

The background features a large, glowing orange-red sun on the left side. In the upper right quadrant, there is a solid black circle. The bottom of the image shows a dark blue silhouette of a city skyline with various architectural structures. The overall background is a dark, starry space.

UV LIGHT AND THE PROSPECTS
FOR LIFE IN THE UNIVERSE
SUKRIT RANJAN

1
00:00:09,710 --> 00:00:07,130

[Music]

2
00:00:11,150 --> 00:00:09,720

so thanks again for that introduction as

3
00:00:12,500 --> 00:00:11,160

Laura pointed out my name is sue

4
00:00:14,600 --> 00:00:12,510

Carranza and I'm a skull post doctoral

5
00:00:15,770 --> 00:00:14,610

fellow at MIT and today I'm excited to

6
00:00:17,510 --> 00:00:15,780

tell you a little bit about some of my

7
00:00:19,279 --> 00:00:17,520

thoughts on UV light and the role it

8
00:00:21,170 --> 00:00:19,289

plays on the in the emergence and search

9
00:00:22,370 --> 00:00:21,180

for life in the universe before we get

10
00:00:23,420 --> 00:00:22,380

started I just want to taken one with

11
00:00:24,680 --> 00:00:23,430

acknowledge my colleagues and

12
00:00:26,980 --> 00:00:24,690

collaborators with whom I've done much

13
00:00:30,170 --> 00:00:26,990

of the work that I talk about over here

14

00:00:31,700 --> 00:00:30,180

okay so the session so the meeting

15

00:00:33,350 --> 00:00:31,710

organizers asked me to talk about

16

00:00:35,450 --> 00:00:33,360

prebiotic chemistry and bio signatures

17

00:00:37,340 --> 00:00:35,460

which are two topics which might seem

18

00:00:38,420 --> 00:00:37,350

quite different at face value prebiotic

19

00:00:40,640 --> 00:00:38,430

chemistry is concerned with the question

20

00:00:41,780 --> 00:00:40,650

of the origin of life biosignatures is

21

00:00:43,940 --> 00:00:41,790

concerned with the question of how to

22

00:00:45,470 --> 00:00:43,950

look for it elsewhere but it is it turns

23

00:00:47,690 --> 00:00:45,480

out these questions are related at a

24

00:00:49,640 --> 00:00:47,700

deep and fundamental level provided

25

00:00:51,620 --> 00:00:49,650

chemistry effects by signatures because

26

00:00:53,720 --> 00:00:51,630

theories of abiogenesis can provide

27

00:00:55,580 --> 00:00:53,730

informative priors which we can use to

28

00:00:56,600 --> 00:00:55,590

prioritize scarce telescope time when

29

00:00:58,220 --> 00:00:56,610

are kind of forgot which are the most

30

00:01:00,380 --> 00:00:58,230

interesting planets to scrutinize for

31

00:01:02,479 --> 00:01:00,390

evidence of biosignatures they can also

32

00:01:04,460 --> 00:01:02,489

help us to interpret informative priors

33

00:01:06,830 --> 00:01:04,470

for interpretation of a putative bio

34

00:01:08,179 --> 00:01:06,840

signature if you have a measurement of a

35

00:01:09,200 --> 00:01:08,189

signal and you're trying to describe to

36

00:01:11,149 --> 00:01:09,210

figure out whether to ascribe a

37

00:01:13,100 --> 00:01:11,159

biological or non-biological explanation

38

00:01:14,780 --> 00:01:13,110

the biological explanation is more

39

00:01:16,310 --> 00:01:14,790

convincing if it's in a place where we

40

00:01:18,920 --> 00:01:16,320

think life can emerge in you and a gear

41

00:01:20,620 --> 00:01:18,930

compared to one where it can't but the

42

00:01:22,850 --> 00:01:20,630

link goes the other way as well

43

00:01:24,289 --> 00:01:22,860

biosignatures will will eventually when

44

00:01:26,539 --> 00:01:24,299

we detect them play a critical role in

45

00:01:27,590 --> 00:01:26,549

origin of life specifically the

46

00:01:29,359 --> 00:01:27,600

detection of life on other worlds

47

00:01:31,340 --> 00:01:29,369

provides the strongest lever arm we have

48

00:01:33,050 --> 00:01:31,350

to empirically constrain theories of

49

00:01:34,670 --> 00:01:33,060

abiogenesis which has worked it very

50

00:01:38,390 --> 00:01:34,680

nicely in a kind of basin analysis by

51
00:01:40,310 --> 00:01:38,400
Chen and Kipping last year so these two

52
00:01:41,810 --> 00:01:40,320
questions are intimately linked and one

53
00:01:43,940 --> 00:01:41,820
of the kind of mechanistic things that

54
00:01:45,560 --> 00:01:43,950
links both of them is UV radiation and

55
00:01:47,450 --> 00:01:45,570
the rest of this talk I hope to convince

56
00:01:49,250 --> 00:01:47,460
you that UV radiation plays both a

57
00:01:51,410 --> 00:01:49,260
critical controlling role in prebiotic

58
00:01:53,420 --> 00:01:51,420
chemistry potentially as well as for

59
00:01:54,980 --> 00:01:53,430
sure a strong thrilling role in

60
00:01:56,390 --> 00:01:54,990
biosignature gases in particular the

61
00:01:59,810 --> 00:01:56,400
questions about false positives and

62
00:02:01,280 --> 00:01:59,820
build-up ejectable levels I'm gonna talk

63
00:02:02,929 --> 00:02:01,290

about UV light so I just want to orient

64

00:02:04,190 --> 00:02:02,939

you what exactly I mean when I talk

65

00:02:06,050 --> 00:02:04,200

about UV light and I'm gonna use this

66

00:02:08,929 --> 00:02:06,060

excellent plot from Evan Francis paper

67

00:02:10,609 --> 00:02:08,939

to do so when I when I talk about UV I'm

68

00:02:11,630 --> 00:02:10,619

not talking with the XUV yet we're link

69

00:02:13,280 --> 00:02:11,640

shortened about a hundred nanometers

70

00:02:15,229 --> 00:02:13,290

this has really important implications

71

00:02:16,580 --> 00:02:15,239

for processes like atmospheric escape

72

00:02:19,250 --> 00:02:16,590

like we heard about earlier in this

73

00:02:20,990 --> 00:02:19,260

meeting I'm also not gonna be talking

74

00:02:22,280 --> 00:02:21,000

with the visible in the IR what

75

00:02:24,620 --> 00:02:22,290

place critical rules in planetary

76

00:02:25,850 --> 00:02:24,630

climate instead I'll be focusing on this

77

00:02:27,290 --> 00:02:25,860

bit in the middle here which plays

78

00:02:29,270 --> 00:02:27,300

important roles in chemistry

79

00:02:31,760 --> 00:02:29,280

I just want to zoom in there and

80

00:02:33,080 --> 00:02:31,770

emphasize what I and again orient you a

81

00:02:35,930 --> 00:02:33,090

little bit what I mean when I talk about

82

00:02:38,150 --> 00:02:35,940

UV so this is the top of atmosphere of

83

00:02:39,860 --> 00:02:38,160

flux for Earth analog planets orbiting

84

00:02:42,440 --> 00:02:39,870

the Sun here in black versus that the M

85

00:02:45,980 --> 00:02:42,450

dwarf GJ 1214 here in red taken from the

86

00:02:48,620 --> 00:02:45,990

work of Kevin France 2013 this is a

87

00:02:50,690 --> 00:02:48,630

wavelength in nanometers on the x-axis

88

00:02:53,630 --> 00:02:50,700

top of atmosphere flux and photons on

89

00:02:56,240 --> 00:02:53,640

the y-axis and broadly speaking when I

90

00:02:57,440 --> 00:02:56,250

refer to far UV radiation everyone sets

91

00:02:59,570 --> 00:02:57,450

their cut-offs a little bit differently

92

00:03:00,860 --> 00:02:59,580

but when I refer to far UV I'm talking

93

00:03:02,479 --> 00:03:00,870

about wavelength shorter than 200

94

00:03:04,310 --> 00:03:02,489

nanometers this is placed in a

95

00:03:05,720 --> 00:03:04,320

controlling role in atmospheric co2

96

00:03:07,550 --> 00:03:05,730

chemistry in particular the chemistry of

97

00:03:10,130 --> 00:03:07,560

anoxic atmospheres because it's where

98

00:03:11,870 --> 00:03:10,140

co2 and h2o absorb by contrast when I

99

00:03:13,340 --> 00:03:11,880

talk about new UV radiation I'm

100

00:03:15,320 --> 00:03:13,350

referring to wavelengths longer than

101
00:03:16,580 --> 00:03:15,330
about 200 nanometers and those are the

102
00:03:19,070 --> 00:03:16,590
wavelengths that reach the surface for

103
00:03:21,140 --> 00:03:19,080
anoxic worlds and so play controlling

104
00:03:23,600 --> 00:03:21,150
roles and surficial chemistry's you

105
00:03:26,030 --> 00:03:23,610
might be asking why I'm talking about UV

106
00:03:27,680 --> 00:03:26,040
light in the context of chemistry the

107
00:03:29,030 --> 00:03:27,690
big picture is that well pretty much

108
00:03:31,610 --> 00:03:29,040
everything absorbs there so this is a

109
00:03:32,750 --> 00:03:31,620
plot from functions paper in 2014 and we

110
00:03:34,699 --> 00:03:32,760
see that many of the important

111
00:03:36,890 --> 00:03:34,709
biomolecules in the atmosphere absorb in

112
00:03:39,050 --> 00:03:36,900
this band you might say well maybe

113
00:03:41,030 --> 00:03:39,060

that's a little bit biased so I'm not

114

00:03:42,350 --> 00:03:41,040

trying to overwhelm you over here the

115

00:03:44,600 --> 00:03:42,360

big picture here is that these are just

116

00:03:45,890 --> 00:03:44,610

a bunch of molecules that I've

117

00:03:47,660 --> 00:03:45,900

identified as being important for

118

00:03:49,280 --> 00:03:47,670

biochemistry and for atmospheric

119

00:03:50,840 --> 00:03:49,290

chemistry you can ignore almost

120

00:03:52,520 --> 00:03:50,850

everything except the numbers in red

121

00:03:54,110 --> 00:03:52,530

which are the photon wavelengths

122

00:03:56,150 --> 00:03:54,120

corresponding to the energy system of

123

00:03:59,740 --> 00:03:56,160

the bonds of they're associated with and

124

00:04:02,300 --> 00:03:59,750

the big picture takeaway here is that

125

00:04:04,610 --> 00:04:02,310

photons in the UV regime affect all of

126

00:04:06,170 --> 00:04:04,620

these bonds pretty much so that's the

127

00:04:08,360 --> 00:04:06,180

big picture reason that UV is important

128

00:04:09,590 --> 00:04:08,370

and so far have kind of emphasized bond

129

00:04:11,120 --> 00:04:09,600

so I've been kind of emphasizing

130

00:04:13,370 --> 00:04:11,130

catalysis but of course that's not all

131

00:04:14,690 --> 00:04:13,380

that UV does so UV can create the

132

00:04:16,610 --> 00:04:14,700

Telesis and that's a very important

133

00:04:18,289 --> 00:04:16,620

function but it can also an eyes

134

00:04:19,670 --> 00:04:18,299

molecules so knocking off free electrons

135

00:04:21,560 --> 00:04:19,680

and then go on to participate in further

136

00:04:23,900 --> 00:04:21,570

chemistry which I'll touch on later and

137

00:04:25,250 --> 00:04:23,910

it can also perform photo excitation so

138

00:04:27,230 --> 00:04:25,260

it doesn't have to break up a molecule

139

00:04:28,340 --> 00:04:27,240

it can instead boost its electrons into

140

00:04:29,659 --> 00:04:28,350

a high energy state so they can

141

00:04:32,360 --> 00:04:29,669

participate in chemistry that would then

142

00:04:34,350 --> 00:04:32,370

normally be forbidden so that's kind of

143

00:04:35,850 --> 00:04:34,360

the big picture orientation on what UV

144

00:04:38,339 --> 00:04:35,860

and why we care about it when we think

145

00:04:39,839 --> 00:04:38,349

about chemical systems so my talk is

146

00:04:41,129 --> 00:04:39,849

divided into four parts and I've just

147

00:04:42,540 --> 00:04:41,139

kind of gone through the introduction

148

00:04:44,309 --> 00:04:42,550

aisle next to be stepping through the

149

00:04:45,929 --> 00:04:44,319

first part of a core part of my talk

150

00:04:48,209 --> 00:04:45,939

which is how UV light impacts prebiotic

151
00:04:49,529 --> 00:04:48,219
chemistry then I move on to UV light in

152
00:04:51,779 --> 00:04:49,539
the search for biosignatures and then

153
00:04:53,309 --> 00:04:51,789
I'll summarize some conclusions but

154
00:04:55,679 --> 00:04:53,319
first prebiotic chemistry

155
00:04:56,820 --> 00:04:55,689
what is prebiotic chemistry prebiotic

156
00:04:58,649 --> 00:04:56,830
chemistry is a study of trying to

157
00:05:00,779 --> 00:04:58,659
understand how we went from this in

158
00:05:02,399 --> 00:05:00,789
other words the geology a dead planet to

159
00:05:04,080 --> 00:05:02,409
this something that we would recognize

160
00:05:06,149 --> 00:05:04,090
as being a like for example this model

161
00:05:08,459 --> 00:05:06,159
protocell over here as a consequence

162
00:05:10,619 --> 00:05:08,469
prebiotic chemistry has two natural axes

163
00:05:12,659 --> 00:05:10,629

of study one is kind of planetary

164

00:05:14,700 --> 00:05:12,669

science or geochemical it's trying to

165

00:05:15,990 --> 00:05:14,710

understand this what was the milieu what

166

00:05:17,640 --> 00:05:16,000

was the range of environments under

167

00:05:18,930 --> 00:05:17,650

which life emerged here on earth

168

00:05:20,100 --> 00:05:18,940

what were their abundant what were the

169

00:05:22,350 --> 00:05:20,110

chemical conditions what were the

170

00:05:23,730 --> 00:05:22,360

availability of trace of trace compounds

171

00:05:24,899 --> 00:05:23,740

stuff like that

172

00:05:27,480 --> 00:05:24,909

and that's really the concern of

173

00:05:28,800 --> 00:05:27,490

geochemists of planetary scientists and

174

00:05:30,899 --> 00:05:28,810

so on and so forth and it's where I feel

175

00:05:33,420 --> 00:05:30,909

most comfortable for example the second

176

00:05:34,920 --> 00:05:33,430

axis is this what was a transformation

177

00:05:36,450 --> 00:05:34,930

process how do you get from simple

178

00:05:39,600 --> 00:05:36,460

molecules that geology makes available

179

00:05:41,189 --> 00:05:39,610

in bulk to be more complicated to

180

00:05:43,830 --> 00:05:41,199

increasingly complex molecules and

181

00:05:45,809 --> 00:05:43,840

eventually life this so far is most of

182

00:05:47,820 --> 00:05:45,819

the gain domain of synthetic chemists

183

00:05:49,080 --> 00:05:47,830

which I am NOT but I talked them a

184

00:05:52,950 --> 00:05:49,090

little bit so maybe I can tell you a

185

00:05:54,480 --> 00:05:52,960

little bit about that in the context of

186

00:05:55,980 --> 00:05:54,490

origin of life it may confuse you a

187

00:05:58,350 --> 00:05:55,990

little bit that I'm talking about UV

188

00:05:59,730 --> 00:05:58,360

radiation UV radiation in our field is

189

00:06:02,339 --> 00:05:59,740

typically in both as a strong negative

190

00:06:03,809 --> 00:06:02,349

for life after all if we go outside and

191

00:06:06,649 --> 00:06:03,819

we get too much UV we get skin cancer

192

00:06:08,730 --> 00:06:06,659

this is generally considered negative

193

00:06:10,320 --> 00:06:08,740

kind of more directly if you're a

194

00:06:12,329 --> 00:06:10,330

laboratory microbiologist and you want

195

00:06:14,399 --> 00:06:12,339

to sterilize your glassware one tool you

196

00:06:18,209 --> 00:06:14,409

can use to do that is a radiating with

197

00:06:19,619 --> 00:06:18,219

very high energy Shore UV radiation so

198

00:06:21,119 --> 00:06:19,629

in that case how can i how can we

199

00:06:23,850 --> 00:06:21,129

possibly think about UV as potentially

200

00:06:25,619 --> 00:06:23,860

playing a positive role I think one key

201

00:06:27,059 --> 00:06:25,629

point to keep in mind is that you need

202

00:06:28,980 --> 00:06:27,069

to be cautious when we extrapolate from

203

00:06:31,320 --> 00:06:28,990

modern life to past life and gave to the

204

00:06:35,369 --> 00:06:31,330

origin of life the canonical example of

205

00:06:37,079 --> 00:06:35,379

this is probably oxygen and two first

206

00:06:39,059 --> 00:06:37,089

order oxygen is violently violently

207

00:06:40,909 --> 00:06:39,069

toxic I know this might come as a bit of

208

00:06:43,680 --> 00:06:40,919

surprise to all of us here in this room

209

00:06:45,089 --> 00:06:43,690

and because oxygen is integral for both

210

00:06:47,249 --> 00:06:45,099

for not only for us but for pretty much

211

00:06:48,269 --> 00:06:47,259

all complex life here in this planet but

212

00:06:49,859 --> 00:06:48,279

but the reason we

213

00:06:51,509 --> 00:06:49,869

able to tolerate oxygen is because of

214

00:06:53,759 --> 00:06:51,519

extremely complex biochemical machinery

215

00:06:55,019 --> 00:06:53,769

we built um when Oh to interacts with

216

00:06:56,729 --> 00:06:55,029

cells in critically when it's processed

217

00:06:59,219 --> 00:06:56,739

through meta through metabolic light

218

00:07:01,019 --> 00:06:59,229

like pathways it very readily gives rise

219

00:07:03,449 --> 00:07:01,029

to so-called reactive oxygen species

220

00:07:05,339 --> 00:07:03,459

these oxygens reactive oxygen species

221

00:07:07,589 --> 00:07:05,349

love attacking biomolecules and

222

00:07:09,839 --> 00:07:07,599

essentially blowing them up and this is

223

00:07:12,779 --> 00:07:09,849

why many obligate anaerobes are very

224

00:07:14,699 --> 00:07:12,789

very vulnerable to oxygen toxicity we

225

00:07:16,229 --> 00:07:14,709

have actually bought of oh dear this is

226

00:07:17,879 --> 00:07:16,239

a slightly older version they're

227

00:07:19,229 --> 00:07:17,889

supposed to be things like Kerr exudates

228

00:07:23,909 --> 00:07:19,239

and things like that listed here various

229

00:07:25,769 --> 00:07:23,919

enzymes but so we've we have evolved a

230

00:07:27,479 --> 00:07:25,779

suite a very complex pathway sit deeply

231

00:07:29,429 --> 00:07:27,489

to process to come up with that oxygen

232

00:07:30,869 --> 00:07:29,439

and then to be able to then exploit the

233

00:07:34,079 --> 00:07:30,879

free energy gradients that oxygen makes

234

00:07:36,029 --> 00:07:34,089

available to us and in fact it's thought

235

00:07:38,569 --> 00:07:36,039

that at the rise of oxygen led to the

236

00:07:41,549 --> 00:07:38,579

first great mass extinction by many and

237

00:07:43,169 --> 00:07:41,559

even more fundamental and non-intuitive

238

00:07:45,119 --> 00:07:43,179

result comes in the form of liquid water

239

00:07:46,919 --> 00:07:45,129

liquid water is essential for all life

240

00:07:48,539 --> 00:07:46,929

as we know it it fundamentally guides

241

00:07:50,459 --> 00:07:48,549

our search for life in the universe our

242

00:07:52,799 --> 00:07:50,469

astrobiology strategy is to literally

243

00:07:54,479 --> 00:07:52,809

follow the water but so it might

244

00:07:55,619 --> 00:07:54,489

surprise you to learn that h₂ is

245

00:07:57,029 --> 00:07:55,629

actually somewhat corrosive to

246

00:07:59,159 --> 00:07:57,039

biomolecules and in particular to

247

00:08:01,589 --> 00:07:59,169

proteins and nucleic acids because it

248

00:08:03,509 --> 00:08:01,599

love doing hydrolysis reactions this has

249

00:08:05,519 --> 00:08:03,519

given rise to what is the so called ah

250

00:08:07,439 --> 00:08:05,529

the so-called water Bihar ducks which

251
00:08:09,509 --> 00:08:07,449
was enunciated in the NRC report on the

252
00:08:11,399 --> 00:08:09,519
limits of life in planetary systems and

253
00:08:13,439 --> 00:08:11,409
another review paper by Steve Benner and

254
00:08:15,479 --> 00:08:13,449
what it essentially boils down to is

255
00:08:17,369 --> 00:08:15,489
this if you take biomolecules for

256
00:08:19,259 --> 00:08:17,379
example this is a schematic of a nucleic

257
00:08:20,759 --> 00:08:19,269
acid and you look at the lifetimes of

258
00:08:22,799 --> 00:08:20,769
each of these each of the bonds that

259
00:08:23,939 --> 00:08:22,809
make it up in liquid water you find that

260
00:08:25,499 --> 00:08:23,949
its standard conditions are all

261
00:08:27,539 --> 00:08:25,509
geologically short they're order a

262
00:08:29,009 --> 00:08:27,549
hundred years or less so theories of the

263
00:08:30,600 --> 00:08:29,019

origin of life that we rely on

264

00:08:32,429 --> 00:08:30,610

drip-feeding in organics and building

265

00:08:33,689 --> 00:08:32,439

them up over mega years that's a little

266

00:08:34,889 --> 00:08:33,699

bit of a problem because they won't just

267

00:08:37,139 --> 00:08:34,899

build up build actually decay on a

268

00:08:38,699 --> 00:08:37,149

relatively short timescale and so this

269

00:08:41,459 --> 00:08:38,709

is called this is a so-called water

270

00:08:42,449 --> 00:08:41,469

paradox it's also why organic chemists

271

00:08:44,219 --> 00:08:42,459

when they perform their synthesis

272

00:08:46,460 --> 00:08:44,229

typically use organic solvents not water

273

00:08:48,389 --> 00:08:46,470

which I recently learned has prompted a

274

00:08:50,879 --> 00:08:48,399

sustainability crisis in organic

275

00:08:52,019 --> 00:08:50,889

chemistry and it's also why even

276

00:08:53,309 --> 00:08:52,029

grizzled organic chemists don't

277

00:08:54,660 --> 00:08:53,319

immediately laugh us out of the room

278

00:08:56,970 --> 00:08:54,670

when we talk about life and organic

279

00:08:58,799 --> 00:08:56,980

solvents untighten because truth be told

280

00:09:00,419 --> 00:08:58,809

many of them were trying to design life

281

00:09:01,060 --> 00:09:00,429

from the ground up they might not use a

282

00:09:03,280 --> 00:09:01,070

liquid

283

00:09:05,650 --> 00:09:03,290

either so the key takeaway from here is

284

00:09:07,480 --> 00:09:05,660

it's not as simple as saying is is this

285

00:09:08,950 --> 00:09:07,490

good for life or bad for life everything

286

00:09:10,510 --> 00:09:08,960

has good aspects and bad aspects you

287

00:09:12,370 --> 00:09:10,520

have to ask does the good outweigh the

288

00:09:13,810 --> 00:09:12,380

bad and ie there's a construct of

289

00:09:16,990 --> 00:09:13,820

chemistry dominant or the destructive

290

00:09:19,060 --> 00:09:17,000

chemistry in this view through this lens

291

00:09:21,730 --> 00:09:19,070

UV starts looking a little bit different

292

00:09:23,230 --> 00:09:21,740

ah it's there there's kind of three

293

00:09:24,790 --> 00:09:23,240

broad families of reasons to think that

294

00:09:26,380 --> 00:09:24,800

UV light is relevant to the origin of

295

00:09:28,150 --> 00:09:26,390

life the first is experimental and

296

00:09:29,980 --> 00:09:28,160

stretches back I think at this point six

297

00:09:31,720 --> 00:09:29,990

decades and it's the fact that in the

298

00:09:33,100 --> 00:09:31,730

laboratory UV life has been shown to a

299

00:09:34,990 --> 00:09:33,110

driver to drive a diverse range of

300

00:09:38,010 --> 00:09:35,000

synthesis it can form each of the major

301

00:09:40,780 --> 00:09:38,020

classes of biomolecules ie sugars

302

00:09:43,900 --> 00:09:40,790

nuclear bases and nucleotides amino

303

00:09:45,430 --> 00:09:43,910

acids lipid the cursors it can also

304

00:09:47,950 --> 00:09:45,440

drive a number of processes including

305

00:09:49,780 --> 00:09:47,960

earth oligomerization and so on and so

306

00:09:51,160 --> 00:09:49,790

forth one of the pathways that I'm most

307

00:09:53,800 --> 00:09:51,170

excited about is that UV light is

308

00:09:55,840 --> 00:09:53,810

integral to the only pathway but the

309

00:09:57,610 --> 00:09:55,850

Selective high-yield synthesis are the

310

00:10:00,880 --> 00:09:57,620

ribonucleotides the main funding mental

311

00:10:02,230 --> 00:10:00,890

components of RNA and UV light is

312

00:10:04,030 --> 00:10:02,240

utterly key to that in ways that I'll

313

00:10:06,370 --> 00:10:04,040

talk about I'll touch on just a little

314

00:10:08,020 --> 00:10:06,380

bit later so that's experimental it

315

00:10:09,880 --> 00:10:08,030

works in the lab there's also a

316

00:10:11,200 --> 00:10:09,890

theoretical argument not only was UV

317

00:10:12,610 --> 00:10:11,210

light the most abundant source of

318

00:10:13,870 --> 00:10:12,620

chemical free energy to the surface of

319

00:10:16,930 --> 00:10:13,880

early Earth by several orders of

320

00:10:19,000 --> 00:10:16,940

magnitude it also turns out that because

321

00:10:20,710 --> 00:10:19,010

that UV light arrives quantized right of

322

00:10:22,630 --> 00:10:20,720

the energy of those molecular bonds it's

323

00:10:24,070 --> 00:10:22,640

capable of directly effecting changes in

324

00:10:26,440 --> 00:10:24,080

the electronic states of molecular

325

00:10:28,090 --> 00:10:26,450

systems in other words it's capable of

326

00:10:29,380 --> 00:10:28,100

affecting irreversible changes in the

327

00:10:31,300 --> 00:10:29,390

entropy of molecules is capable of

328

00:10:32,860 --> 00:10:31,310

kinetically trapping them in ways that

329

00:10:34,320 --> 00:10:32,870

other sources of energy like thermal

330

00:10:36,760 --> 00:10:34,330

energy can't do because there's always a

331

00:10:37,990 --> 00:10:36,770

reversibility problem there and that was

332

00:10:41,140 --> 00:10:38,000

worked out in a very nice paper by

333

00:10:42,730 --> 00:10:41,150

Robert Pascale in 2012 but perhaps the

334

00:10:45,190 --> 00:10:42,740

most compelling piece of evidence is is

335

00:10:46,540 --> 00:10:45,200

historical there's a long body of work

336

00:10:48,100 --> 00:10:46,550

here but I think it reaches the POE

337

00:10:50,740 --> 00:10:48,110

theosis so far and work by Ashley

338

00:10:53,170 --> 00:10:50,750

Beckstead in 2016 what this is a plot

339

00:10:54,580 --> 00:10:53,180

here is of the nucleus of the UV

340

00:10:55,810 --> 00:10:54,590

resistance of different nucleobases so

341

00:10:57,420 --> 00:10:55,820

if you shine light on a nuclear base

342

00:11:01,060 --> 00:10:57,430

will it blow up or not

343

00:11:02,470 --> 00:11:01,070

the blue squares over here the nuclear

344

00:11:04,660 --> 00:11:02,480

bases it like uses the biogenic

345

00:11:06,160 --> 00:11:04,670

nucleobases the red circles are nuclear

346

00:11:07,450 --> 00:11:06,170

bases that life doesn't use there's a

347

00:11:08,830 --> 00:11:07,460

whole bunch more of these red ones way

348

00:11:10,630 --> 00:11:08,840

over here but that later didn't butter

349

00:11:12,820 --> 00:11:10,640

show because you're getting the picture

350

00:11:14,070 --> 00:11:12,830

already this is a log scale over here

351
00:11:15,540 --> 00:11:14,080
the lower you are the more you

352
00:11:17,040 --> 00:11:15,550
resistant you are so something here is

353
00:11:18,750 --> 00:11:17,050
ten times more UV resistant than

354
00:11:20,580 --> 00:11:18,760
something here and we see that the

355
00:11:22,050 --> 00:11:20,590
biogenic nucleobases are united in being

356
00:11:23,970 --> 00:11:22,060
extremely resistant to UV attack they

357
00:11:25,310 --> 00:11:23,980
have extremely efficient non rated photo

358
00:11:28,260 --> 00:11:25,320
excitation happens

359
00:11:29,280 --> 00:11:28,270
photo photo D excitation pathways which

360
00:11:32,880 --> 00:11:29,290
has been evidence that they at least

361
00:11:34,410 --> 00:11:32,890
evolved in high UV environment okay so

362
00:11:35,910 --> 00:11:34,420
UV light might be relevant to the order

363
00:11:37,410 --> 00:11:35,920

of life people have flushed the people

364

00:11:39,780 --> 00:11:37,420

have flushed out a lot in the past

365

00:11:41,160 --> 00:11:39,790

decades but this fundamental idea has

366

00:11:42,180 --> 00:11:41,170

been around for a little while so people

367

00:11:43,500 --> 00:11:42,190

have been thinking about it for a little

368

00:11:45,390 --> 00:11:43,510

while and in particular asking the

369

00:11:47,910 --> 00:11:45,400

question what exactly was the nature of

370

00:11:49,170 --> 00:11:47,920

the UV radiation on early Earth tamiya

371

00:11:50,550 --> 00:11:49,180

knowledge some of the first work on this

372

00:11:52,440 --> 00:11:50,560

was done by charles koch held back at

373

00:11:54,300 --> 00:11:52,450

the turn of the century and the key

374

00:11:56,370 --> 00:11:54,310

result that came out of his work was

375

00:11:57,480 --> 00:11:56,380

that if you just kind of take by do

376

00:11:59,550 --> 00:11:57,490

tional models of the earlier its

377

00:12:00,960 --> 00:11:59,560

atmospheric state and plugged in through

378

00:12:02,220 --> 00:12:00,970

a radiative transfer model you

379

00:12:03,810 --> 00:12:02,230

essentially get nothing at wavelengths

380

00:12:05,460 --> 00:12:03,820

shorter than 200 and that's because of

381

00:12:08,220 --> 00:12:05,470

atmospheric co2 that really robustly

382

00:12:09,600 --> 00:12:08,230

absorbs there you might say well that's

383

00:12:11,250 --> 00:12:09,610

all well and good but that's that's a

384

00:12:12,750 --> 00:12:11,260

final model there's a lot of uncertainty

385

00:12:15,390 --> 00:12:12,760

about the earlier its atmospheric state

386

00:12:17,670 --> 00:12:15,400

how can you be sure that's the case and

387

00:12:19,020 --> 00:12:17,680

the reason we can actually be relatively

388

00:12:21,810 --> 00:12:19,030

certain that's the case boils down to

389

00:12:22,740 --> 00:12:21,820

the existence of atmospheric co2 so we

390

00:12:24,510 --> 00:12:22,750

know that there must have been a certain

391

00:12:26,900 --> 00:12:24,520

minimum amount of co2 in order to solve

392

00:12:29,460 --> 00:12:26,910

the faint young Sun problem the lure and

393

00:12:30,780 --> 00:12:29,470

the minimum amount of co2 that's allowed

394

00:12:31,800 --> 00:12:30,790

when the climate models comes from the

395

00:12:33,540 --> 00:12:31,810

work though of Wordsworth and Pierre

396

00:12:35,280 --> 00:12:33,550

Humber it's if you have a ton of n2 in

397

00:12:37,680 --> 00:12:35,290

the atmosphere you can have as little as

398

00:12:39,900 --> 00:12:37,690

eight hundred micro Birds of co2 and

399

00:12:42,870 --> 00:12:39,910

that's shown here in this what color is

400

00:12:44,370 --> 00:12:42,880

it on this one not great in this purple

401
00:12:46,110 --> 00:12:44,380
line over here so this is showing the UV

402
00:12:47,880 --> 00:12:46,120
surface environment for early Earth

403
00:12:50,070 --> 00:12:47,890
assuming point nine bars of nitrogen

404
00:12:51,960 --> 00:12:50,080
bearing amounts of co2 the black line is

405
00:12:53,550 --> 00:12:51,970
what the young Sun was putting out this

406
00:12:55,890 --> 00:12:53,560
line is eight hundred micro bars of co2

407
00:12:56,670 --> 00:12:55,900
and we see that even with this low co2

408
00:12:58,110 --> 00:12:56,680
inventory

409
00:13:00,300 --> 00:12:58,120
we've already essentially put in place

410
00:13:01,830 --> 00:13:00,310
at 200 nanometer cutoff so even at the

411
00:13:03,870 --> 00:13:01,840
minimum amount of co2 you don't get

412
00:13:05,610 --> 00:13:03,880
anything short of 200 most other

413
00:13:06,690 --> 00:13:05,620

components of the planets of earlier its

414

00:13:10,020 --> 00:13:06,700

atmosphere that we think were there like

415

00:13:12,210 --> 00:13:10,030

h₂ n₂ ch₄ h₂o they all those they all

416

00:13:13,530 --> 00:13:12,220

absorb over here there's you can't get

417

00:13:15,720 --> 00:13:13,540

blow from a stone those photons are

418

00:13:17,880 --> 00:13:15,730

already all gone due to co₂ as a

419

00:13:19,590 --> 00:13:17,890

consequence you don't know

420

00:13:20,460 --> 00:13:19,600

as a consequence we're not sensitive to

421

00:13:23,070 --> 00:13:20,470

the uncertainty in those parameters

422

00:13:23,970 --> 00:13:23,080

although it is considerable so we don't

423

00:13:26,040 --> 00:13:23,980

care about it in that degree of

424

00:13:27,960 --> 00:13:26,050

uncertainty what about the other extreme

425

00:13:29,460 --> 00:13:27,970

this is the minimum amount of co₂

426
00:13:31,050 --> 00:13:29,470
the maximum amount of co2 we could

427
00:13:32,819 --> 00:13:31,060
reasonably have is given by this red

428
00:13:34,379 --> 00:13:32,829
line over here that's if you have 70

429
00:13:35,910 --> 00:13:34,389
bars of co2 in the atmosphere it's what

430
00:13:37,550 --> 00:13:35,920
you get if you volatilize the entire

431
00:13:40,139 --> 00:13:37,560
crustal carbonate inventory of the earth

432
00:13:43,139 --> 00:13:40,149
co2 so it's kind of an extreme upper

433
00:13:44,220 --> 00:13:43,149
limit but it isn't up limit and so you

434
00:13:45,809 --> 00:13:44,230
can think of this as kind of being the

435
00:13:46,920 --> 00:13:45,819
minimum amount of UV and you see that

436
00:13:48,329 --> 00:13:46,930
this curve and this curve aren't

437
00:13:49,949 --> 00:13:48,339
actually that different and that's

438
00:13:51,329 --> 00:13:49,959

because C o2 saturation sets in

439

00:13:53,040 --> 00:13:51,339

relatively early in the absorbing regime

440

00:13:54,809 --> 00:13:53,050

long word of two or four nanometers you

441

00:13:56,460 --> 00:13:54,819

only have scattering and there are

442

00:13:57,540 --> 00:13:56,470

transmission drops of only slowly with

443

00:13:59,610 --> 00:13:57,550

optical depth because it's purely

444

00:14:00,689 --> 00:13:59,620

scattering so as its as a result we have

445

00:14:02,639 --> 00:14:00,699

a pretty good sense of this particular

446

00:14:04,139 --> 00:14:02,649

initial condition which is consistent

447

00:14:06,350 --> 00:14:04,149

with which is consisting with available

448

00:14:08,249 --> 00:14:06,360

geochemical constraints like Smith

449

00:14:09,449 --> 00:14:08,259

interestingly this is also in

450

00:14:11,939 --> 00:14:09,459

concordance with the results of some

451
00:14:13,350 --> 00:14:11,949
experiments my colleague Zoe Todd has

452
00:14:14,970 --> 00:14:13,360
started a program where she takes some

453
00:14:16,230 --> 00:14:14,980
of these UV dependent prebiotic pathways

454
00:14:17,519 --> 00:14:16,240
they're all mentioned they're pretty

455
00:14:19,650 --> 00:14:17,529
much almost all measured in the lab

456
00:14:21,480 --> 00:14:19,660
using a monochromatic source so she

457
00:14:22,740 --> 00:14:21,490
asked the question which sum which many

458
00:14:24,240 --> 00:14:22,750
planetary science think is obvious but

459
00:14:25,350 --> 00:14:24,250
is not obvious in the bio community

460
00:14:26,699 --> 00:14:25,360
which is what is the wavelength

461
00:14:29,040 --> 00:14:26,709
dependence of these pathways could they

462
00:14:30,990 --> 00:14:29,050
work under realistic UV and she finds

463
00:14:32,639 --> 00:14:31,000

that she's only looked at a few of these

464

00:14:35,970 --> 00:14:32,649

pathways so far it turns out lab work is

465

00:14:37,860 --> 00:14:35,980

hard but the few pathway she's looked at

466

00:14:39,389 --> 00:14:37,870

she's found that broadband UV pretty

467

00:14:41,129 --> 00:14:39,399

much every wavelength long word about

468

00:14:43,230 --> 00:14:41,139

200 to 10 nanometers works pretty

469

00:14:44,369 --> 00:14:43,240

effectively all the way up to about 300

470

00:14:45,509 --> 00:14:44,379

at which point it starts dropping off

471

00:14:46,610 --> 00:14:45,519

you're not getting enough juice to get

472

00:14:48,480 --> 00:14:46,620

the thing going

473

00:14:51,299 --> 00:14:48,490

intriguingly and this is much more

474

00:14:52,949 --> 00:14:51,309

tentative so far and the path wishes

475

00:14:54,119 --> 00:14:52,959

looked at shortened the far UV

476
00:14:55,980 --> 00:14:54,129
wavelengths wavelength shorter than

477
00:14:57,900 --> 00:14:55,990
about 2 10 nanometers tend to be

478
00:15:00,449 --> 00:14:57,910
strictly destructive so ah

479
00:15:01,889 --> 00:15:00,459
at these kind of moderate UV what I

480
00:15:03,869 --> 00:15:01,899
called a near UV regime you'll get

481
00:15:05,009 --> 00:15:03,879
constructive chemistry and at the far UV

482
00:15:06,809 --> 00:15:05,019
at least in the two pathways she's

483
00:15:08,670 --> 00:15:06,819
looked at so far she's gotten strict

484
00:15:09,840 --> 00:15:08,680
destruction so that aligns relatively

485
00:15:11,429 --> 00:15:09,850
well with this atmospheric window so

486
00:15:12,840 --> 00:15:11,439
that's nothing serious here because

487
00:15:13,980 --> 00:15:12,850
we've only evaluated if you pass this

488
00:15:16,259 --> 00:15:13,990

but it's something we're continuing to

489

00:15:18,119 --> 00:15:16,269

look into and the story is pretty

490

00:15:22,230 --> 00:15:18,129

similar for early Mars with the caveat

491

00:15:24,509 --> 00:15:22,240

for the for dust ah so you have this UV

492

00:15:25,799 --> 00:15:24,519

what exactly can I do for you it turns

493

00:15:27,509 --> 00:15:25,809

out there's a whole bunch of stuff but I

494

00:15:28,980 --> 00:15:27,519

want to focus on it's on the rule UV

495

00:15:30,420 --> 00:15:28,990

plays in salt and potentially solving

496

00:15:32,790 --> 00:15:30,430

one long-standing problem that's been

497

00:15:35,069 --> 00:15:32,800

around since ever since the planetary

498

00:15:37,379 --> 00:15:35,079

scientists told the told the biochemists

499

00:15:39,329 --> 00:15:37,389

they weren't the prebiotic chemists that

500

00:15:41,369 --> 00:15:39,339

they weren't allowed to have super

501
00:15:43,679 --> 00:15:41,379
methane-rich early earth atmosphere and

502
00:15:45,389 --> 00:15:43,689
it's a question of reductants most of

503
00:15:47,219 --> 00:15:45,399
the carbon that volcanoes cut out comes

504
00:15:49,409 --> 00:15:47,229
in the form of CO_2 most of the carbon

505
00:15:51,210 --> 00:15:49,419
and biomolecules is reduced how do you

506
00:15:53,099 --> 00:15:51,220
reduce it in the absence of atmospheric

507
00:15:53,669 --> 00:15:53,109
reductants so this has been a puzzle for

508
00:15:56,460 --> 00:15:53,679
a while

509
00:15:57,749 --> 00:15:56,470
ah a few a few years ago it was proposed

510
00:16:00,839 --> 00:15:57,759
that one potential solution to the

511
00:16:02,960 --> 00:16:00,849
puzzle came from UV light and

512
00:16:06,749 --> 00:16:02,970
specifically the idea is if you take

513
00:16:08,399 --> 00:16:06,759

hydrogen sulfide HS^- coppers at a

514

00:16:09,929 --> 00:16:08,409

catalytic counterpart and UV light and

515

00:16:12,389 --> 00:16:09,939

shine them together you generate

516

00:16:13,649 --> 00:16:12,399

solvated electrons and solvated

517

00:16:14,399 --> 00:16:13,659

electrons are literally a minus charge

518

00:16:16,829 --> 00:16:14,409

floating around

519

00:16:18,449 --> 00:16:16,839

it is literally reducing power and it's

520

00:16:19,739 --> 00:16:18,459

because it's just a free electron it's

521

00:16:21,779 --> 00:16:19,749

actually quite reactive it can go off

522

00:16:23,039 --> 00:16:21,789

and reduce all sorts of things and so

523

00:16:24,479 --> 00:16:23,049

this was a solution that was put forward

524

00:16:25,859 --> 00:16:24,489

for how do you get reducing power and a

525

00:16:28,409 --> 00:16:25,869

comparatively oxidized earlier

526
00:16:30,389 --> 00:16:28,419
environment there's a couple of problems

527
00:16:32,399 --> 00:16:30,399
with this scenario one is its reliance

528
00:16:33,839 --> 00:16:32,409
on copper as a catalytic partner because

529
00:16:35,429 --> 00:16:33,849
copper is geologically rare and not very

530
00:16:37,109 --> 00:16:35,439
plausible the other is that it's

531
00:16:39,179 --> 00:16:37,119
actually not very efficient

532
00:16:40,889 --> 00:16:39,189
it doesn't in particular it doesn't work

533
00:16:42,389 --> 00:16:40,899
under early Earth UV which is something

534
00:16:43,889 --> 00:16:42,399
that Palmer figured out when he tried to

535
00:16:46,979 --> 00:16:43,899
simulate realistic environments in the

536
00:16:48,389 --> 00:16:46,989
lab however as planetary scientists we

537
00:16:50,429 --> 00:16:48,399
know that sulfide is not the only s

538
00:16:52,559 --> 00:16:50,439

carrier on earth in fact it's not

539

00:16:54,809 --> 00:16:52,569

even a major one most S comes out of

540

00:16:57,239 --> 00:16:54,819

volcanoes as SO₂ and in the absence of

541

00:16:59,069 --> 00:16:57,249

oxygen that S will then dissolve into

542

00:17:00,809 --> 00:16:59,079

liquid water it'll precipitate or it'll

543

00:17:01,139 --> 00:17:00,819

sorry not disproportionate dissociate to

544

00:17:04,079 --> 00:17:01,149

form

545

00:17:06,090 --> 00:17:04,089

sulfides the cell fights as a three two

546

00:17:07,740 --> 00:17:06,100

- HS - three - and so on and so forth

547

00:17:09,629 --> 00:17:07,750

and if you just do a very simple model

548

00:17:10,829 --> 00:17:09,639

of that process for shallow ponds you

549

00:17:12,389 --> 00:17:10,839

find that prebiotic ponds should have

550

00:17:15,600 --> 00:17:12,399

been sulphide rich concentrations of 10

551
00:17:16,889 --> 00:17:15,610
micromolar or higher and we told that we

552
00:17:18,899 --> 00:17:16,899
had a discussion with this about her

553
00:17:20,159 --> 00:17:18,909
prebiotic chemistry colleagues I don't

554
00:17:21,299 --> 00:17:20,169
know when those guys sleep because we

555
00:17:22,769 --> 00:17:21,309
had our conversation around 4:00 p.m.

556
00:17:25,019 --> 00:17:22,779
and we had preliminary results next

557
00:17:27,509 --> 00:17:25,029
morning they essentially plugged yeah

558
00:17:29,340 --> 00:17:27,519
they work real hard over there they

559
00:17:30,629 --> 00:17:29,350
plugged it into there about a chemistry

560
00:17:32,310 --> 00:17:30,639
pathways and the net thing that they

561
00:17:34,649 --> 00:17:32,320
found is that not only does sulfide work

562
00:17:37,289 --> 00:17:34,659
it works a lot better it works with it

563
00:17:38,730 --> 00:17:37,299

works under realistic UV radiation so it

564

00:17:40,769 --> 00:17:38,740

provides those others electrons of the

565

00:17:42,810 --> 00:17:40,779

right pace and it works with iron is a

566

00:17:44,639 --> 00:17:42,820

con as a catalytic partner not offer and

567

00:17:46,259 --> 00:17:44,649

that's important because iron is much

568

00:17:47,669 --> 00:17:46,269

more poetically plausible so you get two

569

00:17:49,590 --> 00:17:47,679

improvements for the price of one here

570

00:17:50,850 --> 00:17:49,600

so that's one way in which you can

571

00:17:53,050 --> 00:17:50,860

really help them solve under some of

572

00:17:57,190 --> 00:17:53,060

these long-standing problems

573

00:17:59,920 --> 00:17:57,200

however UV giveth UV taketh away and in

574

00:18:01,330 --> 00:17:59,930

particular because UV is delivering so

575

00:18:03,520 --> 00:18:01,340

much chemical free energy it's doing all

576

00:18:05,200 --> 00:18:03,530

sorts of things one of the things that's

577

00:18:07,540 --> 00:18:05,210

doing is it's controlling the inventory

578

00:18:09,370 --> 00:18:07,550

of UV sensitive molecules of the surface

579

00:18:11,760 --> 00:18:09,380

of the earlier and this is important

580

00:18:14,350 --> 00:18:11,770

where it comes to the nitrogen question

581

00:18:15,700 --> 00:18:14,360

biomolecules incorporate nitrogen we do

582

00:18:18,130 --> 00:18:15,710

have a ton of nitrogen that's floating

583

00:18:19,330 --> 00:18:18,140

all around this as nitrogen gas but as

584

00:18:21,520 --> 00:18:19,340

Colin told us earlier in the meeting

585

00:18:23,830 --> 00:18:21,530

that nitrogen gas on its own isn't very

586

00:18:25,390 --> 00:18:23,840

helpful because it's bound it's it was

587

00:18:27,910 --> 00:18:25,400

nitrogen atoms are printed connected by

588

00:18:29,920 --> 00:18:27,920

the high energy really strong triple

589

00:18:31,420 --> 00:18:29,930

bond it's really hard for even modern

590

00:18:32,890 --> 00:18:31,430

life to break apart that bond light

591

00:18:35,560 --> 00:18:32,900

merging is often the limiting ingredient

592

00:18:36,730 --> 00:18:35,570

in modern biology and it's even harder

593

00:18:39,520 --> 00:18:36,740

to figure out how you could do that

594

00:18:40,990 --> 00:18:39,530

abiotic way one mechanism that's been

595

00:18:43,660 --> 00:18:41,000

proposed for over the last three decades

596

00:18:44,950 --> 00:18:43,670

is all lightning the idea that if you

597

00:18:47,050 --> 00:18:44,960

had lightning in an end to co2

598

00:18:48,460 --> 00:18:47,060

atmosphere that should that should be

599

00:18:50,560 --> 00:18:48,470

able to jazz apart that entry on that

600

00:18:52,510 --> 00:18:50,570

co2 the ends in the O's can then combine

601
00:18:54,040 --> 00:18:52,520
and form NO X which can then rain out

602
00:18:56,110 --> 00:18:54,050
and potentially accumulate in prebiotic

603
00:18:58,180 --> 00:18:56,120
reservoirs this is an idea that's been

604
00:19:00,790 --> 00:18:58,190
simulated with increasing precision over

605
00:19:02,500 --> 00:19:00,800
the past as past few decades culminating

606
00:19:03,730 --> 00:19:02,510
in a recent couple of papers which

607
00:19:05,170 --> 00:19:03,740
predicted the concentration of these

608
00:19:08,440 --> 00:19:05,180
molecules should reach up to 10

609
00:19:10,120 --> 00:19:08,450
millimolar for a reference to the modern

610
00:19:13,060 --> 00:19:10,130
I know X concentration in the bulk ocean

611
00:19:15,040 --> 00:19:13,070
is 50 micromolar so this is so people

612
00:19:16,780 --> 00:19:15,050
were predicting that you get 200 times

613
00:19:18,070 --> 00:19:16,790

as much I know X in big early ocean in

614

00:19:19,900 --> 00:19:18,080

the absence of biological carbon

615

00:19:23,290 --> 00:19:19,910

nitrogen fixation compared to the modern

616

00:19:25,600 --> 00:19:23,300

ocean and this would be correct if the

617

00:19:26,950 --> 00:19:25,610

Sun didn't have any UV emission the

618

00:19:28,590 --> 00:19:26,960

challenge here is that what people

619

00:19:31,090 --> 00:19:28,600

hadn't included before is the fact that

620

00:19:32,980 --> 00:19:31,100

UV light is not--there's robustly known

621

00:19:34,600 --> 00:19:32,990

to photolyze nitrate and nitrite in

622

00:19:36,490 --> 00:19:34,610

natural waters this is observed in situ

623

00:19:37,630 --> 00:19:36,500

and it's also observed in the lab if you

624

00:19:39,250 --> 00:19:37,640

include the effects of this rate

625

00:19:40,570 --> 00:19:39,260

constant you find that the oceans would

626
00:19:41,890 --> 00:19:40,580
never have built up pre medically

627
00:19:44,250 --> 00:19:41,900
relevant by which I'd be more than one

628
00:19:46,300 --> 00:19:44,260
micromolar concentrations of that wax

629
00:19:47,620 --> 00:19:46,310
this is a sink that's about three to

630
00:19:49,240 --> 00:19:47,630
five orders of magnitude stronger than

631
00:19:51,280 --> 00:19:49,250
the earlier sink which was processing at

632
00:19:52,960 --> 00:19:51,290
deep sea hydrothermal vents and this

633
00:19:54,340 --> 00:19:52,970
mechanism would probably keep fixed

634
00:19:57,550 --> 00:19:54,350
nitrogen concentrations low and most

635
00:19:59,260 --> 00:19:57,560
bodies of water you they could get to be

636
00:20:00,880 --> 00:19:59,270
high in a very particular scenario that

637
00:20:03,250 --> 00:20:00,890
is to say specifically in shallow ponds

638
00:20:05,380 --> 00:20:03,260

with large drainage ratios and the idea

639

00:20:06,460 --> 00:20:05,390

there is that if you're delivering your

640

00:20:07,659 --> 00:20:06,470

nitrogen from the atmosphere

641

00:20:09,310 --> 00:20:07,669

it's shallower you dilute the

642

00:20:11,289 --> 00:20:09,320

atmospheric supply over a thinner column

643

00:20:12,879 --> 00:20:11,299

and if you have a large catchment area

644

00:20:14,560 --> 00:20:12,889

you can integrate runoff from a larger

645

00:20:16,509 --> 00:20:14,570

area so maybe you can get more nos that

646

00:20:18,730 --> 00:20:16,519

way and if you have such a favored

647

00:20:20,289 --> 00:20:18,740

lavond then you can access periodically

648

00:20:25,450 --> 00:20:20,299

relevant concentrations of nitrate and

649

00:20:27,639 --> 00:20:25,460

nitrite there's except so this is a

650

00:20:28,779 --> 00:20:27,649

theoretical prediction I was kind of

651

00:20:30,909 --> 00:20:28,789

expecting it to be a theoretical

652

00:20:32,889 --> 00:20:30,919

prediction for a while because night

653

00:20:35,710 --> 00:20:32,899

minerals of nitrate are very very

654

00:20:38,350 --> 00:20:35,720

soluble however nitrogen or organic dung

655

00:20:39,820 --> 00:20:38,360

is not very soluble it turns out that

656

00:20:41,230 --> 00:20:39,830

one of the messengers we have about

657

00:20:43,240 --> 00:20:41,240

ancient nitrogen is in the form of

658

00:20:45,549 --> 00:20:43,250

Kerrigan's and there was a group that

659

00:20:48,340 --> 00:20:45,559

last year published a paper analyzing

660

00:20:51,460 --> 00:20:48,350

Carrigan's from 3.2 billion year old

661

00:20:53,830 --> 00:20:51,470

carriages organic dung from both Oceanic

662

00:20:55,480 --> 00:20:53,840

and lacustrine Lake environments and

663

00:20:57,279 --> 00:20:55,490

they identified a signature in the

664

00:20:58,659 --> 00:20:57,289

nitrogen isotopes in the lakes that was

665

00:20:59,440 --> 00:20:58,669

consistent with nitrogen fixation in

666

00:21:01,210 --> 00:20:59,450

some of the lakes

667

00:21:02,830 --> 00:21:01,220

I'm sorry nitrogen with denitrification

668

00:21:04,149 --> 00:21:02,840

in some of the lakes so it seemed like

669

00:21:06,100 --> 00:21:04,159

microbes are eating nitrate over there

670

00:21:07,419 --> 00:21:06,110

however they did not identify that

671

00:21:09,279 --> 00:21:07,429

feature in all the lakes nor do they

672

00:21:10,990 --> 00:21:09,289

identified in the oceans so the

673

00:21:12,310 --> 00:21:11,000

implication of this is that some lakes

674

00:21:13,930 --> 00:21:12,320

and ponds and early Earth for prebiotic

675

00:21:16,060 --> 00:21:13,940

on prebiotic earth or nitro rich but not

676
00:21:17,740 --> 00:21:16,070
the oceans and not all ponds which is in

677
00:21:19,119 --> 00:21:17,750
broad concealing swith our scenario so

678
00:21:20,440 --> 00:21:19,129
we're kind of excited about the prospect

679
00:21:24,279 --> 00:21:20,450
that maybe we can test these predictions

680
00:21:25,480 --> 00:21:24,289
more rigorously there but still far I've

681
00:21:27,279 --> 00:21:25,490
talked to you only about planetary

682
00:21:29,499 --> 00:21:27,289
science and this is XO claims after all

683
00:21:30,909 --> 00:21:29,509
let's let's go to a different planet ask

684
00:21:36,519 --> 00:21:30,919
for how things change in particular

685
00:21:37,779 --> 00:21:36,529
let's go to M dwarfs the gospel of the M

686
00:21:39,399 --> 00:21:37,789
dwarf has already been presented in this

687
00:21:41,320 --> 00:21:39,409
meeting so I won't go the labor it in

688
00:21:42,700 --> 00:21:41,330

too much depth but just as a quick

689

00:21:44,169 --> 00:21:42,710

reminder for some of our colleagues who

690

00:21:46,930 --> 00:21:44,179

may not be as familiar with it you are

691

00:21:49,539 --> 00:21:46,940

being preached to M dwarfs are a really

692

00:21:51,039 --> 00:21:49,549

interesting class of the class of star

693

00:21:52,299 --> 00:21:51,049

they're the tharok stars that are

694

00:21:53,680 --> 00:21:52,309

smaller dimmer and cooler than our own

695

00:21:55,240 --> 00:21:53,690

Sun they're the most common type of star

696

00:21:56,649 --> 00:21:55,250

in the galaxy studies from Kepler show

697

00:21:58,720 --> 00:21:56,659

that potentially habitable planets are

698

00:21:59,889 --> 00:21:58,730

common around them a statistical finding

699

00:22:01,600 --> 00:21:59,899

which is received experimental

700

00:22:03,129 --> 00:22:01,610

validation with the number of individual

701
00:22:04,629 --> 00:22:03,139
planet discoveries like that or the

702
00:22:06,279 --> 00:22:04,639
Trappist one system which contains

703
00:22:08,590 --> 00:22:06,289
two to three potentially habitable

704
00:22:09,940 --> 00:22:08,600
planets which is quite exciting in

705
00:22:11,200 --> 00:22:09,950
addition they're the only possible

706
00:22:12,610 --> 00:22:11,210
targets for near-term atmospheric

707
00:22:14,230 --> 00:22:12,620
characterization over at least the next

708
00:22:15,549 --> 00:22:14,240
decade or two that's just because M

709
00:22:16,029 --> 00:22:15,559
groups are small so the relative

710
00:22:18,909 --> 00:22:16,039
spectral

711
00:22:20,110 --> 00:22:18,919
amplitude of atmospheric absorption is

712
00:22:22,090 --> 00:22:20,120
much stronger around these

713
00:22:23,650 --> 00:22:22,100

Jex so they're the most common potential

714

00:22:25,240 --> 00:22:23,660

home for life in the universe s rate and

715

00:22:27,490 --> 00:22:25,250

alluded to in the introduction to this

716

00:22:29,380 --> 00:22:27,500

meeting they're the only place we can

717

00:22:30,940 --> 00:22:29,390

look for life beyond Earth and of course

718

00:22:32,440 --> 00:22:30,950

and so this has fueled a robust debate

719

00:22:34,450 --> 00:22:32,450

about whether life can emerge and endear

720

00:22:35,740 --> 00:22:34,460

on these objects this debate has many

721

00:22:37,510 --> 00:22:35,750

axes some of which we've heard about

722

00:22:40,000 --> 00:22:37,520

earlier in this meeting I'm gonna focus

723

00:22:41,200 --> 00:22:40,010

on just one part of this debate which is

724

00:22:42,550 --> 00:22:41,210

the UV environment and then the

725

00:22:46,540 --> 00:22:42,560

implications for the emergence of life

726

00:22:47,830 --> 00:22:46,550

ah 15 minutes actually isn't that long

727

00:22:50,050 --> 00:22:47,840

so I'm gonna skip the build-up and just

728

00:22:52,390 --> 00:22:50,060

go straight to the conclusions which is

729

00:22:54,550 --> 00:22:52,400

that M dwarf planet surfaces are UV poor

730

00:22:55,840 --> 00:22:54,560

so what this is showing this well this

731

00:22:57,580 --> 00:22:55,850

is essentially showing here's a surface

732

00:22:58,930 --> 00:22:57,590

UV radiation environment on M dwarf

733

00:23:00,520 --> 00:22:58,940

planets you have wavelength in

734

00:23:02,770 --> 00:23:00,530

nanometers on the x axis the surface

735

00:23:04,690 --> 00:23:02,780

radiation in photons on the y axis the

736

00:23:06,460 --> 00:23:04,700

black line is what you had access to on

737

00:23:08,020 --> 00:23:06,470

early Earth and the colored lines is

738

00:23:09,460 --> 00:23:08,030

what you'd have access to in an earlier

739

00:23:10,840 --> 00:23:09,470

an analogue planet orbiting these M

740

00:23:13,600 --> 00:23:10,850

dwarfs are filtered through that one bar

741

00:23:14,920 --> 00:23:13,610

one bar and two co2 atmosphere and I

742

00:23:17,170 --> 00:23:14,930

should point out that the data sources

743

00:23:18,460 --> 00:23:17,180

here are primarily from the from the

744

00:23:20,620 --> 00:23:18,470

muscle survey but also from the virtual

745

00:23:22,810 --> 00:23:20,630

planetary leopard Laboratories online

746

00:23:24,880 --> 00:23:22,820

compendium and the key takeaway here is

747

00:23:26,740 --> 00:23:24,890

that ember planet surfaces are UV poor

748

00:23:28,240 --> 00:23:26,750

because a long word of 200 nanometers

749

00:23:30,430 --> 00:23:28,250

which is the only thing that makes it to

750

00:23:32,170 --> 00:23:30,440

the surface the radiation is formed at

751
00:23:33,430 --> 00:23:32,180
the photosphere embers are cool so they

752
00:23:35,530 --> 00:23:33,440
have much less photosphere @qv

753
00:23:36,700 --> 00:23:35,540
so that's all that's going on there we

754
00:23:38,320 --> 00:23:36,710
can quantify this a little bit by

755
00:23:40,300 --> 00:23:38,330
computing the reaction rates for

756
00:23:42,160 --> 00:23:40,310
prebiotic irrelevant processes and we

757
00:23:43,630 --> 00:23:42,170
can say that overall abiotic number of

758
00:23:45,280 --> 00:23:43,640
plants have about two to three orders of

759
00:23:47,230 --> 00:23:45,290
magnitude less by octave you be then

760
00:23:48,820 --> 00:23:47,240
prebiotic earth this has real

761
00:23:50,860 --> 00:23:48,830
implications for potential provided

762
00:23:52,630 --> 00:23:50,870
chemistry and it's not just you wait a

763
00:23:54,250 --> 00:23:52,640

hundred thousand times longer because

764

00:23:55,300 --> 00:23:54,260

you always have thermal back reactions

765

00:23:57,400 --> 00:23:55,310

to your photo chemistry needs to be

766

00:23:58,900 --> 00:23:57,410

building biomolecules faster than your

767

00:24:01,090 --> 00:23:58,910

thermo chemistry destroys them so

768

00:24:02,860 --> 00:24:01,100

there's a threshold amount of UV and if

769

00:24:04,030 --> 00:24:02,870

you don't don't exceed that threshold UV

770

00:24:05,640 --> 00:24:04,040

dependent provided chemistry may not

771

00:24:08,050 --> 00:24:05,650

proceed may not proceed

772

00:24:09,700 --> 00:24:08,060

Paul Rimmer in collaboration with others

773

00:24:10,750 --> 00:24:09,710

including DD ACLU's and John Sutherland

774

00:24:12,520 --> 00:24:10,760

at the University of Cambridge has

775

00:24:14,080 --> 00:24:12,530

started looking at this question he's

776

00:24:15,400 --> 00:24:14,090

looked at it for a couple of pathways in

777

00:24:16,810 --> 00:24:15,410

particular and he's shown that that

778

00:24:18,190 --> 00:24:16,820

driver nucleotide synthesis pathway I

779

00:24:19,390 --> 00:24:18,200

told you about the only one known for

780

00:24:21,370 --> 00:24:19,400

their high yield selective synthesis

781

00:24:23,140 --> 00:24:21,380

can't operate under steady state em door

782

00:24:24,790 --> 00:24:23,150

Q key which has given rise to what

783

00:24:26,980 --> 00:24:24,800

called policy it calls the abiogenesis

784

00:24:28,690 --> 00:24:26,990

own the idea that maybe high mass stars

785

00:24:31,000 --> 00:24:28,700

are much more clayman places for life to

786

00:24:32,320 --> 00:24:31,010

emerge there's one glaring caveat here

787

00:24:33,659 --> 00:24:32,330

that I can tell half of you are sitting

788

00:24:36,239 --> 00:24:33,669

on your hands about and

789

00:24:37,739 --> 00:24:36,249

Flair's Ambrose or flair stars they

790

00:24:39,089 --> 00:24:37,749

flirt who can be they flare often and

791

00:24:40,469 --> 00:24:39,099

when they flare they go from putting out

792

00:24:42,359 --> 00:24:40,479

less UV than the Sun to putting out more

793

00:24:44,219 --> 00:24:42,369

UV to the Sun which raises the question

794

00:24:46,680 --> 00:24:44,229

can intense with transient UV from

795

00:24:48,810 --> 00:24:46,690

flares substitute for high steady-state

796

00:24:50,549 --> 00:24:48,820

UV this question is being addressed on

797

00:24:54,329 --> 00:24:50,559

both booth observational and

798

00:24:57,359 --> 00:24:54,339

experimental II yeah sorry this is a

799

00:25:00,449 --> 00:24:57,369

little bit out of order observational II

800

00:25:02,219 --> 00:25:00,459

uh folks including Max guntur at MIT are

801
00:25:03,930 --> 00:25:02,229
using tests to do flare frequency

802
00:25:04,979 --> 00:25:03,940
distribution studies of M dwarfs trying

803
00:25:06,419 --> 00:25:04,989
to figure out how much they flare and

804
00:25:08,430 --> 00:25:06,429
how much energy that they put out and

805
00:25:10,169 --> 00:25:08,440
their preliminary findings so far is

806
00:25:12,029 --> 00:25:10,179
that maybe ten percent of M dwarfs put

807
00:25:13,949 --> 00:25:12,039
out enough energy may be put out an F

808
00:25:14,940 --> 00:25:13,959
energy to compensate and Paul Rimmer as

809
00:25:16,739 --> 00:25:14,950
I mentioned before is leading

810
00:25:18,359 --> 00:25:16,749
experimental studies to figure out can

811
00:25:20,369 --> 00:25:18,369
the camera can be proposed periodic

812
00:25:22,169 --> 00:25:20,379
chemistry uses intense radiation can it

813
00:25:24,209 --> 00:25:22,179

compensate if the answer to this

814

00:25:26,579 --> 00:25:24,219

question is yes it provides a rare

815

00:25:29,369 --> 00:25:26,589

positive tip for the habitability of

816

00:25:31,409 --> 00:25:29,379

active M so it provides a positive entry

817

00:25:33,209 --> 00:25:31,419

into that ledger if the answer is no I

818

00:25:34,769 --> 00:25:33,219

think that's the most important case of

819

00:25:36,659 --> 00:25:34,779

all because it constitutes a testable

820

00:25:38,489 --> 00:25:36,669

prediction if this pathway is required

821

00:25:40,109 --> 00:25:38,499

for the emergence of life if UV light is

822

00:25:41,339 --> 00:25:40,119

essential for the emergence of life then

823

00:25:42,659 --> 00:25:41,349

you don't find it and then you shouldn't

824

00:25:44,430 --> 00:25:42,669

find like on planets orbiting Emperor's

825

00:25:46,229 --> 00:25:44,440

so if you find biosignatures there any

826

00:25:47,060 --> 00:25:46,239

way you can falsify this theory which is

827

00:25:50,519 --> 00:25:47,070

lovely

828

00:25:51,810 --> 00:25:50,529

so those so that brings the prebiotic

829

00:25:53,729 --> 00:25:51,820

chemistry part of the talk to a close

830

00:25:55,079 --> 00:25:53,739

the key takeaways are we have a pretty

831

00:25:57,149 --> 00:25:55,089

good sense of what early Earth and early

832

00:25:59,459 --> 00:25:57,159

marcia was like it's broadband north of

833

00:26:00,449 --> 00:25:59,469

200 nanometers this can power a lot of

834

00:26:01,769 --> 00:26:00,459

constructive chemistry and in

835

00:26:03,859 --> 00:26:01,779

conjunction with sulfide can solve the

836

00:26:06,029 --> 00:26:03,869

long-standing production problem it

837

00:26:07,319 --> 00:26:06,039

controls other aspects of the surface

838

00:26:08,969 --> 00:26:07,329

environment as well in particular it

839

00:26:10,789 --> 00:26:08,979

controls the abundance of NO_x a fixed

840

00:26:12,690 --> 00:26:10,799

nitrogen on the early Earth and

841

00:26:14,579 --> 00:26:12,700

restricts you to ponds if you really

842

00:26:15,719 --> 00:26:14,589

want a lot of that prebiotic amber

843

00:26:17,969 --> 00:26:15,729

plants are a little bit different

844

00:26:20,219 --> 00:26:17,979

because they have a lot less UV this is

845

00:26:21,419 --> 00:26:20,229

potentially quite exciting first we

846

00:26:22,889 --> 00:26:21,429

first have to figure out if flares can

847

00:26:25,019 --> 00:26:22,899

compensate the flare UV can compensate

848

00:26:26,310 --> 00:26:25,029

your steady-state M graph UV if it can't

849

00:26:27,839 --> 00:26:26,320

that's really exciting because you can

850

00:26:29,899 --> 00:26:27,849

potentially use exoplanet observations

851
00:26:32,099 --> 00:26:29,909
to constrain origin of life theories

852
00:26:33,599 --> 00:26:32,109
this seeks me really nicely into the

853
00:26:35,129 --> 00:26:33,609
next part of my talk which is how are we

854
00:26:37,889 --> 00:26:35,139
gonna find life on planets orbiting

855
00:26:40,169 --> 00:26:37,899
other stars UV light and biosignatures

856
00:26:41,519 --> 00:26:40,179
before I jump into this I'm going to

857
00:26:43,349 --> 00:26:41,529
take a moment and pause about the

858
00:26:45,269 --> 00:26:43,359
magnitude of the opportunity exoplanets

859
00:26:47,030 --> 00:26:45,279
offer offer us it's not just that

860
00:26:49,730 --> 00:26:47,040
there's so many potentially habitable x

861
00:26:50,660 --> 00:26:49,740
a potential of potentially hundreds or

862
00:26:52,220 --> 00:26:50,670
thousands that we can hope to

863
00:26:53,330 --> 00:26:52,230

potentially hundreds that we could hope

864

00:26:56,000 --> 00:26:53,340

to observe if we get good enough

865

00:26:58,160 --> 00:26:56,010

telescopes it's that it's the it's this

866

00:26:59,810 --> 00:26:58,170

each and every planet is a prebiotic

867

00:27:01,400 --> 00:26:59,820

chemistry experiment it's a prebiotic

868

00:27:03,350 --> 00:27:01,410

chemistry experiment running at scale

869

00:27:05,330 --> 00:27:03,360

thousands tens of thousands of square

870

00:27:07,580 --> 00:27:05,340

kilometers off wide range of conditions

871

00:27:10,160 --> 00:27:07,590

and cycles operating operating over

872

00:27:11,810 --> 00:27:10,170

geologic time we could we can never do

873

00:27:13,970 --> 00:27:11,820

prebiotic chemistry experiments as well

874

00:27:15,410 --> 00:27:13,980

as planets can and if you can just read

875

00:27:17,480 --> 00:27:15,420

the outcome of those prebiotic chemistry

876

00:27:20,720 --> 00:27:17,490

experiments we can get we can gain

877

00:27:22,910 --> 00:27:20,730

really fundamental insights into the

878

00:27:27,830 --> 00:27:22,920

nature but into what might be laws of

879

00:27:28,700 --> 00:27:27,840

biology exoplanets offer and this has

880

00:27:30,290 --> 00:27:28,710

been the quantum this has been

881

00:27:32,120 --> 00:27:30,300

quantified an abrasion framework by Sant

882

00:27:34,010 --> 00:27:32,130

Eddie Andy Sandberg here and by tipping

883

00:27:35,480 --> 00:27:34,020

in Chen and by Lingam and love a little

884

00:27:37,100 --> 00:27:35,490

bit and the essential thing that they

885

00:27:38,750 --> 00:27:37,110

point out is that if you detect even one

886

00:27:40,180 --> 00:27:38,760

biosphere beyond Earth you strongly

887

00:27:43,790 --> 00:27:40,190

constrain many theories of abiogenesis

888

00:27:45,290 --> 00:27:43,800

for example one still extent debate is

889

00:27:47,510 --> 00:27:45,300

contingency versus inevitability of

890

00:27:49,820 --> 00:27:47,520

origin of life are there processes out

891

00:27:51,170 --> 00:27:49,830

there that inevitably drive chemical

892

00:27:53,300 --> 00:27:51,180

complexification in the emergence of

893

00:27:54,740 --> 00:27:53,310

life or did a bunch of molecules one day

894

00:27:56,300 --> 00:27:54,750

just to decide the quantum tunnel

895

00:27:57,560 --> 00:27:56,310

together and give us Luca we can't

896

00:27:59,150 --> 00:27:57,570

actually exclude the latter right now

897

00:28:01,190 --> 00:27:59,160

even though we don't like it very much

898

00:28:02,960 --> 00:28:01,200

the detection of even one biosphere

899

00:28:04,100 --> 00:28:02,970

would rule strongly on that beyond Earth

900

00:28:06,020 --> 00:28:04,110

would rule strongly on that and

901
00:28:07,340 --> 00:28:06,030
similarly if we can detect a few then we

902
00:28:08,930 --> 00:28:07,350
can start making broad statements about

903
00:28:12,260 --> 00:28:08,940
what conditions fuel the origin of life

904
00:28:13,520 --> 00:28:12,270
versus disfavor it exoplanets are

905
00:28:14,480 --> 00:28:13,530
particularly outstanding here because

906
00:28:16,040 --> 00:28:14,490
they're an opportunity for an

907
00:28:17,780 --> 00:28:16,050
uncontaminated experiment

908
00:28:18,920 --> 00:28:17,790
I love the solar system bodies I love

909
00:28:20,240 --> 00:28:18,930
each and every one of them they have

910
00:28:21,890 --> 00:28:20,250
fundamental things to teach us in a be

911
00:28:23,540 --> 00:28:21,900
detect life there it'll be an amazing

912
00:28:25,460 --> 00:28:23,550
discovery and it'll tell us a lot about

913
00:28:27,500 --> 00:28:25,470

habitability but it won't necessarily

914

00:28:29,030 --> 00:28:27,510

tell us about the origin of life

915

00:28:30,950 --> 00:28:29,040

particularly if it has it biochemistry

916

00:28:32,660 --> 00:28:30,960

similar to ours and that's because of

917

00:28:34,190 --> 00:28:32,670

the risk of terrestrial contamination we

918

00:28:35,270 --> 00:28:34,200

know the terrestrial bodies swap rocks

919

00:28:37,100 --> 00:28:35,280

back and forth we know this from the

920

00:28:38,240 --> 00:28:37,110

existence of Martian meteorites we know

921

00:28:40,130 --> 00:28:38,250

that the interiors of those meteorites

922

00:28:42,860 --> 00:28:40,140

experience cream and surface climate

923

00:28:44,960 --> 00:28:42,870

conditions not exceeding 40 Celsius and

924

00:28:47,210 --> 00:28:44,970

we know that from n-body simulations for

925

00:28:49,820 --> 00:28:47,220

example by were that all at Penn State

926
00:28:52,250 --> 00:28:49,830
that Earth has transferred on the order

927
00:28:54,140 --> 00:28:52,260
of a mega of a Megaton of matter to the

928
00:28:56,150 --> 00:28:54,150
icy moons alone and much much more of

929
00:28:57,440 --> 00:28:56,160
course to Mars so there's a real risk of

930
00:28:58,670 --> 00:28:57,450
terrestrial contamination if you detect

931
00:29:00,050 --> 00:28:58,680
life there you can't be sure that it

932
00:29:00,950 --> 00:29:00,060
wasn't exchanged back and forth in the

933
00:29:03,350 --> 00:29:00,960
solar system

934
00:29:04,880 --> 00:29:03,360
exoplanets avoid that problem so it

935
00:29:06,830 --> 00:29:04,890
would be super great to to detect life

936
00:29:08,900 --> 00:29:06,840
there so how are we thinking about doing

937
00:29:10,220 --> 00:29:08,910
this the essential paradigm is right now

938
00:29:13,910 --> 00:29:10,230

we are discovering potentially habitable

939

00:29:15,290 --> 00:29:13,920

up to probably rocky worlds today we can

940

00:29:17,540 --> 00:29:15,300

spectrally characterize the atmospheres

941

00:29:19,640 --> 00:29:17,550

of large planets and see what's in them

942

00:29:21,410 --> 00:29:19,650

in future we hope to do the same with

943

00:29:23,480 --> 00:29:21,420

smaller rocky planets and scrutinize

944

00:29:25,910 --> 00:29:23,490

them for evidence of life what do we

945

00:29:27,380 --> 00:29:25,920

mean by evidence of life to think about

946

00:29:29,390 --> 00:29:27,390

this question we can go back to the

947

00:29:31,730 --> 00:29:29,400

granddaddy of them all the only time has

948

00:29:33,770 --> 00:29:31,740

actually been tried which is a very

949

00:29:37,040 --> 00:29:33,780

clever experiment by Carl Sagan and this

950

00:29:38,960 --> 00:29:37,050

collaborators back in 1993 so when when

951
00:29:41,900 --> 00:29:38,970
Galileo was on its way out to Jupiter it

952
00:29:43,310 --> 00:29:41,910
swung by earth on the way so they just

953
00:29:44,570 --> 00:29:43,320
had a very simple idea they stuck out

954
00:29:45,770 --> 00:29:44,580
all its instruments they trained them on

955
00:29:47,210 --> 00:29:45,780
earth and they tried to see if they

956
00:29:49,160 --> 00:29:47,220
could remotely detect evidence of life

957
00:29:50,660 --> 00:29:49,170
on earth it was not as straightforward

958
00:29:53,300 --> 00:29:50,670
as you might imagine as long as these

959
00:29:55,520 --> 00:29:53,310
things like TV signals that is I'm gonna

960
00:29:57,560 --> 00:29:55,530
begin me but the most robust evidence

961
00:29:59,090 --> 00:29:57,570
that they found for life on Earth was

962
00:30:01,130 --> 00:29:59,100
essentially in this auto over here this

963
00:30:03,230 --> 00:30:01,140

is a spectrum of the rational atmosphere

964

00:30:04,670 --> 00:30:03,240

and they have detected a number of

965

00:30:06,710 --> 00:30:04,680

molecules that add relatively high

966

00:30:09,500 --> 00:30:06,720

concentrations so they detected two oh

967

00:30:10,700 --> 00:30:09,510

three which is biogenic but they that's

968

00:30:12,110 --> 00:30:10,710

not a good evidence for life because

969

00:30:13,790 --> 00:30:12,120

there's a robust UV difference false

970

00:30:15,890 --> 00:30:13,800

positive if you UV irradiate an o₂

971

00:30:18,170 --> 00:30:15,900

atmosphere you may go three not

972

00:30:20,240 --> 00:30:18,180

convincing they found oh to an end to Oh

973

00:30:21,410 --> 00:30:20,250

which they were more excited about but

974

00:30:22,940 --> 00:30:21,420

again there was significant false

975

00:30:24,560 --> 00:30:22,950

positive risks and they concluded that

976

00:30:25,400 --> 00:30:24,570

they couldn't conclude that life was

977

00:30:27,830 --> 00:30:25,410

there based on that alone

978

00:30:29,600 --> 00:30:27,840

what did eventually convince them was

979

00:30:32,570 --> 00:30:29,610

the existence of seach for in an oxy

980

00:30:34,820 --> 00:30:32,580

gaseous fear ch4 is known to be biogenic

981

00:30:36,020 --> 00:30:34,830

it was Alba I was also present added

982

00:30:37,190 --> 00:30:36,030

abundance about a hundred and forty

983

00:30:38,660 --> 00:30:37,200

eight orders of magnitude out of

984

00:30:39,740 --> 00:30:38,670

thermochemical equilibrium so that was

985

00:30:41,450 --> 00:30:39,750

weird

986

00:30:43,640 --> 00:30:41,460

it had a let it should have had a

987

00:30:44,810 --> 00:30:43,650

lifetime of about ten years which meant

988

00:30:47,900 --> 00:30:44,820

said kinetics should have been able to

989

00:30:49,760 --> 00:30:47,910

restore that equilibrium very quickly so

990

00:30:51,800 --> 00:30:49,770

the so something must be pumping it up

991

00:30:53,030 --> 00:30:51,810

and retain and maintaining it they went

992

00:30:54,440 --> 00:30:53,040

through the list of a byte across the

993

00:30:56,360 --> 00:30:54,450

seas they no ll knew about which would

994

00:30:57,830 --> 00:30:56,370

make ch4 concluded that none of them

995

00:30:59,900 --> 00:30:57,840

could maintain the required flux and

996

00:31:01,610 --> 00:30:59,910

concluded that Occam's razor forced to

997

00:31:03,290 --> 00:31:01,620

conclude that there was life there so

998

00:31:04,550 --> 00:31:03,300

this is a kind of analysis that one day

999

00:31:08,389 --> 00:31:04,560

we hope to do with the next planet so

1000

00:31:13,259 --> 00:31:11,159

in terms of oxic atmospheres the biasing

1001
00:31:16,619 --> 00:31:13,269
here that they identified CH 402 and

1002
00:31:17,969 --> 00:31:16,629
ideally h2o remains the most remains

1003
00:31:20,069 --> 00:31:17,979
probably the most robust one we've come

1004
00:31:24,089 --> 00:31:20,079
up with so far the challenge it really

1005
00:31:25,589 --> 00:31:24,099
faces is one of observation the first

1006
00:31:26,969 --> 00:31:25,599
method first you kind of have a

1007
00:31:28,589 --> 00:31:26,979
trade-off between oxygen abundance and

1008
00:31:30,989 --> 00:31:28,599
methane abundance over Earth history as

1009
00:31:32,849 --> 00:31:30,999
Olson at all 2016 and Reinhardt and

1010
00:31:34,169 --> 00:31:32,859
colleagues in 2017 pointed out either

1011
00:31:35,729 --> 00:31:34,179
you have high methane so it's easy to

1012
00:31:37,799 --> 00:31:35,739
detector or high oxygen typically not

1013
00:31:39,209 --> 00:31:37,809

though you also have kind of more

1014

00:31:41,339 --> 00:31:39,219

fundamental observational challenges

1015

00:31:43,829 --> 00:31:41,349

than that for example Oh - absorbs at

1016

00:31:45,419 --> 00:31:43,839

relatively short wavelengths ch4 absorbs

1017

00:31:46,919 --> 00:31:45,429

that are relatively long wavelengths you

1018

00:31:48,599 --> 00:31:46,929

need different different big

1019

00:31:51,029 --> 00:31:48,609

observatories to be able to detect them

1020

00:31:52,649 --> 00:31:51,039

to be able to detect them and it's ch4

1021

00:31:53,999 --> 00:31:52,659

you also run into the problem that ch4

1022

00:31:55,499 --> 00:31:54,009

absorbs like this so does almost every

1023

00:31:56,909 --> 00:31:55,509

other hydrocarbon so you have to figure

1024

00:32:00,119 --> 00:31:56,919

out how can you discriminate those guys

1025

00:32:01,409 --> 00:32:00,129

apart so those are some so these are I'm

1026
00:32:02,579 --> 00:32:01,419
not saying that this is a bad by sector

1027
00:32:04,109 --> 00:32:02,589
them by far the opposite we should

1028
00:32:05,459 --> 00:32:04,119
definitely look for this but these are

1029
00:32:07,549 --> 00:32:05,469
some of the reasons people have kept on

1030
00:32:10,289 --> 00:32:07,559
thinking about this problem a little bit

1031
00:32:13,109 --> 00:32:10,299
so what would an ideal biosignature gas

1032
00:32:14,430 --> 00:32:13,119
be what would i well obviously it would

1033
00:32:16,739 --> 00:32:14,440
be by Jen it could be produced by life

1034
00:32:18,509 --> 00:32:16,749
for example the way oxygen is produced

1035
00:32:19,889 --> 00:32:18,519
by phytoplankton here on earth it would

1036
00:32:21,180 --> 00:32:19,899
be spectrally distinguishable we should

1037
00:32:22,829 --> 00:32:21,190
be able to clearly tell it apart from

1038
00:32:24,749 --> 00:32:22,839

other molecules that might absorb in the

1039

00:32:26,430 --> 00:32:24,759

same region of the spectrum and it

1040

00:32:30,199 --> 00:32:26,440

should have no abiotic pulse positives

1041

00:32:32,999 --> 00:32:31,769

finally we would like it to be

1042

00:32:34,829 --> 00:32:33,009

detectable we need to be able to

1043

00:32:38,729 --> 00:32:34,839

accumulate a detectable concentrations

1044

00:32:40,169 --> 00:32:38,739

on habit of inhabitable planets both the

1045

00:32:41,849 --> 00:32:40,179

UV light comes in to both of these

1046

00:32:44,609 --> 00:32:41,859

questions see these second two questions

1047

00:32:45,569 --> 00:32:44,619

over here that's what I'll do and that's

1048

00:32:47,129 --> 00:32:45,579

the work that I've been doing in that

1049

00:32:50,129 --> 00:32:47,139

that's what a little bit of what I'll

1050

00:32:51,629 --> 00:32:50,139

share with you today I can't talk about

1051
00:32:53,969 --> 00:32:51,639
bio signatures without talking about the

1052
00:32:55,889 --> 00:32:53,979
granddaddy of them all Oh - OH - is a

1053
00:32:57,899 --> 00:32:55,899
excellent bio signature in many ways

1054
00:32:59,819 --> 00:32:57,909
it's biogenic it's detectable it's

1055
00:33:01,889 --> 00:32:59,829
distinguishable it has an excellent

1056
00:33:04,469 --> 00:33:01,899
terrestrial motivation but the big risk

1057
00:33:06,659 --> 00:33:04,479
of it is is that it has a lot of false

1058
00:33:08,789 --> 00:33:06,669
positive possibilities

1059
00:33:10,409 --> 00:33:08,799
driven by both photochemistry and escape

1060
00:33:11,819 --> 00:33:10,419
but a chemistry is a little bit less of

1061
00:33:14,339 --> 00:33:11,829
a concern now thanks to the recent work

1062
00:33:15,959 --> 00:33:14,349
of sunny harmon showing that you showing

1063
00:33:18,389 --> 00:33:15,969

that like me the products of lightning

1064

00:33:19,739 --> 00:33:18,399

suppress this false positive signal but

1065

00:33:20,370 --> 00:33:19,749

the escape different false positives

1066

00:33:22,230 --> 00:33:20,380

remain and the

1067

00:33:24,060 --> 00:33:22,240

fundamental picture that all was down to

1068

00:33:25,590 --> 00:33:24,070

as you can come up with scenarios where

1069

00:33:27,390 --> 00:33:25,600

you have water vapor which is present on

1070

00:33:28,799 --> 00:33:27,400

habitable worlds and you can come up

1071

00:33:30,840 --> 00:33:28,809

with ways that that water we converted

1072

00:33:32,610 --> 00:33:30,850

associate the H can escape the O remains

1073

00:33:34,680 --> 00:33:32,620

and so you filled up at me by to go to

1074

00:33:37,140 --> 00:33:34,690

layer and all these escapes in air is

1075

00:33:38,490 --> 00:33:37,150

basically bow down to that there's ways

1076

00:33:39,720 --> 00:33:38,500

you can discriminate out some of them as

1077

00:33:42,180 --> 00:33:39,730

was shown that Eddie sweeter man in a

1078

00:33:44,310 --> 00:33:42,190

2016 paper and the idea is that for

1079

00:33:46,049 --> 00:33:44,320

example if you're owed to you to Co

1080

00:33:47,630 --> 00:33:46,059

potala co2 catalysis you should have

1081

00:33:50,549 --> 00:33:47,640

lots of co so you can look for that

1082

00:33:52,020 --> 00:33:50,559

alternatively if you're if you have a

1083

00:33:53,610 --> 00:33:52,030

really a lot of o to like a hundred bars

1084

00:33:55,799 --> 00:33:53,620

of it turned by the escape of an ocean

1085

00:33:57,120 --> 00:33:55,809

kind of trophic escape of an ocean that

1086

00:33:58,740 --> 00:33:57,130

should produce OH - OH - die memories

1087

00:34:00,470 --> 00:33:58,750

which you can also look for but there's

1088

00:34:02,909 --> 00:34:00,480

a bit a big regime in the Middle where

1089

00:34:04,649 --> 00:34:02,919

we can't necessarily discriminate out

1090

00:34:05,820 --> 00:34:04,659

all those false positives so that's a

1091

00:34:08,550 --> 00:34:05,830

potential challenge so that's a

1092

00:34:09,960 --> 00:34:08,560

potential challenger though - this is in

1093

00:34:11,639 --> 00:34:09,970

fact a potential challenge with all the

1094

00:34:12,930 --> 00:34:11,649

quote unquote easy simple molecules the

1095

00:34:14,820 --> 00:34:12,940

molecules that it's relatively easy for

1096

00:34:16,169 --> 00:34:14,830

life to me that's because the molecules

1097

00:34:19,050 --> 00:34:16,179

that it's relatively easy for life to

1098

00:34:20,790 --> 00:34:19,060

make are also relatively easy for me for

1099

00:34:22,710 --> 00:34:20,800

like a non life to make a biotic

1100

00:34:25,889 --> 00:34:22,720

processes to make nature can exploit the

1101

00:34:28,260 --> 00:34:25,899

same basic the same basic thermal for

1102

00:34:29,430 --> 00:34:28,270

energy gradients that life can so this

1103

00:34:30,570 --> 00:34:29,440

has motivated people to think a little

1104

00:34:32,399 --> 00:34:30,580

bit about heart to make molecules

1105

00:34:33,510 --> 00:34:32,409

molecules at its root that it's really

1106

00:34:36,270 --> 00:34:33,520

hard to make that you would seem to

1107

00:34:39,570 --> 00:34:36,280

uniquely need life by a biological

1108

00:34:40,680 --> 00:34:39,580

enzymatic machinery can make people have

1109

00:34:42,300 --> 00:34:40,690

mostly thought about of this in the

1110

00:34:43,859 --> 00:34:42,310

context of an ox gamma spheres because

1111

00:34:45,780 --> 00:34:43,869

these hard to make molecules also tend

1112

00:34:48,540 --> 00:34:45,790

to be reactive and the idea is that

1113

00:34:49,859 --> 00:34:48,550

anoxic oxygen is pretty reactive anoxic

1114

00:34:51,720 --> 00:34:49,869

atmospheres are hopefully less reactive

1115

00:34:54,990 --> 00:34:51,730

and even better places for these gases

1116

00:34:56,820 --> 00:34:55,000

to build up this also has a very robust

1117

00:34:58,410 --> 00:34:56,830

geological motivation in the sense that

1118

00:35:00,930 --> 00:34:58,420

for about half of Earth's history it was

1119

00:35:02,550 --> 00:35:00,940

anoxic so if you don't think about

1120

00:35:04,200 --> 00:35:02,560

anoxic atmospheres you will literally

1121

00:35:07,010 --> 00:35:04,210

throw out about half of your potential

1122

00:35:09,570 --> 00:35:07,020

of your potential biospheres

1123

00:35:10,920 --> 00:35:09,580

the first work in this regard to my

1124

00:35:12,990 --> 00:35:10,930

knowledge was done by Sean Domino

1125

00:35:14,700 --> 00:35:13,000

Goldman's group back in 2011 and what

1126

00:35:17,910 --> 00:35:14,710

they did is they looked at the

1127

00:35:20,520 --> 00:35:17,920

organosulfur ch3 organist vm v VMs the

1128

00:35:22,560 --> 00:35:20,530

MVS and so on and so forth as potential

1129

00:35:25,770 --> 00:35:22,570

biosignatures these are the product of

1130

00:35:28,470 --> 00:35:25,780

so fear of sulfur-based of biochemistry

1131

00:35:29,790 --> 00:35:28,480

ah they're essential finding is that

1132

00:35:31,079 --> 00:35:29,800

these are really good biosignatures in

1133

00:35:32,540 --> 00:35:31,089

many ways in particularly they don't

1134

00:35:34,070 --> 00:35:32,550

have false positive risk

1135

00:35:35,540 --> 00:35:34,080

but you need very high fluxes in order

1136

00:35:36,890 --> 00:35:35,550

for them to become built to detectable

1137

00:35:38,990 --> 00:35:36,900

concentrations in the atmosphere and

1138

00:35:41,120 --> 00:35:39,000

that's you be limited and they've and

1139

00:35:43,730 --> 00:35:41,130

they felt that such high fluxes who were

1140

00:35:45,410 --> 00:35:43,740

unrealistic we think that this approach

1141

00:35:50,300 --> 00:35:45,420

overall is a very sensible one

1142

00:35:51,980 --> 00:35:50,310

so at over at MIT William Bane's William

1143

00:35:53,660 --> 00:35:51,990

vanes Janish Krakowski and Sara Seager

1144

00:35:55,580 --> 00:35:53,670

are leading with what we call the all

1145

00:35:56,870 --> 00:35:55,590

small molecules project an effort to

1146

00:35:57,950 --> 00:35:56,880

look at all the things that life makes

1147

00:35:59,810 --> 00:35:57,960

and evaluate them as potential

1148

00:36:01,340 --> 00:35:59,820

biosignatures this is a bit of an

1149

00:36:02,810 --> 00:36:01,350

undertaking given that even after our

1150

00:36:05,810 --> 00:36:02,820

initial course cuts you still have about

1151
00:36:07,040 --> 00:36:05,820
10,000 of them but we're pleased to

1152
00:36:08,420 --> 00:36:07,050
report that the first results in this

1153
00:36:10,250 --> 00:36:08,430
program are hardly starting to roll in

1154
00:36:11,720 --> 00:36:10,260
the first gas I want to tell you a

1155
00:36:13,160 --> 00:36:11,730
little bit about today adding to that

1156
00:36:16,490 --> 00:36:13,170
inventory that's already been built is

1157
00:36:17,750 --> 00:36:16,500
ph3 bossing page three has a number of

1158
00:36:19,640 --> 00:36:17,760
appealing characteristics as a bio

1159
00:36:21,130 --> 00:36:19,650
signature it has strong detectable

1160
00:36:23,450 --> 00:36:21,140
spectral features you can tell in part

1161
00:36:26,540 --> 00:36:23,460
and I should mention this is working led

1162
00:36:28,040 --> 00:36:26,550
by Clark Sousa Silva there has strong

1163
00:36:28,970 --> 00:36:28,050

detectable spectral features you can

1164

00:36:31,100 --> 00:36:28,980

tell it apart from a lot of other

1165

00:36:33,140 --> 00:36:31,110

molecules it has no known geological

1166

00:36:35,300 --> 00:36:33,150

false-positive mechanisms and we looked

1167

00:36:36,980 --> 00:36:35,310

at a lot of them it's a Chili's heel

1168

00:36:38,330 --> 00:36:36,990

after the ads but the organic Sulphurs

1169

00:36:41,690 --> 00:36:38,340

is that it's really efficiently

1170

00:36:43,030 --> 00:36:41,700

photochemically destroyed so and we

1171

00:36:45,050 --> 00:36:43,040

figured that out by doing a lot by

1172

00:36:46,520 --> 00:36:45,060

calculating the conservation of page

1173

00:36:48,770 --> 00:36:46,530

from the atmospheres of various kinds of

1174

00:36:50,450 --> 00:36:48,780

exoplanets as a function of total pH_3

1175

00:36:51,920 --> 00:36:50,460

flux to the atmosphere that's what's

1176
00:36:55,040 --> 00:36:51,930
shown in these spaghetti plots over here

1177
00:36:56,420 --> 00:36:55,050
thank you Tom for that name and so let

1178
00:36:57,560 --> 00:36:56,430
me just walk it this is kind of one of

1179
00:36:59,000 --> 00:36:57,570
our core results so let me walk you

1180
00:37:00,620 --> 00:36:59,010
through it a little bit here I'm

1181
00:37:02,300 --> 00:37:00,630
simulating kind of the optimum ejection

1182
00:37:05,000 --> 00:37:02,310
case and h2 dominated atmosphere

1183
00:37:06,230 --> 00:37:05,010
orbiting an M dwarf star so that's the

1184
00:37:09,320 --> 00:37:06,240
kind of easiest thing we can hope to

1185
00:37:11,420 --> 00:37:09,330
detect the x axis here is molar

1186
00:37:14,030 --> 00:37:11,430
concentration the Y exit to access is

1187
00:37:16,130 --> 00:37:14,040
altitude in kilometers the solid lines

1188
00:37:17,930 --> 00:37:16,140

refer to an atmosphere forced by 10 to

1189

00:37:19,700 --> 00:37:17,940

the 10 molecules of pH 3 per square

1190

00:37:23,270 --> 00:37:19,710

centimeter per second and the dashed

1191

00:37:24,740 --> 00:37:23,280

lines by 10 for 10 to the 11 pH 3 ends

1192

00:37:26,860 --> 00:37:24,750

up being detectable at 10 to the 10 in

1193

00:37:29,960 --> 00:37:26,870

emission and 10 to the 11 in

1194

00:37:31,520 --> 00:37:29,970

transmission so how does it so these

1195

00:37:33,350 --> 00:37:31,530

numbers have no context how can you tell

1196

00:37:35,810 --> 00:37:33,360

if this is big or not oh well for

1197

00:37:37,940 --> 00:37:35,820

reference the modern methane flux is 10

1198

00:37:39,740 --> 00:37:37,950

to the 11 so what this means is in order

1199

00:37:41,270 --> 00:37:39,750

for PSA to be detectable it needs to be

1200

00:37:44,180 --> 00:37:41,280

a primary product of the biosphere

1201
00:37:45,980 --> 00:37:44,190
emitted of the same sort of a minute of

1202
00:37:46,880 --> 00:37:45,990
the same rates that methane is so this

1203
00:37:48,980 --> 00:37:46,890
bias tree needs to

1204
00:37:50,809 --> 00:37:48,990
choosing to make pastry at the same rate

1205
00:37:52,460 --> 00:37:50,819
that our biosphere is choosing to make

1206
00:37:53,599 --> 00:37:52,470
methane there are scenarios in which we

1207
00:37:55,910 --> 00:37:53,609
can begin envision this happening

1208
00:37:57,620 --> 00:37:55,920
particularly acidic and acidic a toxic

1209
00:37:59,599 --> 00:37:57,630
and warm environments but this is by no

1210
00:38:01,579 --> 00:37:59,609
means guaranteed so the punchline here

1211
00:38:02,990 --> 00:38:01,589
is if you see pH 3 it's a pretty good

1212
00:38:04,400 --> 00:38:03,000
sign view but life we shouldn't

1213
00:38:08,210 --> 00:38:04,410

necessarily go ahead and put the house

1214

00:38:09,950 --> 00:38:08,220

that you'll find pH 3 the scenario is

1215

00:38:14,390 --> 00:38:09,960

the situation is pretty similar for

1216

00:38:16,640 --> 00:38:14,400

isoprene so isoprene has is a is a

1217

00:38:19,099 --> 00:38:16,650

relatively calm Jaime is a relatively

1218

00:38:20,839 --> 00:38:19,109

big hydrocarbon it has the advantage

1219

00:38:22,339 --> 00:38:20,849

that unlike pastry it is a massive

1220

00:38:24,289 --> 00:38:22,349

product of biochemistry it's emitted of

1221

00:38:26,180 --> 00:38:24,299

the same mass flux that methane is and

1222

00:38:27,859 --> 00:38:26,190

it's emitted by almost every kind of

1223

00:38:29,359 --> 00:38:27,869

lights if it's emitted by microbes its

1224

00:38:31,250 --> 00:38:29,369

emitted by trees it's made up by us

1225

00:38:33,109 --> 00:38:31,260

everything pretty much everything gives

1226

00:38:34,099 --> 00:38:33,119

up by isoprene it's very deeply rooted

1227

00:38:37,039 --> 00:38:34,109

in the chain of the Tree of Life

1228

00:38:38,839 --> 00:38:37,049

it's spectrally detectable with a giant

1229

00:38:40,670 --> 00:38:38,849

glaring caveat that it's easy to confuse

1230

00:38:42,170 --> 00:38:40,680

with ch4 so you need to be careful in

1231

00:38:44,450 --> 00:38:42,180

your observations in a few bands to make

1232

00:38:46,339 --> 00:38:44,460

sure you can distinguish between ch4 an

1233

00:38:48,680 --> 00:38:46,349

ice cream and it has no non false

1234

00:38:50,990 --> 00:38:48,690

positive mechanisms but it's even more

1235

00:38:52,940 --> 00:38:51,000

photo chemically reactive than pH 3 is

1236

00:38:55,069 --> 00:38:52,950

and you'd need on the order of 10 to the

1237

00:38:56,900 --> 00:38:55,079

12 you'd need on the order of 10 to the

1238

00:38:58,730 --> 00:38:56,910

twelfth molecules per square centimeter

1239

00:39:00,140 --> 00:38:58,740

every second detected so you need your

1240

00:39:03,140 --> 00:39:00,150

biosphere to be producing it at about

1241

00:39:05,569 --> 00:39:03,150

about a rate of 20 or 30 times that our

1242

00:39:07,670 --> 00:39:05,579

biosphere produces isoprene today so not

1243

00:39:09,559 --> 00:39:07,680

ruled so not completely implausible but

1244

00:39:10,819 --> 00:39:09,569

also not something it but now some it's

1245

00:39:14,150 --> 00:39:10,829

particularly so it's worth checking for

1246

00:39:15,559 --> 00:39:14,160

but not worth betting the house on the

1247

00:39:16,940 --> 00:39:15,569

key thing that jumps out to us in both

1248

00:39:20,120 --> 00:39:16,950

of these scenarios that M dwarfs are

1249

00:39:21,769 --> 00:39:20,130

really an ideal detection case all of

1250

00:39:23,120 --> 00:39:21,779

these gases are able to build up to much

1251

00:39:24,890 --> 00:39:23,130

higher concentrations and planets

1252

00:39:27,349 --> 00:39:24,900

orbiting M dwarfs because M works our

1253

00:39:28,759 --> 00:39:27,359

low UV environments and the main control

1254

00:39:30,700 --> 00:39:28,769

of the concentrations of all of these

1255

00:39:33,079 --> 00:39:30,710

gases directly or indirectly are UV

1256

00:39:35,599 --> 00:39:33,089

directly UV can directly fertilize these

1257

00:39:37,940 --> 00:39:35,609

molecules but indirectly UV will anyway

1258

00:39:39,740 --> 00:39:37,950

fertilize molecules like CO_2 and H_2O and

1259

00:39:41,210 --> 00:39:39,750

the radicals they generate will then

1260

00:39:43,099 --> 00:39:41,220

wander around a blow of these molecules

1261

00:39:45,019 --> 00:39:43,109

as well in fact for these molecules in

1262

00:39:46,370 --> 00:39:45,029

the scenarios we simulated radical loss

1263

00:39:48,289 --> 00:39:46,380

was the main lost mechanism and

1264

00:39:49,600 --> 00:39:48,299

ultimately that is controlled by the UV

1265

00:39:52,360 --> 00:39:49,610

environment

1266

00:39:54,850 --> 00:39:52,370

that's just that's illustrated and uh so

1267

00:39:57,070 --> 00:39:54,860

this is a result that that is similar to

1268

00:39:59,350 --> 00:39:57,080

what Segura at all 2005 on procedure

1269

00:40:01,720 --> 00:39:59,360

series IIan CH sport and this is just an

1270

00:40:05,020 --> 00:40:01,730

illustration of that this here I've

1271

00:40:06,730 --> 00:40:05,030

simulated ps3 build up in to exoplanet

1272

00:40:07,870 --> 00:40:06,740

atmospheres the parameters are identical

1273

00:40:09,640 --> 00:40:07,880

except that one of them orbits a

1274

00:40:11,500 --> 00:40:09,650

sun-like stars and one of them orbits

1275

00:40:12,850 --> 00:40:11,510

Emperor and we see that in the case of

1276
00:40:14,860 --> 00:40:12,860
the Emperor it built it goes much higher

1277
00:40:15,910 --> 00:40:14,870
so better for transmission and it builds

1278
00:40:20,410 --> 00:40:15,920
up to a few orders of magnitude higher

1279
00:40:22,360 --> 00:40:20,420
in concentration so M Dwarfs mmm gross

1280
00:40:25,270 --> 00:40:22,370
remain an ideal a detection case the

1281
00:40:26,770 --> 00:40:25,280
cult of M Perkins continues so to

1282
00:40:29,320 --> 00:40:26,780
summarize the key takeaways from the bio

1283
00:40:31,030 --> 00:40:29,330
signatures part of the talk the gold

1284
00:40:34,030 --> 00:40:31,040
band standard by a signature if you can

1285
00:40:35,320 --> 00:40:34,040
detect it remains o to ch4 in h2o if

1286
00:40:36,820 --> 00:40:35,330
you're not able to detect it and you're

1287
00:40:38,860 --> 00:40:36,830
looking for a single gas by a signature

1288
00:40:41,770 --> 00:40:38,870

for example but this is a to CH for

1289

00:40:43,630 --> 00:40:41,780

trade off the simple molecules like o to

1290

00:40:45,880 --> 00:40:43,640

methane and to and so on and so forth

1291

00:40:47,290 --> 00:40:45,890

are excellent detection prospects but

1292

00:40:48,610 --> 00:40:47,300

they have a substantial false positive

1293

00:40:50,770 --> 00:40:48,620

risk because nature can make those

1294

00:40:52,750 --> 00:40:50,780

molecules relatively easily as well the

1295

00:40:54,730 --> 00:40:52,760

complicated molecules like ch₃

1296

00:40:57,160 --> 00:40:54,740

organosulfur is pitched in isoprene a

1297

00:40:59,050 --> 00:40:57,170

little false positive risk but you need

1298

00:41:00,640 --> 00:40:59,060

very high fluxes in order for them to be

1299

00:41:01,900 --> 00:41:00,650

detectable and it's not clearly at

1300

00:41:03,970 --> 00:41:01,910

whether or not that's plausible only

1301

00:41:06,700 --> 00:41:03,980

observations will tell on the end in all

1302

00:41:08,200 --> 00:41:06,710

cases m-dwarf during the aqwal variant

1303

00:41:09,700 --> 00:41:08,210

optimal not just for their small sizes

1304

00:41:11,980 --> 00:41:09,710

but because of their small UV fluxes

1305

00:41:12,850 --> 00:41:11,990

which means that it's easy for these

1306

00:41:16,870 --> 00:41:12,860

gases they build up to high

1307

00:41:18,130 --> 00:41:16,880

concentrations so to bring them bring

1308

00:41:19,780 --> 00:41:18,140

the talk back to the new questions that

1309

00:41:21,220 --> 00:41:19,790

motivated it we wanted to understand a

1310

00:41:22,510 --> 00:41:21,230

little bit about prebiotic chemistry of

1311

00:41:24,430 --> 00:41:22,520

bias occurs in the connection between

1312

00:41:26,110 --> 00:41:24,440

them mediated by UV light these are

1313

00:41:27,760 --> 00:41:26,120

giant fields in Korean which have only

1314

00:41:29,260 --> 00:41:27,770

touched necessarily in a few small parts

1315

00:41:31,090 --> 00:41:29,270

of it so if you have more questions I

1316

00:41:34,120 --> 00:41:31,100

hope you'll ask them well you'll ask

1317

00:41:36,190 --> 00:41:34,130

them to Q&A but to summarize the parts

1318

00:41:37,870 --> 00:41:36,200

of it that I talked about in terms of UV

1319

00:41:39,190 --> 00:41:37,880

light and prebiotic chemistry UV light

1320

00:41:40,330 --> 00:41:39,200

plays a controlling role in the crea

1321

00:41:42,640 --> 00:41:40,340

biotic environment that controls a

1322

00:41:44,110 --> 00:41:42,650

buildup of the environmental reagents

1323

00:41:47,340 --> 00:41:44,120

that could power the emergence of life

1324

00:41:49,600 --> 00:41:47,350

in particular it restricts and ox2

1325

00:41:50,950 --> 00:41:49,610

strictly to shallow ponds so if origin

1326

00:41:52,810 --> 00:41:50,960

of life does require and wax

1327

00:41:55,000 --> 00:41:52,820

it'll have trouble working in erosion

1328

00:41:56,200 --> 00:41:55,010

but it might work in a shallow pond so

1329

00:41:57,310 --> 00:41:56,210

we should think about those in grounds a

1330

00:41:59,380 --> 00:41:57,320

little bit

1331

00:42:01,120 --> 00:41:59,390

if you do have that UV you can also do

1332

00:42:02,500 --> 00:42:01,130

great things for you it can power a wide

1333

00:42:04,390 --> 00:42:02,510

range of synthesis pathways in

1334

00:42:06,630 --> 00:42:04,400

particular if conduction with sulphide

1335

00:42:08,800 --> 00:42:06,640

it can solve the reduction problem and

1336

00:42:10,300 --> 00:42:08,810

Ember ups are a really exciting test

1337

00:42:11,560 --> 00:42:10,310

case in this regard because they're low

1338

00:42:12,670 --> 00:42:11,570

UV environments which means that we

1339

00:42:15,160 --> 00:42:12,680

might be able to use them to test

1340

00:42:16,540 --> 00:42:15,170

theories of abiogenesis in terms of UV

1341

00:42:18,100 --> 00:42:16,550

light and bio signatures you use this

1342

00:42:19,570 --> 00:42:18,110

ability as important here because it's

1343

00:42:21,370 --> 00:42:19,580

the ultimate control on the build-up of

1344

00:42:24,280 --> 00:42:21,380

potential biomolecule signatures in

1345

00:42:26,080 --> 00:42:24,290

planetary atmospheres biosignatures we

1346

00:42:27,670 --> 00:42:26,090

divided to tell it two categories one

1347

00:42:29,320 --> 00:42:27,680

are the simple molecules which tend to

1348

00:42:31,990 --> 00:42:29,330

have high false positive risk but are

1349

00:42:33,910 --> 00:42:32,000

very detectable and the other category

1350

00:42:35,500 --> 00:42:33,920

are the hard to make molecules which

1351

00:42:36,880 --> 00:42:35,510

have a little false positive risk but

1352

00:42:38,230 --> 00:42:36,890

you need very high flux does it affect

1353

00:42:39,100 --> 00:42:38,240

them and it's not clear that biology

1354

00:42:40,830 --> 00:42:39,110

will choose to make that choice

1355

00:42:43,300 --> 00:42:40,840

elsewhere in the universe

1356

00:42:44,260 --> 00:42:43,310

in all scenarios UV controls are built

1357

00:42:46,300 --> 00:42:44,270

up as a consequence

1358

00:42:47,770 --> 00:42:46,310

mber ups means the ideal place to look

1359

00:42:49,690 --> 00:42:47,780

vote for the perspective of constraining

1360

00:42:51,040 --> 00:42:49,700

theories of abiogenesis and also just in

1361

00:42:52,030 --> 00:42:51,050

the perspective of being able to make

1362

00:42:54,910 --> 00:42:52,040

that constraint of the first place

1363

00:42:56,380 --> 00:42:54,920

looking for these IO signatures that's

1364

00:42:57,640 --> 00:42:56,390

about all I've got I'd like to thank my

1365

00:42:59,410 --> 00:42:57,650

colleagues collaborators and especially

1366

00:43:01,060 --> 00:42:59,420

my funding source assignments foundation

1367

00:43:10,259 --> 00:43:01,070

I'll leave my slides up and I'd love to

1368

00:43:14,170 --> 00:43:12,579

thank you for that talk and while the

1369

00:43:15,849 --> 00:43:14,180

mics are going around I wanted to take

1370

00:43:19,299 --> 00:43:15,859

the prior to pass the first question and

1371

00:43:21,309 --> 00:43:19,309

it's about flares so you said that the

1372

00:43:23,799 --> 00:43:21,319

UV controls the build-up of the isoprene

1373

00:43:24,849 --> 00:43:23,809

in the peach 3 but then if the

1374

00:43:27,190 --> 00:43:24,859

steady-state is too low to actually

1375

00:43:28,509 --> 00:43:27,200

destroy them but then the flares would

1376

00:43:30,970 --> 00:43:28,519

have destroyed them because increases

1377

00:43:32,349 --> 00:43:30,980

the UV flux but is the time scale like

1378

00:43:33,970 --> 00:43:32,359

not enough that it can see can you

1379

00:43:35,079 --> 00:43:33,980

building up early that is a great

1380

00:43:36,130 --> 00:43:35,089

question that's something we'd like to

1381

00:43:37,720 --> 00:43:36,140

address in future work what is the

1382

00:43:40,960 --> 00:43:37,730

effect of time written AMA such as

1383

00:43:42,519 --> 00:43:40,970

flares and not just the UV which from

1384

00:43:43,720 --> 00:43:42,529

work by Matt Tilley and I'm taking a

1385

00:43:46,569 --> 00:43:43,730

segura might actually be relatively

1386

00:43:47,799 --> 00:43:46,579

limited but from the particle fluxes so

1387

00:43:49,599 --> 00:43:47,809

that's not something that we understand

1388

00:43:51,039 --> 00:43:49,609

yet my bet is that it would probably not

1389

00:43:52,089 --> 00:43:51,049

do great things for them as biasing

1390

00:43:54,999 --> 00:43:52,099

throughs but we need to think about that

1391

00:44:04,390 --> 00:43:55,009

in a lot more death thank you alright

1392

00:44:07,299 --> 00:44:04,400

question if you can go to see Amelia hi

1393

00:44:10,239 --> 00:44:07,309

I have a question we got a pH 3 SMI your

1394

00:44:13,140 --> 00:44:10,249

signature you were using a hydrogen

1395

00:44:16,269 --> 00:44:13,150

dominated atmospheres regulations but

1396

00:44:19,690 --> 00:44:16,279

you you create a log of pH free without

1397

00:44:21,370 --> 00:44:19,700

any biology involved hydrogen dominated

1398

00:44:22,960 --> 00:44:21,380

atmosphere so how is that the

1399

00:44:24,940 --> 00:44:22,970

biosignature not under habitable

1400

00:44:27,400 --> 00:44:24,950

conditions you don't the formation of pH

1401

00:44:28,630 --> 00:44:27,410

3 in h2 dominated atmospheres is not

1402

00:44:30,190 --> 00:44:28,640

thermodynamically favored at

1403

00:44:32,349 --> 00:44:30,200

temperatures lower than about 800 Kelvin

1404

00:44:34,390 --> 00:44:32,359

in the case of the gas giants where pH 3

1405

00:44:35,589 --> 00:44:34,400

is detected it's thought that it's up

1406

00:44:37,569 --> 00:44:35,599

from deep regions of the atmosphere

1407

00:44:43,620 --> 00:44:37,579

where the conditions are a lot higher

1408

00:44:54,999 --> 00:44:52,690

can we do down here in the front so if I

1409

00:44:57,460 --> 00:44:55,009

understood your points correctly you

1410

00:45:00,519 --> 00:44:57,470

need UV light to power some of those

1411

00:45:01,930 --> 00:45:00,529

prebiotic chemistry and basically as an

1412

00:45:03,880 --> 00:45:01,940

energy source but then I think you're

1413

00:45:05,170 --> 00:45:03,890

also telling us that M drawers are

1414

00:45:07,660 --> 00:45:05,180

particularly good because you don't get

1415

00:45:10,089 --> 00:45:07,670

too much UV so do you foresee there

1416

00:45:12,880 --> 00:45:10,099

being like I don't know maybe not a fine

1417

00:45:15,579 --> 00:45:12,890

tuning problem but a sort of a how

1418

00:45:17,710 --> 00:45:15,589

precise you have to be to be just enough

1419

00:45:19,450 --> 00:45:17,720

as an energy source but not too much UV

1420

00:45:21,789 --> 00:45:19,460

that you're basically killing your

1421

00:45:25,660 --> 00:45:21,799

prospects for

1422

00:45:26,980 --> 00:45:25,670

so I argue that the better way to think

1423

00:45:28,720 --> 00:45:26,990

about this is not let's assume we

1424

00:45:29,980 --> 00:45:28,730

understand how life forms and then try

1425

00:45:32,410 --> 00:45:29,990

to figure out like we can think about

1426

00:45:33,849 --> 00:45:32,420

that a little bit but I think M dwarfs

1427

00:45:35,289 --> 00:45:33,859

are so observationally favorite in so

1428

00:45:36,819 --> 00:45:35,299

many ways they're the ideal test case in

1429

00:45:38,740 --> 00:45:36,829

so many ways we're gonna look for life

1430

00:45:40,359 --> 00:45:38,750

there anyway so you should instead ask

1431

00:45:41,380 --> 00:45:40,369

what can searching for life about M

1432

00:45:43,030 --> 00:45:41,390

gross tell us about theories of

1433

00:45:45,339 --> 00:45:43,040

abiogenesis so we're gonna make the

1434

00:45:46,569 --> 00:45:45,349

measurements anyway I prefer to ask once

1435

00:45:47,380 --> 00:45:46,579

we make those four instruments and we

1436

00:45:48,789 --> 00:45:47,390

find results

1437

00:45:51,789 --> 00:45:48,799

what can the positive negative detection

1438

00:45:54,309 --> 00:45:51,799

tell us a positive detection potentially

1439

00:45:55,569 --> 00:45:54,319

has the opportunity to tell us that UV

1440

00:45:56,710 --> 00:45:55,579

light is not required for the origin of

1441

00:45:58,240 --> 00:45:56,720

life and we need to go back to drawing

1442

00:46:00,609 --> 00:45:58,250

Gordon a lot of this which within of

1443

00:46:04,839 --> 00:46:00,619

itself be quite exciting a negative

1444

00:46:07,210 --> 00:46:04,849

detection well I guess a negative yeah

1445

00:46:08,530 --> 00:46:07,220

well they might be a UV light might have

1446

00:46:09,819 --> 00:46:08,540

helped here but like it wouldn't rule

1447

00:46:11,980 --> 00:46:09,829

out that's true it would at least tell

1448

00:46:13,420 --> 00:46:11,990

you that UV light is not essential by

1449

00:46:14,680 --> 00:46:13,430

contrast and negative detection if you

1450

00:46:16,059 --> 00:46:14,690

keep finding negative defections and you

1451

00:46:17,829 --> 00:46:16,069

do find life elsewhere in the universe

1452

00:46:19,059 --> 00:46:17,839

around higher math stars that would be a

1453

00:46:20,680 --> 00:46:19,069

hint that you'd be life is essential so

1454

00:46:22,049 --> 00:46:20,690

I prefer to think of it in the other way

1455

00:46:24,130 --> 00:46:22,059

around

1456

00:46:25,720 --> 00:46:24,140

do you don't think both of your points

1457

00:46:27,130 --> 00:46:25,730

can be correct then because they seem to

1458

00:46:28,930 --> 00:46:27,140

be then contradicting each other I

1459

00:46:30,460 --> 00:46:28,940

understood you correctly I think that

1460

00:46:31,839 --> 00:46:30,470

this is a big and complicated question

1461

00:46:34,299 --> 00:46:31,849

and we should try to work at it both

1462

00:46:35,799 --> 00:46:34,309

ends if we can and again like the priors

1463

00:46:37,450 --> 00:46:35,809

that I have going into this from what I

1464

00:46:39,910 --> 00:46:37,460

understand at the chemistry aspect of it

1465

00:46:41,770 --> 00:46:39,920

I do favor a little bit the idea that UV

1466

00:46:42,970 --> 00:46:41,780

light is essential so if you ask me to

1467

00:46:45,190 --> 00:46:42,980

put my money on it and that's what

1468

00:46:46,000 --> 00:46:45,200

that's what I would bet on but my

1469

00:46:47,319 --> 00:46:46,010

opinion doesn't matter

1470

00:46:48,490 --> 00:46:47,329

nature's opinion is what matters here

1471

00:46:50,140 --> 00:46:48,500

and what can support it to me about

1472

00:46:51,849 --> 00:46:50,150

exoplanets is that it's an opportunity

1473

00:46:59,770 --> 00:46:51,859

for nature to tell us how she prefers to

1474

00:47:03,069 --> 00:46:59,780

work Colin I've got another question

1475

00:47:05,770 --> 00:47:03,079

about phosphine which is why if we had

1476
00:47:08,319 --> 00:47:05,780
life anything like earth life why would

1477
00:47:12,280 --> 00:47:08,329
it make it at scale because phosphorous

1478
00:47:14,799 --> 00:47:12,290
an essential nutrient and that you with

1479
00:47:17,319 --> 00:47:14,809
the possible exception of using

1480
00:47:19,390 --> 00:47:17,329
methylated compounds to transfer some

1481
00:47:20,829 --> 00:47:19,400
nutrients from the ocean to land where

1482
00:47:23,589 --> 00:47:20,839
they were abundant did the ocean and not

1483
00:47:25,630 --> 00:47:23,599
abundant on land but phosphorous is

1484
00:47:27,940 --> 00:47:25,640
abundant of land and not abundant in the

1485
00:47:31,839 --> 00:47:27,950
ocean so why would we put it into gas

1486
00:47:33,880 --> 00:47:31,849
form to get rid of it I don't know but

1487
00:47:34,660 --> 00:47:33,890
the fundamental answer is life does it

1488
00:47:36,670 --> 00:47:34,670

anyway so

1489

00:47:39,040 --> 00:47:36,680

we should deal with that in particular

1490

00:47:40,840 --> 00:47:39,050

so I think one of the questions you're

1491

00:47:42,790 --> 00:47:40,850

asking is is there by is there detection

1492

00:47:43,420 --> 00:47:42,800

of phosphorous production and the answer

1493

00:47:44,850 --> 00:47:43,430

that question

1494

00:47:47,560 --> 00:47:44,860

broadly speaking seems to be yes

1495

00:47:49,540 --> 00:47:47,570

phosphorus keys being detected over in

1496

00:47:51,580 --> 00:47:49,550

over environments that are anoxic and a

1497

00:47:53,380 --> 00:47:51,590

little bit warm for example it's keeps

1498

00:47:55,540 --> 00:47:53,390

being detected over systems like sewage

1499

00:47:57,670 --> 00:47:55,550

plants it's detected over it's detected

1500

00:47:59,320 --> 00:47:57,680

from the flat land the exhausted various

1501
00:48:01,960 --> 00:47:59,330
animals who's coming out of intestinal

1502
00:48:03,280 --> 00:48:01,970
tracts it's detected and it's also been

1503
00:48:04,840 --> 00:48:03,290
detected in laboratory contexts where

1504
00:48:06,100 --> 00:48:04,850
people have taken these microbes growing

1505
00:48:08,320 --> 00:48:06,110
them on phosphate and it seems to

1506
00:48:09,910 --> 00:48:08,330
convert it most of it to phosphine so it

1507
00:48:11,380 --> 00:48:09,920
seems that life is chosen to do this and

1508
00:48:13,330 --> 00:48:11,390
we should maybe try to figure out why I

1509
00:48:15,970 --> 00:48:13,340
should mention that Jana but Kowski has

1510
00:48:20,080 --> 00:48:15,980
some ideas here in particular under warm

1511
00:48:22,030 --> 00:48:20,090
acidic conditions reduction of I don't

1512
00:48:23,350 --> 00:48:22,040
know the details on this better in his

1513
00:48:25,750 --> 00:48:23,360

paper he argues that reduction of

1514

00:48:26,980 --> 00:48:25,760

phosphate to phosphine can liberate free

1515

00:48:28,360 --> 00:48:26,990

energy so it's potentially an energy

1516

00:48:30,160 --> 00:48:28,370

source if you have phosphate available

1517

00:48:32,110 --> 00:48:30,170

and he also thinks about in the terms of

1518

00:48:33,310 --> 00:48:32,120

a signaling mechanism but I would refer

1519

00:48:37,090 --> 00:48:33,320

to Janish on that one I don't know the

1520

00:48:44,020 --> 00:48:37,100

details of that aspect of it RJ up in

1521

00:48:48,220 --> 00:48:46,510

you mentioned high fluxes of mass

1522

00:48:48,700 --> 00:48:48,230

between planetary bodies in the solar

1523

00:48:52,330 --> 00:48:48,710

system

1524

00:48:54,070 --> 00:48:52,340

and how that that kind of might prevent

1525

00:48:55,510 --> 00:48:54,080

them from giving us much information

1526
00:48:56,710 --> 00:48:55,520
about abiogenesis if we found something

1527
00:48:57,670 --> 00:48:56,720
unlike an icy world or something like

1528
00:48:59,980 --> 00:48:57,680
that cuz I might have come from Earth

1529
00:49:02,880 --> 00:48:59,990
but uh do we have any good idea about

1530
00:49:05,560 --> 00:49:02,890
the flux of mass between stellar systems

1531
00:49:07,810 --> 00:49:05,570
for example like if we found life on a

1532
00:49:09,460 --> 00:49:07,820
planet orbiting an M dwarf how sure

1533
00:49:11,410 --> 00:49:09,470
could we be that it hadn't just pans

1534
00:49:14,140 --> 00:49:11,420
permed from somewhere else that's a

1535
00:49:15,490 --> 00:49:14,150
really great question I actually think

1536
00:49:17,280 --> 00:49:15,500
someone has worked of the numbers on

1537
00:49:19,480 --> 00:49:17,290
this but I don't remember the citation

1538
00:49:20,530 --> 00:49:19,490

so I guess you'll have to take what I

1539

00:49:22,420 --> 00:49:20,540

say with a grain of salt my

1540

00:49:23,890 --> 00:49:22,430

understanding is that it has been

1541

00:49:26,050 --> 00:49:23,900

quantified and it's a very low risk of

1542

00:49:27,400 --> 00:49:26,060

transfer very low rate of transfer but I

1543

00:49:33,940 --> 00:49:27,410

don't remember the reference so I can't

1544

00:49:39,299 --> 00:49:33,950

say that state that for certain yeah I

1545

00:49:47,759 --> 00:49:45,089

and then over the wall to Sara I have a

1546

00:49:49,140 --> 00:49:47,769

quick question and a quick comment I'll

1547

00:49:50,999 --> 00:49:49,150

do the comment first I just wanted to

1548

00:49:52,579 --> 00:49:51,009

emphasize what I presented yesterday

1549

00:49:55,199 --> 00:49:52,589

that we're seeing organosulfur compounds

1550

00:50:00,299 --> 00:49:55,209

in our experiment being a biotic we

1551
00:50:02,669 --> 00:50:00,309
produced the question is if you favor UV

1552
00:50:03,959 --> 00:50:02,679
mechanism to produce nucleobases I was

1553
00:50:05,909 --> 00:50:03,969
intrigued by the fact that you decided

1554
00:50:08,039 --> 00:50:05,919
to completely ignore photons short of

1555
00:50:10,499 --> 00:50:08,049
100 nanometers because if you're going

1556
00:50:12,059 --> 00:50:10,509
to make nucleobases in a nitrogen

1557
00:50:13,439 --> 00:50:12,069
dominated atmosphere you have to break

1558
00:50:15,449 --> 00:50:13,449
the nitrogen somehow and you need

1559
00:50:16,529 --> 00:50:15,459
photons shorter 100 nanometers though I

1560
00:50:18,569 --> 00:50:16,539
missed something

1561
00:50:20,519 --> 00:50:18,579
so there's two really great points here

1562
00:50:21,779 --> 00:50:20,529
one is I think it's a really great point

1563
00:50:23,189 --> 00:50:21,789

about the Organa cell for production

1564

00:50:25,679 --> 00:50:23,199

potentially high up in the atmosphere I

1565

00:50:27,659 --> 00:50:25,689

think it'd be really instructive to gain

1566

00:50:28,679 --> 00:50:27,669

a quantification of the of the amount of

1567

00:50:29,880 --> 00:50:28,689

that we could expect a natural

1568

00:50:31,529 --> 00:50:29,890

environment something as units of

1569

00:50:33,269 --> 00:50:31,539

molecules per square centimeter per

1570

00:50:35,339 --> 00:50:33,279

second that's something we could plug in

1571

00:50:36,509 --> 00:50:35,349

terminal inter models and see if that

1572

00:50:37,890 --> 00:50:36,519

should produce a significant false

1573

00:50:40,109 --> 00:50:37,900

positive feature so that would be really

1574

00:50:41,249 --> 00:50:40,119

cool to have with regards to the second

1575

00:50:42,959 --> 00:50:41,259

base I think that's a really important

1576

00:50:44,880 --> 00:50:42,969

point we're not talking about the

1577

00:50:47,640 --> 00:50:44,890

abiotic synthesis of nucleobases nuclear

1578

00:50:50,009 --> 00:50:47,650

bases are easy you get a nuclear bases

1579

00:50:51,479 --> 00:50:50,019

almost any which way if you just take of

1580

00:50:52,499 --> 00:50:51,489

even moderately reducing mix of

1581

00:50:54,299 --> 00:50:52,509

compounds and even things that are not

1582

00:50:56,309 --> 00:50:54,309

super Mota clear adducing and you just

1583

00:50:57,809 --> 00:50:56,319

blasted for tree energy if you have the

1584

00:50:59,249 --> 00:50:57,819

ingredients available you make nuclear

1585

00:51:01,199 --> 00:50:59,259

bases in high-yield this goes back to

1586

00:51:03,419 --> 00:51:01,209

the classics and C's by arrow back in

1587

00:51:05,549 --> 00:51:03,429

1961 and this has been articulated in

1588

00:51:07,829 --> 00:51:05,559

various ways the key challenge that you

1589

00:51:09,630 --> 00:51:07,839

have is how do you make the nucleotides

1590

00:51:11,489 --> 00:51:09,640

how do you take the people how do you

1591

00:51:13,349 --> 00:51:11,499

can join the nuclear base to the sugar

1592

00:51:14,519 --> 00:51:13,359

to the phosphate group and in particular

1593

00:51:16,409 --> 00:51:14,529

how do you make that intermediate bond

1594

00:51:18,269 --> 00:51:16,419

that high energy and glycosidic c and

1595

00:51:20,399 --> 00:51:18,279

bond that joins the two of them together

1596

00:51:21,899 --> 00:51:20,409

that's what classical synthesis that go

1597

00:51:23,519 --> 00:51:21,909

about that start with the positive with

1598

00:51:25,169 --> 00:51:23,529

the light by making the LEGO pieces and

1599

00:51:26,789 --> 00:51:25,179

putting them together aren't able to do

1600

00:51:28,259 --> 00:51:26,799

so far because that bond is so high

1601
00:51:29,909 --> 00:51:28,269
energy if you inject enough energy into

1602
00:51:32,549 --> 00:51:29,919
the system to make it you break the LEGO

1603
00:51:34,019 --> 00:51:32,559
pieces as well so the the way this

1604
00:51:36,269 --> 00:51:34,029
particular pathway gets around that is

1605
00:51:37,799 --> 00:51:36,279
by cheating a little so the key

1606
00:51:39,569 --> 00:51:37,809
requirement that it has the really key

1607
00:51:41,849 --> 00:51:39,579
requirement in addition to UV is

1608
00:51:43,499 --> 00:51:41,859
availability of HCM and there you have

1609
00:51:44,849 --> 00:51:43,509
the C N bond to begin with so you build

1610
00:51:47,039 --> 00:51:44,859
a door you see you build a molecule

1611
00:51:48,390 --> 00:51:47,049
around it's like you start with it's

1612
00:51:49,649 --> 00:51:48,400
like instead of building a house and

1613
00:51:51,179 --> 00:51:49,659

then the rooms of house and putting it

1614

00:51:52,709 --> 00:51:51,189

together you start with a doorway and

1615

00:51:53,609 --> 00:51:52,719

build the house around that so that's

1616

00:51:58,259 --> 00:51:53,619

the way that they have invokes

1617

00:51:59,579 --> 00:51:58,269

hard to get around that problem I guess

1618

00:52:01,710 --> 00:51:59,589

just a comment that if you want to have

1619

00:52:04,109 --> 00:52:01,720

VN coming from the atmosphere you have

1620

00:52:05,759 --> 00:52:04,119

to break the nitrogen bond yeah you need

1621

00:52:07,170 --> 00:52:05,769

to you need either exogenous delivery or

1622

00:52:08,730 --> 00:52:07,180

you need some kind of mechanism for

1623

00:52:11,130 --> 00:52:08,740

example Attalla source of ch4 high in

1624

00:52:12,809 --> 00:52:11,140

the altitude or scps doing something

1625

00:52:14,279 --> 00:52:12,819

interesting interesting or mechanisms

1626
00:52:15,450 --> 00:52:14,289
like the ones you talked about which is

1627
00:52:17,160 --> 00:52:15,460
one of the reasons would be really great

1628
00:52:25,019 --> 00:52:17,170
to be able to incorporate those into our

1629
00:52:26,400 --> 00:52:25,029
models irrigators universe' why is it

1630
00:52:29,009 --> 00:52:26,410
the question that I thought Sarah was

1631
00:52:31,319 --> 00:52:29,019
going to ask which is what is the effect

1632
00:52:33,089 --> 00:52:31,329
of aerosols or clouds on the UV fluxes

1633
00:52:33,539 --> 00:52:33,099
at the surface that is an excellent

1634
00:52:36,930 --> 00:52:33,549
question

1635
00:52:44,489 --> 00:52:36,940
do I have a slide on this maybe hold on

1636
00:52:46,470 --> 00:52:44,499
how do I escape this where it is sorry I

1637
00:52:48,059 --> 00:52:46,480
have a lot of backup slides okay the

1638
00:52:49,200 --> 00:52:48,069

short term answer is that so we looked

1639

00:52:52,410 --> 00:52:49,210

at this particularly in the context of

1640

00:52:54,509 --> 00:52:52,420

early Mars the short answer is it

1641

00:52:56,339 --> 00:52:54,519

doesn't seem to be the key thing that's

1642

00:52:59,309 --> 00:52:56,349

going on here is that long long rid of

1643

00:53:01,319 --> 00:52:59,319

200 nanometres both CO₂ ice particles

1644

00:53:03,210 --> 00:53:01,329

and H₂ ice particles are again in that

1645

00:53:04,589 --> 00:53:03,220

strictly scattering regime which means

1646

00:53:06,420 --> 00:53:04,599

that again optical depth drops off

1647

00:53:08,249 --> 00:53:06,430

relatively slowly with a relatively

1648

00:53:10,259 --> 00:53:08,259

sorry transmission drops up slow with

1649

00:53:12,479 --> 00:53:10,269

the optical depth it goes as $1/\tau$

1650

00:53:14,009 --> 00:53:12,489

ought to be $e^{-\tau}$ in order to

1651
00:53:15,809 --> 00:53:14,019
significantly infect the surface of the

1652
00:53:17,249 --> 00:53:15,819
environment you need relatively thick

1653
00:53:19,859 --> 00:53:17,259
cloud decks you need to have context of

1654
00:53:22,019 --> 00:53:19,869
the order of optical depths of 10 to 100

1655
00:53:24,150 --> 00:53:22,029
in order to really suppress it and in

1656
00:53:25,920 --> 00:53:24,160
order and at least from the GCM models

1657
00:53:28,109 --> 00:53:25,930
of for example words were that all 2016

1658
00:53:33,170 --> 00:53:28,119
such thick cloud decks

1659
00:53:40,319 --> 00:53:36,979
and I'm sorry I don't know your name

1660
00:53:43,349 --> 00:53:40,329
well written by leiden observatory you

1661
00:53:46,380 --> 00:53:43,359
mentioned some high production rate for

1662
00:53:48,599 --> 00:53:46,390
some bio signature I was wondering did

1663
00:53:50,609 --> 00:53:48,609

you check about the impact on the

1664

00:53:52,739 --> 00:53:50,619

evolution of the atmosphere because of

1665

00:53:54,720 --> 00:53:52,749

this prediction rate for example in term

1666

00:53:56,430 --> 00:53:54,730

of greenhouse oh-ho

1667

00:53:57,509 --> 00:53:56,440

no we don't that's because impacts are

1668

00:53:59,069 --> 00:53:57,519

harder than we don't know how to do them

1669

00:54:02,609 --> 00:53:59,079

if you do please please please work with

1670

00:54:02,619 --> 00:54:11,490

right up front

1671

00:54:15,099 --> 00:54:13,510

my understanding is that is that

1672

00:54:17,529 --> 00:54:15,109

phosphate is the only really

1673

00:54:21,190 --> 00:54:17,539

biologically available form of

1674

00:54:24,220 --> 00:54:21,200

phosphorus and so on earth that comes

1675

00:54:27,010 --> 00:54:24,230

from a mineral exerting kind of

1676
00:54:29,559 --> 00:54:27,020
mineralogy I think it's new from apatite

1677
00:54:32,470 --> 00:54:29,569
apatite so how common do we expect

1678
00:54:35,079 --> 00:54:32,480
phosphorus to be on planets in terms of

1679
00:54:37,390 --> 00:54:35,089
delivery of phosphorus and how special

1680
00:54:38,829 --> 00:54:37,400
does a those a planets geochemistry have

1681
00:54:41,170 --> 00:54:38,839
to be in order to make a source of

1682
00:54:42,460 --> 00:54:41,180
phosphate do you have there any thoughts

1683
00:54:44,529 --> 00:54:42,470
on that

1684
00:54:46,059 --> 00:54:44,539
so that's a really good question the

1685
00:54:47,620 --> 00:54:46,069
phosphate cycle is something that's

1686
00:54:49,480 --> 00:54:47,630
really complicated and I don't know very

1687
00:54:52,059 --> 00:54:49,490
much about to be honest the phosphorous

1688
00:54:53,620 --> 00:54:52,069

cycle on modern earth so I can't say

1689

00:54:58,059 --> 00:54:53,630

state anything with a very high degree

1690

00:55:01,769 --> 00:54:58,069

of certainty oh yeah let me see if

1691

00:55:05,589 --> 00:55:04,120

don't actually think there is like I

1692

00:55:06,700 --> 00:55:05,599

think you and I both have the same basic

1693

00:55:08,319 --> 00:55:06,710

understanding of it which is that

1694

00:55:11,289 --> 00:55:08,329

phosphorus is important it's often

1695

00:55:13,029 --> 00:55:11,299

limiting is it we did check is there any

1696

00:55:15,099 --> 00:55:13,039

phosphorus on the surface of for example

1697

00:55:16,539 --> 00:55:15,109

earth or in the other rocky planets in

1698

00:55:17,980 --> 00:55:16,549

our solar system to produce these

1699

00:55:19,930 --> 00:55:17,990

detectable signatures and the answer is

1700

00:55:21,279 --> 00:55:19,940

definitely yes we don't even use we

1701
00:55:23,380 --> 00:55:21,289
don't even use a percentage of use much

1702
00:55:25,299 --> 00:55:23,390
much less so the number of phosphorus

1703
00:55:26,500 --> 00:55:25,309
atoms is not a limiting supply but in

1704
00:55:27,640 --> 00:55:26,510
terms of the more to compute I'll do

1705
00:55:29,170 --> 00:55:27,650
chemical cycling anything more

1706
00:55:32,710 --> 00:55:29,180
sophisticated we haven't done that yet

1707
00:55:35,260 --> 00:55:32,720
yeah and a related thing from nuclear

1708
00:55:36,279 --> 00:55:35,270
synthesis talks I've been at it seems

1709
00:55:38,650 --> 00:55:36,289
that although you would expect

1710
00:55:41,470 --> 00:55:38,660
phosphorus to be easily synthesized in

1711
00:55:43,029 --> 00:55:41,480
in high mass stars it's actually hard to

1712
00:55:44,349 --> 00:55:43,039
find where it's being synthesized and

1713
00:55:46,510 --> 00:55:44,359

there are a lot of seems to be open

1714

00:55:58,710 --> 00:55:46,520

questions about nucleosynthesis of

1715

00:56:04,030 --> 00:56:01,690

um I noticed in the like list of names

1716

00:56:06,730 --> 00:56:04,040

you gave her the very start you had John

1717

00:56:08,290 --> 00:56:06,740

Sutherland and I've read so his papers

1718

00:56:09,670 --> 00:56:08,300

were a prebiotic chemistry and I've read

1719

00:56:11,380 --> 00:56:09,680

some papers by this guy Bill Russell

1720

00:56:13,120 --> 00:56:11,390

who's a big proponent of like the

1721

00:56:14,950 --> 00:56:13,130

alkaline hydrothermal vent model and

1722

00:56:16,660 --> 00:56:14,960

they like they always like jab at each

1723

00:56:19,000 --> 00:56:16,670

other they like seem to think that each

1724

00:56:21,520 --> 00:56:19,010

other's ideas are both just on the face

1725

00:56:23,530 --> 00:56:21,530

of it ridiculous and and implausible so

1726

00:56:27,610 --> 00:56:23,540

do you think the alkaline hydrothermal

1727

00:56:29,880 --> 00:56:27,620

vent idea is dumb I know I certainly

1728

00:56:32,230 --> 00:56:29,890

don't think it is so I think that again

1729

00:56:33,820 --> 00:56:32,240

opinions of people tend to be relatively

1730

00:56:35,020 --> 00:56:33,830

useless what's relevant are experiments

1731

00:56:38,500 --> 00:56:35,030

and observations that will ultimately

1732

00:56:40,090 --> 00:56:38,510

constrain these answers I think that the

1733

00:56:43,240 --> 00:56:40,100

vents theory of life has many exciting

1734

00:56:44,710 --> 00:56:43,250

things going for it which is that which

1735

00:56:46,270 --> 00:56:44,720

is among other things it explains in

1736

00:56:48,880 --> 00:56:46,280

many aspects of modern biochemistry for

1737

00:56:51,910 --> 00:56:48,890

example the role of gradients I think

1738

00:56:54,040 --> 00:56:51,920

that what for me though I had the thing

1739

00:56:55,420 --> 00:56:54,050

that really convinces me is showing

1740

00:56:57,070 --> 00:56:55,430

something in a lab and showing that it

1741

00:56:59,260 --> 00:56:57,080

works so one thing that I would really

1742

00:57:00,880 --> 00:56:59,270

love to see from and I know the events

1743

00:57:02,620 --> 00:57:00,890

community is working on this is showing

1744

00:57:03,880 --> 00:57:02,630

simulating some of these scenarios and

1745

00:57:05,890 --> 00:57:03,890

showing how some of these more complex

1746

00:57:07,450 --> 00:57:05,900

biomolecules and systems cycles that

1747

00:57:09,160 --> 00:57:07,460

have been for which the theory isn't

1748

00:57:10,720 --> 00:57:09,170

work that well can be created in the lab

1749

00:57:12,820 --> 00:57:10,730

so that's something that would be really

1750

00:57:14,080 --> 00:57:12,830

cool that we're really cool to see they

1751
00:57:15,670 --> 00:57:14,090
should not be taken by the way as in

1752
00:57:17,260 --> 00:57:15,680
implicit criticism - I haven't done the

1753
00:57:18,760 --> 00:57:17,270
experiments that's because people have

1754
00:57:20,290 --> 00:57:18,770
been thinking about this this synthetic

1755
00:57:21,970 --> 00:57:20,300
kind of chemistry for much longer than

1756
00:57:23,710 --> 00:57:21,980
we're thinking about vent chemistry's so

1757
00:57:26,020 --> 00:57:23,720
they haven't had enough time yet so my

1758
00:57:27,880 --> 00:57:26,030
personal perspective is that we can't

1759
00:57:30,340 --> 00:57:27,890
rule we can't favor or disfavor strongly

1760
00:57:31,630 --> 00:57:30,350
either one yet we need to keep doing

1761
00:57:34,210 --> 00:57:31,640
experiments with the objective of

1762
00:57:36,250 --> 00:57:34,220
linking it fundamentally to in the end

1763
00:57:40,630 --> 00:57:36,260

something we can either measure in the