,596  
and so it's a much faster way of

8612  
09:48:11,030 --> 09:48:09,120  
exploring the space of possibilities and

8613  
09:48:13,550 --> 09:48:11,040

so what happened in early life is

8614

09:48:17,210 --> 09:48:13,560

organisms were very porous

8615

09:48:19,490 --> 09:48:17,220

there's a lot of endosymbiosis so you

8616

09:48:21,230 --> 09:48:19,500

know today we we only you know you and I

8617

09:48:24,470 --> 09:48:21,240

are not horizontally transferring genes

8618

09:48:26,810 --> 09:48:24,480

the bacteria in our guts are but in

8619

09:48:28,550 --> 09:48:26,820

early life organisms would sort of Pulp

8620

09:48:31,310 --> 09:48:28,560

go through each other and Collide and

8621

09:48:32,870 --> 09:48:31,320

and subsume each other and so on and so

8622

09:48:35,030 --> 09:48:32,880

there was a very natural built-in

8623

09:48:36,586 --> 09:48:35,040

mechanism for genes to be horizontally

8624

09:48:40,730 --> 09:48:36,596

transferred

8625

09:48:43,370 --> 09:48:40,740

and so when we when we model that in our

8626

09:48:45,290 --> 09:48:43,380

in our simulations what we see is that

8627

09:48:46,850 --> 09:48:45,300

is enormously effective in accelerating

8628

09:48:49,730 --> 09:48:46,860

the evolution rate

8629

09:48:51,290 --> 09:48:49,740

so so bottom line is horizontal Gene

8630

09:48:52,426 --> 09:48:51,300

transfer is just one way to accelerate

8631

09:48:54,406 --> 09:48:52,436

evolution

8632

09:48:56,330 --> 09:48:54,416

and if you accelerate Evolution you

8633

09:48:57,950 --> 09:48:56,340

don't get stuck in local Minima if you

8634

09:49:00,766 --> 09:48:57,960

don't get stuck in local minimum as it

8635

09:49:03,050 --> 09:49:00,776

were you'd then find the true

8636

09:49:05,030 --> 09:49:03,060

best code or the best whatever it is

8637

09:49:07,490 --> 09:49:05,040

that you're optimizing and and that's

8638

09:49:09,890 --> 09:49:07,500

why that's why it works so did I answer

8639

09:49:11,870 --> 09:49:09,900

your question what was the bit what was

8640

09:49:15,110 --> 09:49:11,880

the bit that I hadn't explained that

8641

09:49:18,890 --> 09:49:17,330

I I saw empirically that it was true but

8642

09:49:21,406 --> 09:49:18,900

the mechanism oh okay so I'll explain

8643

09:49:25,670 --> 09:49:21,416

that yeah go ahead thank you okay yeah

8644

09:49:28,010 --> 09:49:25,680

hey there hi uh I'm Maddie from MIT

8645

09:49:30,050 --> 09:49:28,020

um great talk I was kind of interested

8646

09:49:33,050 --> 09:49:30,060

based on your like um idea of evolution

8647

09:49:34,970 --> 09:49:33,060

of this like Pro Genoa like horizontal

8648

09:49:36,710 --> 09:49:34,980

Gene transfer dominated system evolving

8649

09:49:38,266 --> 09:49:36,720

to this darwinian phase where do you

8650

09:49:40,190 --> 09:49:38,276

think kind of the universality of like

8651  
09:49:41,510 --> 09:49:40,200  
essential Dogma kind of starts to evolve

8652  
09:49:43,730 --> 09:49:41,520  
when we think of like the genetic code

8653  
09:49:45,110 --> 09:49:43,740  
of like codons to proteins and DNA like

8654  
09:49:47,570 --> 09:49:45,120  
is that something that might have

8655  
09:49:49,070 --> 09:49:47,580  
existed with like this pre-state or

8656  
09:49:51,170 --> 09:49:49,080  
would this be something we only see with

8657  
09:49:53,690 --> 09:49:51,180  
like the rise of like I don't think the

8658  
09:49:56,390 --> 09:49:53,700  
central dogma even exists today

8659  
09:49:58,246 --> 09:49:56,400  
okay we we know we know that that's we

8660  
09:50:01,070 --> 09:49:58,256  
know that that's not true we know that

8661  
09:50:02,150 --> 09:50:01,080  
there are there are ways that um that

8662  
09:50:03,710 --> 09:50:02,160  
that there can be you know

8663  
09:50:06,170 --> 09:50:03,720

post-translational modifications you

8664

09:50:08,570 --> 09:50:06,180

have a virtual transcription and so on

8665

09:50:12,890 --> 09:50:08,580

and so forth so so organisms uh even

8666

09:50:13,970 --> 09:50:12,900

today can rewrite their their genome and

8667

09:50:16,490 --> 09:50:13,980

so

8668

09:50:19,070 --> 09:50:16,500

um you know when when did the you know

8669

09:50:21,530 --> 09:50:19,080

of course we we you know we

8670

09:50:23,746 --> 09:50:21,540

the first people didn't

8671

09:50:26,450 --> 09:50:23,756

you know didn't know about that Crick

8672

09:50:28,070 --> 09:50:26,460

called it the central dogma as a joke

8673

09:50:30,290 --> 09:50:28,080

um but today we know that you know

8674

09:50:32,870 --> 09:50:30,300

viruses are doing this or all the time

8675

09:50:36,230 --> 09:50:32,880

so we have lots of endogenous retro bio

8676

09:50:40,246 --> 09:50:36,240

DNA in our own genomes so so I'm not so

8677

09:50:42,766 --> 09:50:40,256

convinced that um that the um the

8678

09:50:45,406 --> 09:50:42,776

central dogma world as it were

8679

09:50:48,530 --> 09:50:45,416

ever existed or at least even exists uh

8680

09:50:51,230 --> 09:50:48,540

even exists exists now but the extent to

8681

09:50:54,350 --> 09:50:51,240

which you know genome editing

8682

09:50:55,790 --> 09:50:54,360

self-genome editing um evolved in time

8683

09:50:57,230 --> 09:50:55,800

that's not something that I've looked at

8684

09:50:59,030 --> 09:50:57,240

but you certainly couldn't you could you

8685

09:51:01,490 --> 09:50:59,040

could imagine it uh suddenly being

8686

09:51:05,086 --> 09:51:01,500

accelerated during the progenya for

8687

09:51:07,030 --> 09:51:05,096

example but it's going on today so so

8688

09:51:09,530 --> 09:51:07,040

um so um

8689

09:51:11,510 --> 09:51:09,540

did I answer your question or did I just

8690

09:51:13,310 --> 09:51:11,520

dismiss the premise of the question and

8691

09:51:14,990 --> 09:51:13,320

so it swept it under the rug that way no

8692

09:51:16,670 --> 09:51:15,000

it's very fascinating fascinating answer

8693

09:51:18,890 --> 09:51:16,680

I would say biologists would have a lot

8694

09:51:20,690 --> 09:51:18,900

to discussion I would say biologists

8695

09:51:22,426 --> 09:51:20,700

have a lot to discuss with you about um

8696

09:51:23,990 --> 09:51:22,436

the idea at the central dogma but I

8697

09:51:26,510 --> 09:51:24,000

think that is a fascinating way to think

8698

09:51:28,610 --> 09:51:26,520

about it yeah no no I mean I mean I mean

8699

09:51:30,170 --> 09:51:28,620

you know it may be it may be broadly

8700

09:51:32,746 --> 09:51:30,180

true but there's certainly lots of

8701

09:51:34,730 --> 09:51:32,756

exceptions to it and and so uh and

8702

09:51:37,190 --> 09:51:34,740

that's why I say it's not like it really

8703

09:51:40,610 --> 09:51:37,200

has to happen it's it's just you know

8704

09:51:43,330 --> 09:51:40,620

the balance of you know okay mostly

8705

09:51:46,970 --> 09:51:43,340

these things work but the fact um

8706

09:51:48,950 --> 09:51:46,980

they're not forbidden by any symmetry or

8707

09:51:52,490 --> 09:51:48,960

any law laws of physics or anything like

8708

09:51:54,950 --> 09:51:52,500

this so so how you know fundamentally I

8709

09:51:57,950 --> 09:51:54,960

I think the the main principle of trying

8710

09:52:00,406 --> 09:51:57,960

to underlie genome uh genome stability

8711

09:52:02,570 --> 09:52:00,416

is essentially reproducibility in other

8712

09:52:04,190 --> 09:52:02,580

words you know if everything is

8713

09:52:05,990 --> 09:52:04,200

fluctuating too much

8714

09:52:07,906 --> 09:52:06,000

then you're making too many

8715

09:52:08,990 --> 09:52:07,916

possibilities and and then you're

8716

09:52:10,610 --> 09:52:09,000

getting

8717

09:52:12,350 --> 09:52:10,620

um generalists as well but not new

8718

09:52:14,890 --> 09:52:12,360

Specialists and so it's really tied up

8719

09:52:17,030 --> 09:52:14,900

with you know whether the organisms are

8720

09:52:19,370 --> 09:52:17,040

optimized in a particular environment

8721

09:52:21,530 --> 09:52:19,380

and for the for you know for their

8722

09:52:22,850 --> 09:52:21,540

niches in in the ecosystem so I think

8723

09:52:23,990 --> 09:52:22,860

these these things are balanced like

8724

09:52:28,850 --> 09:52:24,000

that

8725

09:52:32,990 --> 09:52:30,530

so I'm very excited to see you here

8726  
09:52:34,906 --> 09:52:33,000  
because I'm also offices by training and

8727  
09:52:36,830 --> 09:52:34,916  
I have two questions for you so first of

8728  
09:52:37,850 --> 09:52:36,840  
all can there be nuclear signatures for

8729  
09:52:40,190 --> 09:52:37,860  
life

8730  
09:52:41,810 --> 09:52:40,200  
and second question is we just can

8731  
09:52:43,906 --> 09:52:41,820  
observe five percent of our universe the

8732  
09:52:47,510 --> 09:52:43,916  
rest of the universe is dark energy dark

8733  
09:52:50,690 --> 09:52:47,520  
matter can there be dark matter life

8734  
09:52:52,310 --> 09:52:50,700  
um okay I so the question is are there

8735  
09:52:54,170 --> 09:52:52,320  
nuclear signatures of life when you say

8736  
09:52:55,970 --> 09:52:54,180  
nuclear what do you mean by that at the

8737  
09:52:57,890 --> 09:52:55,980  
nuclear level like we talk about

8738  
09:53:03,890 --> 09:52:57,900

biosignatures of Life can there be

8739

09:53:08,810 --> 09:53:06,110

do I don't understand what you mean

8740

09:53:10,730 --> 09:53:08,820

sorry like uh can there be Nuclear

8741

09:53:12,170 --> 09:53:10,740

Physics going on which can lead to life

8742

09:53:18,290 --> 09:53:12,180

oh

8743

09:53:22,970 --> 09:53:19,746

I don't know about

8744

09:53:26,086 --> 09:53:22,980

nuclear it's certainly at Atomic I mean

8745

09:53:27,766 --> 09:53:26,096

there's um I don't really know I don't

8746

09:53:30,130 --> 09:53:27,776

know the answer to your question but but

8747

09:53:33,950 --> 09:53:30,140

I'll give you an example there's um

8748

09:53:34,850 --> 09:53:33,960

there is a particular excitation

8749

09:53:39,170 --> 09:53:34,860

um

8750

09:53:41,390 --> 09:53:39,180

in carbon the the oil excitation and and

8751

09:53:43,190 --> 09:53:41,400

it's probably the the first or maybe

8752

09:53:46,070 --> 09:53:43,200

only successful application of the

8753

09:53:47,266 --> 09:53:46,080

anthropic principle uh where he guessed

8754

09:53:49,246 --> 09:53:47,276

that there had to be such an excitation

8755

09:53:51,230 --> 09:53:49,256

for some process to occur that was

8756

09:53:52,970 --> 09:53:51,240

essential for life and indeed it was

8757

09:53:54,350 --> 09:53:52,980

later discovered to be true

8758

09:53:56,030 --> 09:53:54,360

so

8759

09:53:58,070 --> 09:53:56,040

I don't really know the answer to your

8760

09:54:01,190 --> 09:53:58,080

question it's not impossible because

8761

09:54:02,926 --> 09:54:01,200

this whole example is is a sort of very

8762

09:54:05,150 --> 09:54:02,936

strange one it's obviously something

8763

09:54:06,766 --> 09:54:05,160

that if you take a sort of perspective

8764

09:54:09,406 --> 09:54:06,776

that you should be looking at large

8765

09:54:10,906 --> 09:54:09,416

scales of systems you would never think

8766

09:54:12,586 --> 09:54:10,916

that there would be this kind of thing

8767

09:54:15,050 --> 09:54:12,596

happening but we also know in physics

8768

09:54:16,266 --> 09:54:15,060

that there was a scale interference and

8769

09:54:18,050 --> 09:54:16,276

that small

8770

09:54:20,150 --> 09:54:18,060

negligible effects can have large

8771

09:54:23,510 --> 09:54:20,160

consequences I have a whole other talk

8772

09:54:25,730 --> 09:54:23,520

about about that in trying to understand

8773

09:54:28,246 --> 09:54:25,740

um the the the tree-like evolution of

8774

09:54:31,550 --> 09:54:28,256

Life which I'm not going to talk about

8775

09:54:33,110 --> 09:54:31,560

um so so I don't I don't really know

8776

09:54:34,906 --> 09:54:33,120

um there was a second question a second

8777

09:54:36,406 --> 09:54:34,916

question was we can only observe five

8778

09:54:38,810 --> 09:54:36,416

percent of our universe because the rest

8779

09:54:40,426 --> 09:54:38,820

of the universe is not right so can

8780

09:54:41,990 --> 09:54:40,436

there be dark matter can there be dark

8781

09:54:49,630 --> 09:54:42,000

matter and can you have can you have

8782

09:54:58,030 --> 09:54:52,130

is very very enthusiastically ready to

8783

09:55:03,766 --> 09:55:01,670

so I I think that that life is you know

8784

09:55:05,330 --> 09:55:03,776

is essentially an inexorable consequence

8785

09:55:07,010 --> 09:55:05,340

of the laws of physics I don't think

8786

09:55:09,170 --> 09:55:07,020

it's Unique or an accident

8787

09:55:11,390 --> 09:55:09,180

so yes that's why I asked that but I

8788

09:55:12,650 --> 09:55:11,400

have no scientific reason for for

8789

09:55:14,030 --> 09:55:12,660

answering your question in the

8790

09:55:15,950 --> 09:55:14,040

affirmative

8791

09:55:16,790 --> 09:55:15,960

yes please go ahead yes hello Professor

8792

09:55:21,110 --> 09:55:16,800

like

8793

09:55:23,030 --> 09:55:21,120

am after your talk so thank you thank

8794

09:55:27,050 --> 09:55:23,040

you so much actually I have the similar

8795

09:55:29,086 --> 09:55:27,060

notion like uh I the like uh

8796

09:55:30,950 --> 09:55:29,096

like whatever you have presented here

8797

09:55:32,510 --> 09:55:30,960

like I'm I'm literally feeling we share

8798

09:55:35,086 --> 09:55:32,520

the similar Vibe actually I'm the second

8799

09:55:39,350 --> 09:55:35,096

year PhD student in astronomy and I have

8800

09:55:41,210 --> 09:55:39,360

a degree in physics and so like I'm

8801  
09:55:46,610 --> 09:55:41,220  
sorry I'm a little nervous but I have I

8802  
09:55:53,746 --> 09:55:49,850  
so uh yeah I I want to ask like uh What

8803  
09:55:56,030 --> 09:55:53,756  
uh since uh yeah like I also like

8804  
09:55:58,310 --> 09:55:56,040  
the earth-centric like investigation of

8805  
09:56:00,650 --> 09:55:58,320  
life it it it really doesn't convince me

8806  
09:56:04,310 --> 09:56:00,660  
to for like to to see the life outside

8807  
09:56:06,470 --> 09:56:04,320  
the universe and so like I'm really

8808  
09:56:08,510 --> 09:56:06,480  
interested to study the like uh physical

8809  
09:56:10,906 --> 09:56:08,520  
Evolution like how how we can study the

8810  
09:56:13,790 --> 09:56:10,916  
life like outside the universe like and

8811  
09:56:17,030 --> 09:56:13,800  
and it is true that uh we should have a

8812  
09:56:19,426 --> 09:56:17,040  
generic uh like generic definition how

8813  
09:56:20,450 --> 09:56:19,436

should life look like so that's why I'm

8814

09:56:22,490 --> 09:56:20,460

very much interested in the

8815

09:56:24,406 --> 09:56:22,500

thermodynamic evolution of life so I

8816

09:56:26,630 --> 09:56:24,416

just want to know like what are your

8817

09:56:28,426 --> 09:56:26,640

thoughts about like what do you what do

8818

09:56:30,586 --> 09:56:28,436

you think about like because there are

8819

09:56:32,086 --> 09:56:30,596

many uh researchers who are doing uh

8820

09:56:34,130 --> 09:56:32,096

great work on that the on the

8821

09:56:36,530 --> 09:56:34,140

thermodynamic evolution of life so I

8822

09:56:39,350 --> 09:56:36,540

just want to know your thoughts on that

8823

09:56:42,406 --> 09:56:39,360

and I'm like I'm super excited to work

8824

09:56:44,870 --> 09:56:42,416

on on this field and uh yeah like even

8825

09:56:46,730 --> 09:56:44,880

I'm in second year and I like I have

8826  
09:56:48,290 --> 09:56:46,740  
already decided I want my second PhD in

8827  
09:56:50,630 --> 09:56:48,300  
biophysics and I want to study the

8828  
09:56:51,730 --> 09:56:50,640  
thermodynamic evolution of Life So yeah

8829  
09:56:57,470 --> 09:56:51,740  
thank you

8830  
09:56:58,730 --> 09:56:57,480  
your kind words and um now I don't I

8831  
09:57:02,830 --> 09:56:58,740  
don't quite understand what is the

8832  
09:57:11,266 --> 09:57:07,610  
the microphone is next year yeah so uh

8833  
09:57:13,970 --> 09:57:11,276  
there is uh the the the Third Law of

8834  
09:57:16,790 --> 09:57:13,980  
like uh thermodynamics yes yeah the

8835  
09:57:20,086 --> 09:57:16,800  
thermo uh yeah the entropy so it it says

8836  
09:57:22,030 --> 09:57:20,096  
like um every natural uh laws in the

8837  
09:57:25,970 --> 09:57:22,040  
world they have a particular direction

8838  
09:57:28,130 --> 09:57:25,980

and it find this is if that's that's if

8839

09:57:31,490 --> 09:57:28,140

if we think about that that's that's

8840

09:57:34,010 --> 09:57:31,500

itself is a is a very great like itself

8841

09:57:36,110 --> 09:57:34,020

is a very great it tells like every

8842

09:57:38,266 --> 09:57:36,120

natural you know process in the world

8843

09:57:40,906 --> 09:57:38,276

they have a specific Direction and what

8844

09:57:43,010 --> 09:57:40,916

I feel like yeah what I what I feel like

8845

09:57:45,766 --> 09:57:43,020

that's that's my hypothesis like that

8846

09:57:48,110 --> 09:57:45,776

life is not the you know the the most

8847

09:57:51,050 --> 09:57:48,120

like the the most probable state of

8848

09:57:53,570 --> 09:57:51,060

state of the of the nature nature

8849

09:57:56,266 --> 09:57:53,580

doesn't want right that's what I think

8850

09:57:58,246 --> 09:57:56,276

and I want to study this uh with uh like

8851

09:58:00,530 --> 09:57:58,256

thermodynamic evolution of life that's

8852

09:58:02,510 --> 09:58:00,540

why uh yeah I want to study that so I

8853

09:58:05,570 --> 09:58:02,520

wanted to know your uh okay so I think I

8854

09:58:07,610 --> 09:58:05,580

think I I think I'm sorry I was so long

8855

09:58:10,070 --> 09:58:07,620

I think I can paraphrase your your

8856

09:58:12,130 --> 09:58:10,080

question so it tell me if this is a

8857

09:58:16,790 --> 09:58:12,140

reasonable paraphrasing of your question

8858

09:58:19,670 --> 09:58:16,800

why why the why does life inexorably

8859

09:58:23,390 --> 09:58:19,680

become more and more complex

8860

09:58:25,670 --> 09:58:23,400

I I and I think that is a very important

8861

09:58:27,586 --> 09:58:25,680

foundational question because you might

8862

09:58:30,050 --> 09:58:27,596

say okay let's suppose you believed in

8863

09:58:32,390 --> 09:58:30,060

the RNA World which which I actually as

8864

09:58:34,490 --> 09:58:32,400

I happened I I don't believe in it but

8865

09:58:37,130 --> 09:58:34,500

but let's suppose you did then you might

8866

09:58:39,230 --> 09:58:37,140

say well okay so I get these uh these uh

8867

09:58:42,170 --> 09:58:39,240

these all the catalytic uh uh

8868

09:58:45,586 --> 09:58:42,180

replicators I have RNA doing all the

8869

09:58:48,406 --> 09:58:45,596

functions of of Life uh why isn't the

8870

09:58:50,870 --> 09:58:48,416

world just you know knee-deep in uh

8871

09:58:53,086 --> 09:58:50,880

self-replicating RNA molecules you know

8872

09:58:55,370 --> 09:58:53,096

why do we have arts and elephants and

8873

09:58:57,850 --> 09:58:55,380

and blue whales and things like this and

8874

09:59:01,490 --> 09:58:57,860

so so I think the the you know the the

8875

09:59:04,190 --> 09:59:01,500

fundamental question is why do you have

8876  
09:59:07,130 --> 09:59:04,200  
this uh Evolution to greater and greater

8877  
09:59:08,390 --> 09:59:07,140  
complexity and I think that's a

8878  
09:59:10,730 --> 09:59:08,400  
um that's a question that we don't have

8879  
09:59:12,170 --> 09:59:10,740  
a good answer for now I'll tell you what

8880  
09:59:13,790 --> 09:59:12,180  
happens when we try to model living

8881  
09:59:18,710 --> 09:59:13,800  
systems

8882  
09:59:20,810 --> 09:59:18,720  
say in a computer you make an artificial

8883  
09:59:23,570 --> 09:59:20,820  
ecosystem lots of things interacting

8884  
09:59:25,730 --> 09:59:23,580  
with each other and you run it and what

8885  
09:59:27,890 --> 09:59:25,740  
happens is it does evolve in complexity

8886  
09:59:28,970 --> 09:59:27,900  
just a little bit and then it just stops

8887  
09:59:31,190 --> 09:59:28,980  
evolving

8888  
09:59:33,530 --> 09:59:31,200

it just stay it stays constantly and it

8889

09:59:35,926 --> 09:59:33,540

really the simulation does not involve

8890

09:59:40,130 --> 09:59:35,936

more and more arbitrarily complex Life

8891

09:59:43,426 --> 09:59:40,140

As Time proceeds so we try to figure out

8892

09:59:45,830 --> 09:59:43,436

uh what is the fundamental mechanisms

8893

09:59:48,530 --> 09:59:45,840

genetic mechanisms that could enable

8894

09:59:52,370 --> 09:59:48,540

this increase to give you as you put it

8895

09:59:54,710 --> 09:59:52,380

this directionality of life and and what

8896

09:59:57,110 --> 09:59:54,720

we discovered was this and it relates to

8897

09:59:59,746 --> 09:59:57,120

things I emphasize in the talk

8898

10:00:01,070 --> 09:59:59,756

mostly when we think about Evolution you

8899

10:00:03,650 --> 10:00:01,080

know you read the newspapers you think

8900

10:00:05,870 --> 10:00:03,660

about uh mutations and point mutations

8901

10:00:08,150 --> 10:00:05,880

and things like this I don't think those

8902

10:00:09,890 --> 10:00:08,160

things are very important at all for

8903

10:00:12,766 --> 10:00:09,900

evolution on the large scale what we

8904

10:00:15,290 --> 10:00:12,776

discovered in computer simulations was

8905

10:00:17,810 --> 10:00:15,300

that there's two things that cause life

8906

10:00:19,730 --> 10:00:17,820

to inexorably get more and more complex

8907

10:00:21,586 --> 10:00:19,740

and that is first of all you have

8908

10:00:26,210 --> 10:00:21,596

horizontal Gene transfer

8909

10:00:28,790 --> 10:00:26,220

so you have mechanisms that enable

8910

10:00:31,070 --> 10:00:28,800

essentially an evolving system to really

8911

10:00:33,710 --> 10:00:31,080

find its its local maximum or local

8912

10:00:35,030 --> 10:00:33,720

minimum Optimum and the other is Gene

8913

10:00:39,230 --> 10:00:35,040

duplication

8914

10:00:41,030 --> 10:00:39,240

because you make a copy of a gene and

8915

10:00:42,406 --> 10:00:41,040

then one copy goes off and Carries On

8916

10:00:44,290 --> 10:00:42,416

doing what it was supposed to be doing

8917

10:00:47,210 --> 10:00:44,300

the other one can evolve without

8918

10:00:48,650 --> 10:00:47,220

deleterious effect on the organism and

8919

10:00:51,406 --> 10:00:48,660

when you look in in The evolutionary

8920

10:00:54,110 --> 10:00:51,416

history of of life and you look at uh

8921

10:00:55,906 --> 10:00:54,120

genomes you see throughout this

8922

10:00:58,790 --> 10:00:55,916

pervasive influence of horizontal Gene

8923

10:01:02,210 --> 10:00:58,800

transversely in microbial organisms and

8924

10:01:05,030 --> 10:01:02,220

um and and and Gene duplication and you

8925

10:01:06,290 --> 10:01:05,040

see Gene deportation in all branches of

8926

10:01:08,630 --> 10:01:06,300

life

8927

10:01:11,390 --> 10:01:08,640

um so so I think what you have to try to

8928

10:01:13,266 --> 10:01:11,400

understand is the the interplay between

8929

10:01:16,010 --> 10:01:13,276

these different

8930

10:01:17,630 --> 10:01:16,020

processes at the genetic level then have

8931

10:01:21,050 --> 10:01:17,640

consequences for the large-scale

8932

10:01:24,950 --> 10:01:21,060

complexity of organisms so we we built

8933

10:01:29,210 --> 10:01:26,450

um computer model of an evolving

8934

10:01:32,110 --> 10:01:29,220

ecosystem which has continual growth of

8935

10:01:35,210 --> 10:01:32,120

complexity due to those particular

8936

10:01:37,190 --> 10:01:35,220

genetic operators and it's not a very

8937

10:01:39,406 --> 10:01:37,200

realistic model and the model and the

8938

10:01:41,926 --> 10:01:39,416

method of the the way we measured

8939

10:01:43,850 --> 10:01:41,936

complexity was completely unrealistic

8940

10:01:46,010 --> 10:01:43,860

and we measured it by the length of the

8941

10:01:47,810 --> 10:01:46,020

genome as opposed to something like

8942

10:01:50,630 --> 10:01:47,820

common golf complexity or some other

8943

10:01:54,370 --> 10:01:50,640

algorithmic complexity measure but um

8944

10:01:58,246 --> 10:01:54,380

but it it does show you that certain

8945

10:01:59,510 --> 10:01:58,256

genetic processes can give rise when

8946

10:02:01,130 --> 10:01:59,520

they interact with the environment and

8947

10:02:04,010 --> 10:02:01,140

that was important in our in our

8948

10:02:06,350 --> 10:02:04,020

calculation I can give rise to this

8949

10:02:07,970 --> 10:02:06,360

direction of life this ever increasing

8950

10:02:09,586 --> 10:02:07,980

growth of complexity

8951

10:02:12,406 --> 10:02:09,596

so that's the best I can do in answering

8952

10:02:13,790 --> 10:02:12,416

your question is that helpful

8953

10:02:14,990 --> 10:02:13,800

okay unfortunately we've run out of time

8954

10:02:17,086 --> 10:02:15,000

for questions so hopefully you can find

8955

10:02:26,210 --> 10:02:17,096

Nigel at the dinner but let's thank our

8956

10:02:30,650 --> 10:02:28,490

okay so I'm sure everyone's pretty

8957

10:02:32,570 --> 10:02:30,660

hungry and tired at this point but if we

8958

10:02:34,610 --> 10:02:32,580

could just get about another 10 minutes

8959

10:02:37,010 --> 10:02:34,620

or so just to finish up setting uh

8960

10:02:39,350 --> 10:02:37,020

Surfside but in the meantime it'd be

8961

10:02:42,766 --> 10:02:39,360

incredibly helpful if people could help

8962

10:02:45,406 --> 10:02:42,776

move clear the tables because uh we have

8963

10:02:47,220 --> 10:02:45,416

the event company that needs to get rid

8964

10:02:47,746 --> 10:02:47,230

of the Linens and such

8965

10:02:50,650 --> 10:02:47,756

[Music]

8966

10:02:55,610 --> 10:02:52,970

but uh there's also there's some garbage

8967

10:03:03,230 --> 10:02:55,620

cans outside the Forum so that'd be

8968

10:03:33,970 --> 10:03:27,000

[Music]