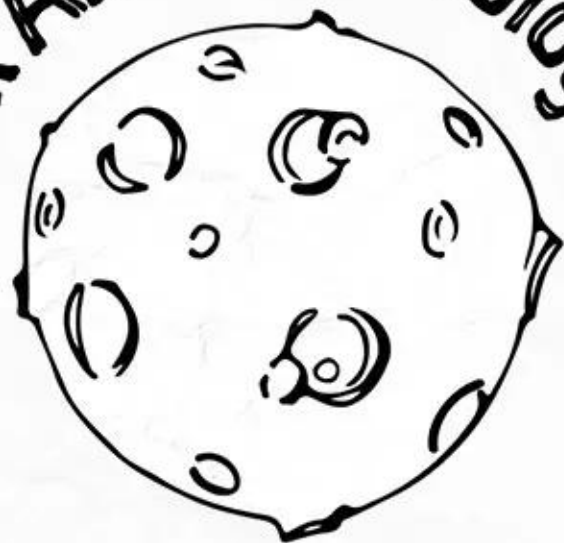


# Ask An Astrobiologist



EPISODE 16: OCTOBER 18<sup>TH</sup>, 2018

**DR. MORGAN CABLE**



**ASTROBIOLOGY PROGRAM**

1  
00:00:00,500 --> 00:00:29,529

[Music]

2  
00:00:33,410 --> 00:00:31,460  
greetings friends of escapology

3  
00:00:35,209 --> 00:00:33,420  
welcome to a brand new episode of ask an

4  
00:00:37,910 --> 00:00:35,219  
astrobiologist a show where we celebrate

5  
00:00:39,290 --> 00:00:37,920  
science and celebrate scientists my name

6  
00:00:41,060 --> 00:00:39,300  
is Sandra um and this program is made

7  
00:00:43,250 --> 00:00:41,070  
possible by contributions from the NASA

8  
00:00:45,830 --> 00:00:43,260  
Astrobiology program and a non profit

9  
00:00:47,690 --> 00:00:45,840  
blue marble space last month he had the

10  
00:00:50,029 --> 00:00:47,700  
great privilege of having at this very

11  
00:00:52,069 --> 00:00:50,039  
seat dr. Graham Lau talked to dr. Amanda

12  
00:00:53,720 --> 00:00:52,079  
Stockton at Georgia Tech and had a

13  
00:00:55,700 --> 00:00:53,730

fantastic conversation on light

14

00:00:58,029 --> 00:00:55,710

detection technologies field work in

15

00:01:01,250 --> 00:00:58,039

Iceland and how to detect life on Mars

16

00:01:03,619 --> 00:01:01,260

this week however and today in specially

17

00:01:05,210 --> 00:01:03,629

we are going to go far away to the solar

18

00:01:08,539 --> 00:01:05,220

system and we're gonna explore and talk

19

00:01:09,800 --> 00:01:08,549

about the moon Titan which is the second

20

00:01:12,109 --> 00:01:09,810

largest moon in the solar system that

21

00:01:13,789 --> 00:01:12,119

orbits the beautiful planet Saturn and

22

00:01:16,760 --> 00:01:13,799

in order to do that we'll be talking

23

00:01:19,700 --> 00:01:16,770

with dr. Morgan Cable who is a scientist

24

00:01:21,710 --> 00:01:19,710

at the famed Jet Propulsion Laboratory

25

00:01:24,289 --> 00:01:21,720

in the City of Pasadena in the United

26

00:01:27,230 --> 00:01:24,299

States but before we talk to her it's

27

00:01:29,539 --> 00:01:27,240

time for your monthly background quiz we

28

00:01:31,399 --> 00:01:29,549

all saw the message armed on the social

29

00:01:34,850 --> 00:01:31,409

medias Mike if you can put up the

30

00:01:37,370 --> 00:01:34,860

background from last month many of you

31

00:01:39,499 --> 00:01:37,380

got it right I think Eve over 40 of you

32

00:01:42,710 --> 00:01:39,509

got the correct answer it is of course

33

00:01:45,590 --> 00:01:42,720

the pamukkala Paulo pamukkale a terraces

34

00:01:48,020 --> 00:01:45,600

in southwest turkey those are travertine

35

00:01:50,240 --> 00:01:48,030

terraces and the water comes out from

36

00:01:53,030 --> 00:01:50,250

those hot springs full of calcium

37

00:01:55,179 --> 00:01:53,040

carbonate and as the co2 the gases the

38

00:01:57,920 --> 00:01:55,189

rocks that carbon carbonate rocks

39

00:02:00,740 --> 00:01:57,930

precipitate down to form a gel and over

40

00:02:02,719 --> 00:02:00,750

time solidify they've been used as pools

41

00:02:05,469 --> 00:02:02,729

for humans for medical reasons for

42

00:02:08,949 --> 00:02:05,479

thousands of years in fact is a Roman

43

00:02:11,809 --> 00:02:08,959

greco-roman rune at the top of it but

44

00:02:13,280 --> 00:02:11,819

humans as they do start to damage it as

45

00:02:13,850 --> 00:02:13,290

more and more more people got to it it

46

00:02:16,220 --> 00:02:13,860

was declared

47

00:02:19,220 --> 00:02:16,230

a World Heritage Site in 1988 so now we

48

00:02:21,170 --> 00:02:19,230

can only enjoy it with your eyes so we

49

00:02:23,210 --> 00:02:21,180

have three winners the third place gets

50

00:02:26,810 --> 00:02:23,220

the NASA stickers

51  
00:02:28,610 --> 00:02:26,820  
it is sarin knurl congratulations and

52  
00:02:31,730 --> 00:02:28,620  
the second place gets the NASA stickers

53  
00:02:33,980 --> 00:02:31,740  
as well as the astrobiology comic novels

54  
00:02:35,900 --> 00:02:33,990  
and those go to Anthony Adler

55  
00:02:38,630 --> 00:02:35,910  
congratulations Anthony and the first

56  
00:02:41,180 --> 00:02:38,640  
place who gets the stickers the graphic

57  
00:02:44,060 --> 00:02:41,190  
novels and the twin class goes to at

58  
00:02:46,790 --> 00:02:44,070  
organism 1974 congratulations to all of

59  
00:02:48,350 --> 00:02:46,800  
you next month we'll be giving out

60  
00:02:51,530 --> 00:02:48,360  
prizes for those of you who can guess

61  
00:02:53,479 --> 00:02:51,540  
what my current background is so enjoy

62  
00:02:56,330 --> 00:02:53,489  
any time during the show you have

63  
00:02:58,220 --> 00:02:56,340

questions from for dr. cable please put

64

00:03:00,380 --> 00:02:58,230

them on the second achat put them on

65

00:03:02,180 --> 00:03:00,390

twitter with hashtag ask astro bio or

66

00:03:07,070 --> 00:03:02,190

write in your comments on facebook live

67

00:03:10,280 --> 00:03:07,080

and here we go so Morgan it is great to

68

00:03:12,920 --> 00:03:10,290

have you on the show welcome hi Sandra

69

00:03:14,900 --> 00:03:12,930

I'm so happy to be here oh you have no

70

00:03:18,590 --> 00:03:14,910

idea I'm loving the Saturn the earrings

71

00:03:20,360 --> 00:03:18,600

here they look great you talk about so

72

00:03:22,280 --> 00:03:20,370

much science today I'm very excited what

73

00:03:24,440 --> 00:03:22,290

what we like to do on this show is get

74

00:03:26,300 --> 00:03:24,450

to know you a bit more as well and we're

75

00:03:27,710 --> 00:03:26,310

wondering you know like we like to do on

76  
00:03:30,020 --> 00:03:27,720  
this program is turning back the wheels

77  
00:03:31,970 --> 00:03:30,030  
of time if you have any stories on what

78  
00:03:35,630 --> 00:03:31,980  
made you interested in science to begin

79  
00:03:38,030 --> 00:03:35,640  
with well I actually grew up in Florida

80  
00:03:39,770 --> 00:03:38,040  
in a little town called Titusville that

81  
00:03:42,440 --> 00:03:39,780  
is right next to you Kennedy Space

82  
00:03:43,820 --> 00:03:42,450  
Center and so as a kid growing up I

83  
00:03:45,410 --> 00:03:43,830  
thought it was just normal to have

84  
00:03:47,990 --> 00:03:45,420  
Rockets kind of going off in your

85  
00:03:49,850 --> 00:03:48,000  
backyard actually all of my like

86  
00:03:53,270 --> 00:03:49,860  
elementary and middle schools we would

87  
00:03:54,949 --> 00:03:53,280  
time our fire drills around launches so

88  
00:03:57,020 --> 00:03:54,959

whatever space shuttle was gonna go up

89

00:03:58,520 --> 00:03:57,030

we would have our regularly scheduled

90

00:04:00,620 --> 00:03:58,530

fire drills and of a queue eight outside

91

00:04:01,880 --> 00:04:00,630

and we get to watch the launch and I

92

00:04:04,520 --> 00:04:01,890

thought that was just like a normal

93

00:04:06,920 --> 00:04:04,530

thing so it definitely had an impact on

94

00:04:10,100 --> 00:04:06,930

me my dad actually worked for NASA - he

95

00:04:12,830 --> 00:04:10,110

was a chemist I had inspiration all over

96

00:04:15,500 --> 00:04:12,840

that you know testing the boundaries of

97

00:04:17,060 --> 00:04:15,510

exploration both in terms of like taking

98

00:04:19,729 --> 00:04:17,070

people there and also extending our

99

00:04:21,890 --> 00:04:19,739

senses with robots just I knew that this

100

00:04:24,200 --> 00:04:21,900

was something we could do I knew I loved

101  
00:04:26,510 --> 00:04:24,210  
science and asking interesting questions

102  
00:04:27,170 --> 00:04:26,520  
and then going out and figuring out the

103  
00:04:28,670 --> 00:04:27,180  
answers to

104  
00:04:30,920 --> 00:04:28,680  
questions and so when I realize that

105  
00:04:33,490 --> 00:04:30,930  
could be a career and I could do it for

106  
00:04:35,600 --> 00:04:33,500  
stuff in space that was a no-brainer

107  
00:04:37,400 --> 00:04:35,610  
that's so exciting you know I went to

108  
00:04:39,650 --> 00:04:37,410  
university in Florida as well and I used

109  
00:04:41,450 --> 00:04:39,660  
to like run out of class during shuttle

110  
00:04:42,680 --> 00:04:41,460  
launches we didn't have any fire drills

111  
00:04:45,830 --> 00:04:42,690  
or any think about just run out of class

112  
00:04:47,240 --> 00:04:45,840  
even you know professor lecturing look

113  
00:04:48,770 --> 00:04:47,250

at the rocket well I'm gonna go back to

114

00:04:53,150 --> 00:04:48,780

class I got in trouble a few times but

115

00:04:55,969 --> 00:04:53,160

yeah it's awesome so then afterwards you

116

00:04:57,499 --> 00:04:55,979

went to do your PhD at Cal Tech but

117

00:05:00,469 --> 00:04:57,509

before that like how did you decide it

118

00:05:03,230 --> 00:05:00,479

wanted to be a doctor of science well my

119

00:05:05,570 --> 00:05:03,240

dad had a PhD in chemistry and so I sort

120

00:05:08,570 --> 00:05:05,580

of saw from him what that career path

121

00:05:10,219 --> 00:05:08,580

could be like and I'm actually a triplet

122

00:05:12,890 --> 00:05:10,229

my brother and sister ended up becoming

123

00:05:14,900 --> 00:05:12,900

MDS the other kind of doctor but we all

124

00:05:17,810 --> 00:05:14,910

sort of through school kind of pushed

125

00:05:20,180 --> 00:05:17,820

each other to do better and to work

126

00:05:21,830 --> 00:05:20,190

harder and to achieve more and that's a

127

00:05:23,870 --> 00:05:21,840

lesson that I carry through actually

128

00:05:25,400 --> 00:05:23,880

until today there's a saying what is it

129

00:05:27,260 --> 00:05:25,410

if you're the smartest person in the

130

00:05:28,999 --> 00:05:27,270

room you're in the wrong room like

131

00:05:32,659 --> 00:05:29,009

surrounding yourself with people who

132

00:05:34,219 --> 00:05:32,669

challenge you is a lesson that I think

133

00:05:37,219 --> 00:05:34,229

is really important and it's one of the

134

00:05:39,529 --> 00:05:37,229

reasons why we're able to do the amazing

135

00:05:44,450 --> 00:05:39,539

science and technological achievements

136

00:05:46,189 --> 00:05:44,460

at JPL that we do every day um so I had

137

00:05:48,469 --> 00:05:46,199

that inspiration when I was an

138

00:05:50,149 --> 00:05:48,479

undergraduate student I stayed in state

139

00:05:52,219 --> 00:05:50,159

I went to a college called Florida

140

00:05:55,730 --> 00:05:52,229

Atlantic University for my undergrad and

141

00:05:57,830 --> 00:05:55,740

I did a summer internship out at JPL now

142

00:05:59,480 --> 00:05:57,840

I strongly encourage this anyone who is

143

00:06:02,120 --> 00:05:59,490

an undergrad I think there are also

144

00:06:04,100 --> 00:06:02,130

programs for high school students and

145

00:06:06,050 --> 00:06:04,110

graduate students as well do an

146

00:06:08,300 --> 00:06:06,060

internship it's a great way for you to

147

00:06:10,580 --> 00:06:08,310

figure out whether it's a NASA Center or

148

00:06:11,930 --> 00:06:10,590

industry or what-have-you it's a great

149

00:06:13,730 --> 00:06:11,940

way for you to actually go there and

150

00:06:15,350 --> 00:06:13,740

figure out if that's a place that you

151  
00:06:18,110 --> 00:06:15,360  
could see yourself working in the future

152  
00:06:20,120 --> 00:06:18,120  
and you can network you can expand your

153  
00:06:22,279 --> 00:06:20,130  
network to be able to connect with

154  
00:06:24,680 --> 00:06:22,289  
people that can potentially hire you one

155  
00:06:26,779 --> 00:06:24,690  
day it's a great opportunity so I did

156  
00:06:29,020 --> 00:06:26,789  
that and ended up falling in love with

157  
00:06:31,640 --> 00:06:29,030  
JPL and with Caltech and that's what

158  
00:06:33,770 --> 00:06:31,650  
solidified my choice to go to Caltech

159  
00:06:35,420 --> 00:06:33,780  
for graduate school in chemistry so I

160  
00:06:38,510 --> 00:06:35,430  
sort of followed in my dad's footsteps

161  
00:06:40,890 --> 00:06:38,520  
that way and did you how do you benefit

162  
00:06:43,320 --> 00:06:40,900  
from from professor in terms of

163  
00:06:44,700 --> 00:06:43,330

who care about you as a person rather

164

00:06:46,320 --> 00:06:44,710

than you as your academics in other

165

00:06:48,360 --> 00:06:46,330

words you have mentors that help support

166

00:06:49,770 --> 00:06:48,370

you as you went through Cal Tech I mean

167

00:06:51,450 --> 00:06:49,780

it's not an easy university

168

00:06:54,390 --> 00:06:51,460

I'm telling more about that support

169

00:06:56,280 --> 00:06:54,400

network you had I yah So Cal Tech was

170

00:06:57,900 --> 00:06:56,290

was a very challenging environment but

171

00:06:59,670 --> 00:06:57,910

also very supportive one they actually

172

00:07:02,310 --> 00:06:59,680

encouraged a lot of collaboration and

173

00:07:04,590 --> 00:07:02,320

mentoring was a big part of my my

174

00:07:07,290 --> 00:07:04,600

education and continues to this day

175

00:07:09,780 --> 00:07:07,300

whether I went out and sought my own

176

00:07:12,960 --> 00:07:09,790

mentors whether they were chemistry

177

00:07:17,580 --> 00:07:12,970

professors people in my field or outside

178

00:07:19,380 --> 00:07:17,590

of my fields and even at JPL there's

179

00:07:22,170 --> 00:07:19,390

actually an official mentoring program

180

00:07:24,480 --> 00:07:22,180

that you can join to help link you with

181

00:07:26,850 --> 00:07:24,490

people who have a sort of higher level

182

00:07:28,860 --> 00:07:26,860

view of all the different projects going

183

00:07:31,860 --> 00:07:28,870

on and sort of where you might fit best

184

00:07:33,990 --> 00:07:31,870

in terms of your skills I think that

185

00:07:36,570 --> 00:07:34,000

whether there's a formal program that

186

00:07:39,390 --> 00:07:36,580

exists wherever you might be or if

187

00:07:41,730 --> 00:07:39,400

you're willing to just reach out to

188

00:07:44,250 --> 00:07:41,740

people either at your current level your

189

00:07:47,430 --> 00:07:44,260

peers or who are further along in their

190

00:07:50,150 --> 00:07:47,440

careers mentoring is a really amazing

191

00:07:53,400 --> 00:07:50,160

opportunity you should take advantage of

192

00:07:56,010 --> 00:07:53,410

Heiko all those words so chemistry is a

193

00:07:58,640 --> 00:07:56,020

very broad discipline what got you

194

00:08:03,450 --> 00:07:58,650

interested in astrobiology in particular

195

00:08:05,160 --> 00:08:03,460

well I've always loved I to me chemistry

196

00:08:06,990 --> 00:08:05,170

is the language through which the

197

00:08:08,790 --> 00:08:07,000

universe communicates right it's it's

198

00:08:12,630 --> 00:08:08,800

sort of the fundamental building blocks

199

00:08:14,190 --> 00:08:12,640

of biology right physics mostly deals

200

00:08:15,810 --> 00:08:14,200

with like atomic interactions right

201  
00:08:18,360 --> 00:08:15,820  
atoms but it's once you combine them

202  
00:08:20,940 --> 00:08:18,370  
into molecules and then you see how

203  
00:08:22,230 --> 00:08:20,950  
those molecules interact and react with

204  
00:08:24,930 --> 00:08:22,240  
each other that's where all the

205  
00:08:27,200 --> 00:08:24,940  
interesting stuff happens and so for me

206  
00:08:29,580 --> 00:08:27,210  
I was always fascinated in knots and

207  
00:08:31,500 --> 00:08:29,590  
actually this goes all the way back to

208  
00:08:34,140 --> 00:08:31,510  
eighth grade I was in eighth grade

209  
00:08:36,330 --> 00:08:34,150  
middle school student and I needed to do

210  
00:08:38,490 --> 00:08:36,340  
a science project at this point I had

211  
00:08:41,970 --> 00:08:38,500  
already been interested in NASA and

212  
00:08:43,890 --> 00:08:41,980  
planetary science and I ended up forming

213  
00:08:47,190 --> 00:08:43,900

a project around the question is there

214

00:08:50,400 --> 00:08:47,200

life on Mars and even at that middle

215

00:08:51,900 --> 00:08:50,410

school level I was able to put forth a

216

00:08:54,030 --> 00:08:51,910

question that was based on this

217

00:08:56,639 --> 00:08:54,040

interaction that basalt of

218

00:08:58,860 --> 00:08:56,649

kena croc has with liquid water it's

219

00:09:01,199 --> 00:08:58,870

called serpentinization it creates

220

00:09:03,930 --> 00:09:01,209

hydrogen and I had read an article in

221

00:09:06,240 --> 00:09:03,940

science news about this bacteria this

222

00:09:08,160 --> 00:09:06,250

actually it was a community of all sorts

223

00:09:10,470 --> 00:09:08,170

of different microorganisms that were

224

00:09:13,530 --> 00:09:10,480

living off of that hydrogen source and

225

00:09:16,050 --> 00:09:13,540

then co<sub>2</sub> was a source of carbon an

226

00:09:17,370 --> 00:09:16,060

inorganic source of carbon and that was

227

00:09:19,530 --> 00:09:17,380

all they needed to survive and I'm

228

00:09:21,150 --> 00:09:19,540

thinking okay well Mars has had

229

00:09:24,269 --> 00:09:21,160

volcanoes so it's called volcanic rock

230

00:09:25,139 --> 00:09:24,279

it's got a co2 atmosphere and deep down

231

00:09:27,090 --> 00:09:25,149

underground

232

00:09:28,379 --> 00:09:27,100

it may have liquid water so if it has

233

00:09:30,269 --> 00:09:28,389

all those three ingredients

234

00:09:32,639 --> 00:09:30,279

maybe this form of life could live there

235

00:09:34,470 --> 00:09:32,649

and so I did to the best of my ability

236

00:09:36,600 --> 00:09:34,480

as an eighth grade student tried to

237

00:09:38,699 --> 00:09:36,610

replicate that environment and my dad

238

00:09:40,519 --> 00:09:38,709

actually helped me he was a professor

239

00:09:42,509 --> 00:09:40,529

part-time at a local community college

240

00:09:46,530 --> 00:09:42,519

that you're not allowed to grow bacteria

241

00:09:48,840 --> 00:09:46,540

at home we every six hours to check the

242

00:09:50,460 --> 00:09:48,850

growth of my bacteria so I was waking up

243

00:09:52,680 --> 00:09:50,470

with my dad like every six hours to

244

00:09:54,360 --> 00:09:52,690

drive there and in the middle of the

245

00:09:55,980 --> 00:09:54,370

night and stuff but it was a wonderful

246

00:09:58,280 --> 00:09:55,990

experience and I think that was the

247

00:10:00,509 --> 00:09:58,290

first taste that got me really hooked on

248

00:10:02,939 --> 00:10:00,519

astrobiology the hunt for life the

249

00:10:05,490 --> 00:10:02,949

question of are we alone in the universe

250

00:10:07,559 --> 00:10:05,500

you know we have the technology now to

251  
00:10:09,870 --> 00:10:07,569  
try to answer that question at least in

252  
00:10:12,120 --> 00:10:09,880  
our own cosmic backyard it's a pretty

253  
00:10:14,360 --> 00:10:12,130  
amazing time to be a planetary scientist

254  
00:10:16,620 --> 00:10:14,370  
and any master biology

255  
00:10:18,660 --> 00:10:16,630  
yeah it's a great time to be alive I

256  
00:10:20,280 --> 00:10:18,670  
think we will be the generation of

257  
00:10:21,750 --> 00:10:20,290  
humans which will be able to answer

258  
00:10:23,009 --> 00:10:21,760  
whether or not we're alone in the

259  
00:10:24,960 --> 00:10:23,019  
universe which is you know it's awesome

260  
00:10:27,360 --> 00:10:24,970  
it's just an incredible time to be alive

261  
00:10:29,910 --> 00:10:27,370  
to do science and so the Cassini

262  
00:10:31,379 --> 00:10:29,920  
spacecraft launched in 1997 I remember

263  
00:10:33,030 --> 00:10:31,389

it quite clearly actually I think I have

264

00:10:34,920 --> 00:10:33,040

my name in one of the CDs that's on the

265

00:10:37,199 --> 00:10:34,930

spacecraft you were involved with

266

00:10:40,290 --> 00:10:37,209

Cassini pretty early on right in your

267

00:10:42,569 --> 00:10:40,300

career um I actually wasn't involved

268

00:10:45,300 --> 00:10:42,579

early in Cassini's history but early in

269

00:10:46,559 --> 00:10:45,310

my career at JPL during the last couple

270

00:10:49,139 --> 00:10:46,569

of years of the Cassini mission

271

00:10:51,809 --> 00:10:49,149

Linda Stoker who's the project scientist

272

00:10:54,059 --> 00:10:51,819

dr. Linda Stoker invited me to join as

273

00:10:56,009 --> 00:10:54,069

something called a project science

274

00:10:57,929 --> 00:10:56,019

systems engineer I know how it sounds

275

00:11:00,269 --> 00:10:57,939

complicated but basically I was the

276

00:11:02,160 --> 00:11:00,279

liaison between the scientists and the

277

00:11:03,929 --> 00:11:02,170

mission and the engineers that are

278

00:11:05,410 --> 00:11:03,939

working on the spacecraft and that

279

00:11:07,449 --> 00:11:05,420

communication is really in

280

00:11:08,860 --> 00:11:07,459

because sometimes scientists and

281

00:11:11,530 --> 00:11:08,870

engineers may speak in different

282

00:11:14,500 --> 00:11:11,540

languages and ultimately the more the

283

00:11:16,389 --> 00:11:14,510

engineers understand the science that we

284

00:11:20,170 --> 00:11:16,399

want to accomplish the better that they

285

00:11:22,840 --> 00:11:20,180

can say plan sequences of Cassini like

286

00:11:25,030 --> 00:11:22,850

what instruments are pointing where and

287

00:11:27,130 --> 00:11:25,040

and those types of serve engineering

288

00:11:29,170 --> 00:11:27,140

problems and then the better scientists

289

00:11:31,180 --> 00:11:29,180

can understand engineering constraints

290

00:11:34,470 --> 00:11:31,190

of a mission they can frame their

291

00:11:36,910 --> 00:11:34,480

science questions better to best use the

292

00:11:39,569 --> 00:11:36,920

instruments to their full limits without

293

00:11:41,949 --> 00:11:39,579

trying to exceed that we always say at

294

00:11:43,780 --> 00:11:41,959

JPL that the scientists want to go to

295

00:11:45,670 --> 00:11:43,790

the interesting places the engineers

296

00:11:47,380 --> 00:11:45,680

want to go to the safe places and we

297

00:11:50,440 --> 00:11:47,390

need to find you know the areas where

298

00:11:52,990 --> 00:11:50,450

that Venn diagram coincides so it was a

299

00:11:55,240 --> 00:11:53,000

really amazing experience the Cassini

300

00:11:58,240 --> 00:11:55,250

mission like you said it launched in 97

301  
00:11:59,470 --> 00:11:58,250  
but it was built before that rights and

302  
00:12:02,560 --> 00:11:59,480  
there are people who have been working

303  
00:12:05,889 --> 00:12:02,570  
on Cassini their entire careers Cassini

304  
00:12:08,530 --> 00:12:05,899  
arrived at Saturn in 2004 and did

305  
00:12:10,540 --> 00:12:08,540  
science for 13 years before we did that

306  
00:12:12,490 --> 00:12:10,550  
elegant swan dive during the grand

307  
00:12:14,920 --> 00:12:12,500  
finale where we plunged into the

308  
00:12:17,740 --> 00:12:14,930  
atmosphere of Saturn and during that

309  
00:12:19,960 --> 00:12:17,750  
time the Cassini team really became a

310  
00:12:22,180 --> 00:12:19,970  
family and to be welcomed into that

311  
00:12:24,009 --> 00:12:22,190  
family near the end of the mission was

312  
00:12:25,569 --> 00:12:24,019  
such an amazing experience I got to

313  
00:12:27,610 --> 00:12:25,579

learn from people who had been doing

314

00:12:30,670 --> 00:12:27,620

this science in this engineering for

315

00:12:32,530 --> 00:12:30,680

decades and being able to carry that

316

00:12:34,030 --> 00:12:32,540

over into future missions it is

317

00:12:36,910 --> 00:12:34,040

something that's really critical I think

318

00:12:38,860 --> 00:12:36,920

to be able to have us you know best when

319

00:12:43,120 --> 00:12:38,870

we're exploring especially the outer

320

00:12:44,740 --> 00:12:43,130

solar system that's fantastic so in 2004

321

00:12:47,949 --> 00:12:44,750

something else really exciting happened

322

00:12:49,389 --> 00:12:47,959

the Cassini spacecraft was had a piggy

323

00:12:52,269 --> 00:12:49,399

back of another payload called the

324

00:12:53,980 --> 00:12:52,279

Huygens probe which separated from the

325

00:12:56,019 --> 00:12:53,990

spacecraft and went through the

326  
00:12:57,730 --> 00:12:56,029  
atmosphere of the moon Titan and landed

327  
00:12:59,410 --> 00:12:57,740  
on the surface this was in collaboration

328  
00:13:02,079 --> 00:12:59,420  
was a European Space Agency

329  
00:13:03,759 --> 00:13:02,089  
I remember refreshing the ESA webpage

330  
00:13:05,740 --> 00:13:03,769  
furiously as the thing was coming down

331  
00:13:07,540 --> 00:13:05,750  
to get the first pictures and we saw

332  
00:13:09,610 --> 00:13:07,550  
those first pictures we saw a world that

333  
00:13:12,490 --> 00:13:09,620  
we're almost familiar with if you were

334  
00:13:14,439 --> 00:13:12,500  
to stand on Titan today Morgan hello

335  
00:13:16,030 --> 00:13:14,449  
bring us there what do you see what you

336  
00:13:17,650 --> 00:13:16,040  
smell what would be look what would it

337  
00:13:18,620 --> 00:13:17,660  
look like awesome

338  
00:13:20,210 --> 00:13:18,630

yeah I loved how

339

00:13:22,340 --> 00:13:20,220

about Titan like you said it's the

340

00:13:24,680 --> 00:13:22,350

second largest moon in our solar system

341

00:13:27,110 --> 00:13:24,690

actually if you count its atmosphere

342

00:13:28,730 --> 00:13:27,120

it's the biggest but we'll let Ganymede

343

00:13:30,079 --> 00:13:28,740

you know have something because Titan I

344

00:13:32,689 --> 00:13:30,089

think it's way more fascinating

345

00:13:34,040 --> 00:13:32,699

sorry Ganymede fans if you were standing

346

00:13:35,720 --> 00:13:34,050

on the surface of Titan

347

00:13:37,970 --> 00:13:35,730

well picture this the atmosphere is

348

00:13:40,069 --> 00:13:37,980

about one-and-a-half times thicker than

349

00:13:42,050 --> 00:13:40,079

Earth's so you wouldn't need a spacesuit

350

00:13:43,610 --> 00:13:42,060

you need a really really thick parka

351

00:13:46,780 --> 00:13:43,620

though because the average surface

352

00:13:49,519 --> 00:13:46,790

temperature is 90 Kelvin which is minus

353

00:13:50,900 --> 00:13:49,529

183 degrees C I don't remember what that

354

00:13:52,519 --> 00:13:50,910

is in Fahrenheit because I'm a scientist

355

00:13:53,210 --> 00:13:52,529

we don't work in Fahrenheit but it's

356

00:13:55,009 --> 00:13:53,220

really cold

357

00:13:56,749 --> 00:13:55,019

though so you need some kind of really

358

00:13:58,879 --> 00:13:56,759

thick parka to keep you warm and you

359

00:14:01,040 --> 00:13:58,889

need to bring your own oxygen because

360

00:14:03,230 --> 00:14:01,050

there is no oxygen and Titan's

361

00:14:04,819 --> 00:14:03,240

atmosphere but it is nitrogen rich it's

362

00:14:07,040 --> 00:14:04,829

got a lot of nitrogen and a lot of

363

00:14:09,019 --> 00:14:07,050

methane so if you were standing on the

364

00:14:11,930 --> 00:14:09,029

surface you would feel I think it would

365

00:14:13,819 --> 00:14:11,940

be the equivalent of you about ten feet

366

00:14:14,300 --> 00:14:13,829

down in your swimming pool in terms of

367

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

the pressure

368

00:14:18,110 --> 00:14:16,800

you'd feel so if you have a swimming

369

00:14:19,699 --> 00:14:18,120

pool just go to the deep end and dig

370

00:14:21,319 --> 00:14:19,709

back to the bottom that's about what you

371

00:14:23,509 --> 00:14:21,329

would feel for one and a half bars of

372

00:14:26,629 --> 00:14:23,519

pressure but because Titan's atmosphere

373

00:14:29,389 --> 00:14:26,639

is thicker and it's gravity is less it's

374

00:14:31,759 --> 00:14:29,399

about 1/7 that of Earth's gravity if you

375

00:14:34,879 --> 00:14:31,769

had wings and you flap them you could

376

00:14:36,259 --> 00:14:34,889

literally fly you'd float off the

377

00:14:39,050 --> 00:14:36,269

surface of Titan and you could fly

378

00:14:41,509 --> 00:14:39,060

around them so it's it's a really cool

379

00:14:43,249 --> 00:14:41,519

like alien environment when it comes to

380

00:14:46,610 --> 00:14:43,259

being able to interact with it in that

381

00:14:49,400 --> 00:14:46,620

way so would you would you be able to

382

00:14:51,769 --> 00:14:49,410

see Saturn what are you reading a flight

383

00:14:54,860 --> 00:14:51,779

because it's so far away so what I've

384

00:14:57,710 --> 00:14:54,870

heard of in terms of the lighting would

385

00:15:00,170 --> 00:14:57,720

be the equivalent of if you were sort of

386

00:15:01,639 --> 00:15:00,180

standing in a parking lot at dusk I

387

00:15:03,050 --> 00:15:01,649

think one scientist said I don't know

388

00:15:04,850 --> 00:15:03,060

why they picked a parking lot but that

389

00:15:07,939 --> 00:15:04,860

was the expression so imagine like

390

00:15:09,530 --> 00:15:07,949

things are really dim but that's in

391

00:15:12,620 --> 00:15:09,540

terms of the sunlight coming from Earth

392

00:15:15,170 --> 00:15:12,630

you might get some sunshine as well but

393

00:15:17,269 --> 00:15:15,180

Titan also has multiple haze layers it

394

00:15:20,569 --> 00:15:17,279

would sort of be like if you are in LA

395

00:15:24,079 --> 00:15:20,579

in dusk on a really smoggy day or smoggy

396

00:15:26,420 --> 00:15:24,089

evening and so it might be difficult to

397

00:15:28,460 --> 00:15:26,430

appear and actually see Saturn itself

398

00:15:30,139 --> 00:15:28,470

through those haze layers essentially

399

00:15:32,270 --> 00:15:30,149

what happens is it's sort of like how

400

00:15:34,190 --> 00:15:32,280

smog is generated here on earth

401

00:15:35,810 --> 00:15:34,200

in four Titan's atmosphere you start

402

00:15:39,170 --> 00:15:35,820

with the two main ingredients which is

403

00:15:43,010 --> 00:15:39,180

nitrogen  $\text{N}_2$  nitrogen gas and methane  $\text{CH}_4$

404

00:15:44,360 --> 00:15:43,020

so you've got N C and H now if you have

405

00:15:47,180 --> 00:15:44,370

your chemistry set which I have

406

00:15:48,830 --> 00:15:47,190

somewhere here at home but I think if

407

00:15:50,420 --> 00:15:48,840

anyone else has one you just put those

408

00:15:52,400 --> 00:15:50,430

three atoms together in whatever

409

00:15:54,830 --> 00:15:52,410

combination you can think of small

410

00:15:58,100 --> 00:15:54,840

molecules big molecules all of those

411

00:16:00,140 --> 00:15:58,110

exist on type they're mostly formed by a

412

00:16:02,300 --> 00:16:00,150

UV radiation there are other energy

413

00:16:04,040 --> 00:16:02,310

sources too in the atmosphere they break

414

00:16:06,230 --> 00:16:04,050

apart those those molecules and they'll

415

00:16:08,540 --> 00:16:06,240

form all sorts of things some of those

416

00:16:10,280 --> 00:16:08,550

will form those haze layers that we see

417

00:16:13,190 --> 00:16:10,290

the same way that smog forms here on

418

00:16:15,110 --> 00:16:13,200

earth and you'll also form particles

419

00:16:17,270 --> 00:16:15,120

that then rain down on the surface of

420

00:16:19,040 --> 00:16:17,280

Titan we actually think that's what the

421

00:16:20,990 --> 00:16:19,050

dunes are made of Titan has a bunch of

422

00:16:23,270 --> 00:16:21,000

dunes in its equatorial region sort of

423

00:16:26,270 --> 00:16:23,280

the waist pan right around the equator

424

00:16:28,460 --> 00:16:26,280

of Titan and it's also got these liquid

425

00:16:30,680 --> 00:16:28,470

methane and ethane lakes at the poles

426

00:16:33,530 --> 00:16:30,690

Titan has weather just like Earth does

427

00:16:36,350 --> 00:16:33,540

it has clouds rain potentially snow -

428

00:16:38,150 --> 00:16:36,360

and so we see these river channels and

429

00:16:40,220 --> 00:16:38,160

gullies that are been etched because of

430

00:16:41,810 --> 00:16:40,230

these erosion processes just like we

431

00:16:45,380 --> 00:16:41,820

have on earth we have them on Titan -

432

00:16:47,420 --> 00:16:45,390

but they're made by different liquid so

433

00:16:50,270 --> 00:16:47,430

they're it's not water it's like rain of

434

00:16:52,130 --> 00:16:50,280

methane that forms Lakes and so it's

435

00:16:54,410 --> 00:16:52,140

very familiar almost this terrain that

436

00:16:56,210 --> 00:16:54,420

we know I mean we're it's not an alien

437

00:16:57,530 --> 00:16:56,220

terrain to report to the point that we

438

00:16:59,390 --> 00:16:57,540

recognize the rivers we couldn't

439

00:17:01,280 --> 00:16:59,400

recognize the lakes we recognize the

440

00:17:04,429 --> 00:17:01,290

rocks but the rocks are different right

441

00:17:06,710 --> 00:17:04,439

now on Titan yeah it all looks similar

442

00:17:08,449 --> 00:17:06,720

but it's made of very different stuff

443

00:17:10,730 --> 00:17:08,459

and that's one of the things that I

444

00:17:13,309 --> 00:17:10,740

encouraged are trying to understand in

445

00:17:16,189 --> 00:17:13,319

the laboratory it turns out Titan is not

446

00:17:17,990 --> 00:17:16,199

that hard to replicate in the lab we use

447

00:17:21,380 --> 00:17:18,000

something called liquid nitrogen which

448

00:17:24,260 --> 00:17:21,390

has a temperature of about 77 K Kelvin

449

00:17:27,230 --> 00:17:24,270

Titan's surface is 19 so you just make

450

00:17:29,690 --> 00:17:27,240

some cryostat it's what we call it cryo

451  
00:17:32,150 --> 00:17:29,700  
is cold so that is just stay so it's a

452  
00:17:33,950 --> 00:17:32,160  
way of maintaining temperature and we'll

453  
00:17:35,300 --> 00:17:33,960  
start it off by cooling it down a liquid

454  
00:17:37,040 --> 00:17:35,310  
nitrogen temperature and then you just

455  
00:17:39,110 --> 00:17:37,050  
have to heat it up a little bit and then

456  
00:17:41,360 --> 00:17:39,120  
you've got Titan and as a liquid

457  
00:17:43,460 --> 00:17:41,370  
nitrogen boils off it makes a nitrogen

458  
00:17:45,910 --> 00:17:43,470  
atmosphere very similar to what titans

459  
00:17:46,870 --> 00:17:45,920  
is like and then we can do experiments

460  
00:17:49,330 --> 00:17:46,880  
we also have some more sophisticated

461  
00:17:51,190 --> 00:17:49,340  
ways of generating those same conditions

462  
00:17:53,740 --> 00:17:51,200  
but in principle that's all we're doing

463  
00:17:55,570 --> 00:17:53,750

now once we do that then we can take

464

00:17:58,210 --> 00:17:55,580

different molecules that we know to

465

00:18:00,539 --> 00:17:58,220

exist on Titan because of the Cassini

466

00:18:03,070 --> 00:18:00,549

Boykins mission both the probe and

467

00:18:05,680 --> 00:18:03,080

orbital observations from the Cassini

468

00:18:07,780 --> 00:18:05,690

spacecraft itself and then we combine

469

00:18:10,240 --> 00:18:07,790

them and so far we've been very

470

00:18:13,660 --> 00:18:10,250

surprised even combining simple things

471

00:18:16,000 --> 00:18:13,670

like benzene which is a solid and ethane

472

00:18:18,250 --> 00:18:16,010

which is a liquid you mix those two

473

00:18:20,230 --> 00:18:18,260

things together and you form essentially

474

00:18:23,049 --> 00:18:20,240

a Titan mineral we think of it as

475

00:18:25,570 --> 00:18:23,059

something similar to a hydrated mineral

476

00:18:27,250 --> 00:18:25,580

here on earth because ethane is part of

477

00:18:29,320 --> 00:18:27,260

a liquid phase of Titan just like water

478

00:18:31,480 --> 00:18:29,330

is part of the liquid phase here on

479

00:18:34,810 --> 00:18:31,490

earth what we're finding is these these

480

00:18:39,100 --> 00:18:34,820

minerals may be ways of storing or

481

00:18:41,200 --> 00:18:39,110

moving or being able to to change some

482

00:18:43,090 --> 00:18:41,210

of the surface properties in ways that

483

00:18:44,710 --> 00:18:43,100

we might not expect and this can be

484

00:18:46,870 --> 00:18:44,720

important for answering a lot of big

485

00:18:50,620 --> 00:18:46,880

questions about Titan that are still

486

00:18:52,690 --> 00:18:50,630

unknown one of those big questions is if

487

00:18:55,450 --> 00:18:52,700

you look at the atmosphere you've got

488

00:18:58,360 --> 00:18:55,460

nitrogen and methane and over the the

489

00:19:00,220 --> 00:18:58,370

history of Titan if if you believe it's

490

00:19:02,409 --> 00:19:00,230

been around since like the beginning of

491

00:19:04,810 --> 00:19:02,419

the solar system we're just what four

492

00:19:06,880 --> 00:19:04,820

and a half billion years then we should

493

00:19:09,130 --> 00:19:06,890

not just have lakes on the surface of

494

00:19:11,770 --> 00:19:09,140

Titan but we should have an ocean all of

495

00:19:13,030 --> 00:19:11,780

the the methane and ethane that's formed

496

00:19:15,460 --> 00:19:13,040

and stuff should have rained down and

497

00:19:18,220 --> 00:19:15,470

made out a really thick ocean but it's

498

00:19:20,020 --> 00:19:18,230

not there and we don't know why and one

499

00:19:21,789 --> 00:19:20,030

of the reasons maybe there are some

500

00:19:23,620 --> 00:19:21,799

minerals that are sucking up some of

501  
00:19:25,299 --> 00:19:23,630  
those those liquids and storing them

502  
00:19:27,460 --> 00:19:25,309  
underground and reservoirs that we can't

503  
00:19:28,900 --> 00:19:27,470  
see no that's one of the questions we're

504  
00:19:31,630 --> 00:19:28,910  
trying to answer with our laboratory

505  
00:19:34,210 --> 00:19:31,640  
work that's fascinating so it's almost a

506  
00:19:36,610 --> 00:19:34,220  
new discipline like Titan petrology the

507  
00:19:38,620 --> 00:19:36,620  
study of rocks that are not silicates

508  
00:19:40,900 --> 00:19:38,630  
like we're familiar with on earth yeah

509  
00:19:42,880 --> 00:19:40,910  
totally I remember the first time we sat

510  
00:19:44,590 --> 00:19:42,890  
in the lab and we were we were looking

511  
00:19:46,090 --> 00:19:44,600  
at some of these molecules with our

512  
00:19:47,590 --> 00:19:46,100  
instrument and we saw some weird Peaks

513  
00:19:51,400 --> 00:19:47,600

come up and one of my colleagues said

514

00:19:53,440 --> 00:19:51,410

huh that's weird and you love that in

515

00:19:55,270 --> 00:19:53,450

science especially as an experimentalist

516

00:19:58,540 --> 00:19:55,280

cuz that's when you know something cool

517

00:19:58,840 --> 00:19:58,550

is about to be discovered maybe and in

518

00:20:03,910 --> 00:19:58,850

this

519

00:20:05,920 --> 00:20:03,920

titan mineral since then we found a

520

00:20:08,020 --> 00:20:05,930

couple others and we have hints at a few

521

00:20:10,480 --> 00:20:08,030

more and because of that one of our

522

00:20:13,780 --> 00:20:10,490

colleagues her name's Helen miner Casely

523

00:20:15,850 --> 00:20:13,790

she's a scientist down in Australia he

524

00:20:17,290 --> 00:20:15,860

works in the Australian nuclear Science

525

00:20:19,180 --> 00:20:17,300

and Technology office we've been

526

00:20:20,860 --> 00:20:19,190

collaborating with her to get crystal

527

00:20:22,630 --> 00:20:20,870

structures of some of these and she

528

00:20:25,000 --> 00:20:22,640

recently wrote a piece of paper talking

529

00:20:27,790 --> 00:20:25,010

about this new field of chitin petrology

530

00:20:30,550 --> 00:20:27,800

it's a really exciting time as a chemist

531

00:20:32,230 --> 00:20:30,560

doing organic chemistry now I need to

532

00:20:34,480 --> 00:20:32,240

learn a lot more about mineralogy and

533

00:20:35,890 --> 00:20:34,490

geology and all of these things so we've

534

00:20:37,990 --> 00:20:35,900

been picking the brains of some of our

535

00:20:40,300 --> 00:20:38,000

colleagues to try to understand how

536

00:20:42,400 --> 00:20:40,310

these organic molecules now are behaving

537

00:20:44,860 --> 00:20:42,410

like minerals and what that might mean

538

00:20:48,430 --> 00:20:44,870

for surface features we see on Titan or

539

00:20:49,750 --> 00:20:48,440

maybe even light let's talk about life

540

00:20:50,170 --> 00:20:49,760

in a second I definitely want to go

541

00:20:51,700 --> 00:20:50,180

there

542

00:20:53,590 --> 00:20:51,710

but first again for those of you who are

543

00:20:55,090 --> 00:20:53,600

watching don't forget to use hashtag ask

544

00:20:57,040 --> 00:20:55,100

Esther bio if you wanna ask us a

545

00:20:58,720 --> 00:20:57,050

question on Twitter if you're watching

546

00:21:00,190 --> 00:20:58,730

on Sagan I'd use this chat function

547

00:21:01,630 --> 00:21:00,200

there if you don't face the client put

548

00:21:04,990 --> 00:21:01,640

your questions down in the comments and

549

00:21:07,210 --> 00:21:05,000

we'll get those to dr. Kable and shortly

550

00:21:09,250 --> 00:21:07,220

but let's talk about life on Titan it's

551  
00:21:12,580 --> 00:21:09,260  
so that the surface temperature on Titan

552  
00:21:14,650 --> 00:21:12,590  
is colder than the lowest temperature

553  
00:21:16,690 --> 00:21:14,660  
that life has been identified with on

554  
00:21:20,170 --> 00:21:16,700  
earth so we need to think more

555  
00:21:22,720 --> 00:21:20,180  
creatively about chemical processes that

556  
00:21:26,380 --> 00:21:22,730  
could be identified possibly as life on

557  
00:21:28,060 --> 00:21:26,390  
Titan you do and actually I should take

558  
00:21:30,160 --> 00:21:28,070  
a step back and say that there are

559  
00:21:32,290 --> 00:21:30,170  
really two environments where we might

560  
00:21:34,060 --> 00:21:32,300  
find life on Titan there's the surface

561  
00:21:35,380 --> 00:21:34,070  
which is sort of weird and alien and

562  
00:21:37,960 --> 00:21:35,390  
we'll talk about that in a moment

563  
00:21:40,630 --> 00:21:37,970

but there's also the subsurface just

564

00:21:43,300 --> 00:21:40,640

like Europa Enceladus and a lot of these

565

00:21:46,840 --> 00:21:43,310

other ocean worlds Titan also has a

566

00:21:48,310 --> 00:21:46,850

global liquid water ocean underneath all

567

00:21:51,130 --> 00:21:48,320

of the cool stuff happening on the

568

00:21:53,650 --> 00:21:51,140

surface and so that ocean is probably

569

00:21:55,900 --> 00:21:53,660

much more amenable to life as we know it

570

00:21:57,910 --> 00:21:55,910

so if we want to define bacteria that

571

00:22:00,460 --> 00:21:57,920

lived in water that would be a place to

572

00:22:02,980 --> 00:22:00,470

look now it may be really hard to drill

573

00:22:05,230 --> 00:22:02,990

down into that ocean it's the crust is I

574

00:22:07,870 --> 00:22:05,240

forget it's it's tens - maybe a hundred

575

00:22:09,490 --> 00:22:07,880

kilometers thick something like that and

576

00:22:12,010 --> 00:22:09,500

so getting down there might be tough

577

00:22:14,440 --> 00:22:12,020

there are a few places on the surface

578

00:22:16,720 --> 00:22:14,450

where we see evidence of what we think

579

00:22:18,730 --> 00:22:16,730

our cryovolcanoes that's a place where

580

00:22:20,620 --> 00:22:18,740

some of that liquid water might have

581

00:22:22,600 --> 00:22:20,630

gotten pushed up and formed this cryo

582

00:22:24,520 --> 00:22:22,610

magma that spilled out on the surface

583

00:22:26,770 --> 00:22:24,530

and that would be an excellent place to

584

00:22:29,890 --> 00:22:26,780

try to look for life as we know it or at

585

00:22:31,450 --> 00:22:29,900

least evidence of it but like I said

586

00:22:33,550 --> 00:22:31,460

there's this other environment this

587

00:22:36,070 --> 00:22:33,560

alien environment that exists on the

588

00:22:38,430 --> 00:22:36,080

surface this is where the liquid phase

589

00:22:40,990 --> 00:22:38,440

is not water but ethane and methane

590

00:22:44,080 --> 00:22:41,000

hydrocarbons now from a fundamental

591

00:22:46,870 --> 00:22:44,090

chemistry perspective water is what we

592

00:22:49,780 --> 00:22:46,880

call a polar solvent methane and ethane

593

00:22:51,520 --> 00:22:49,790

are nonpolar now if you remember your

594

00:22:53,830 --> 00:22:51,530

basic high school chemistry like

595

00:22:54,880 --> 00:22:53,840

dissolves like right you can't dissolve

596

00:22:57,490 --> 00:22:54,890

oil and water

597

00:22:59,610 --> 00:22:57,500

you can dissolve it in methane and

598

00:23:02,260 --> 00:22:59,620

ethane there are very fundamental

599

00:23:04,630 --> 00:23:02,270

differences to the liquids what they

600

00:23:06,880 --> 00:23:04,640

will dissolve how they might react which

601  
00:23:09,610 --> 00:23:06,890  
tells us that any life that were to

602  
00:23:11,200 --> 00:23:09,620  
exist in a methane or ethane lake would

603  
00:23:14,050 --> 00:23:11,210  
have to be very different just

604  
00:23:16,420 --> 00:23:14,060  
chemically from any earth life that

605  
00:23:18,100 --> 00:23:16,430  
existed in water so there's the fact

606  
00:23:20,230 --> 00:23:18,110  
that the solvent is different the liquid

607  
00:23:22,270 --> 00:23:20,240  
is different but also like you said the

608  
00:23:25,420 --> 00:23:22,280  
temperature is different now here on

609  
00:23:27,520 --> 00:23:25,430  
earth were happy at you know 75 degrees

610  
00:23:29,800 --> 00:23:27,530  
fahrenheit there see I use Fahrenheit um

611  
00:23:31,870 --> 00:23:29,810  
or or warmer and like you said the the

612  
00:23:33,340 --> 00:23:31,880  
coldest I can't recall what the coldest

613  
00:23:35,770 --> 00:23:33,350

temperature that life has existed in

614

00:23:39,460 --> 00:23:35,780

it's it's Sub Zero but not too much

615

00:23:43,360 --> 00:23:39,470

below that um that's still a balmy super

616

00:23:45,130 --> 00:23:43,370

hot day on Titan right and whenever for

617

00:23:48,280 --> 00:23:45,140

a chemist or a biochemist whenever you

618

00:23:51,190 --> 00:23:48,290

cool things down reactions slow down or

619

00:23:53,350 --> 00:23:51,200

they may stop completely right chemistry

620

00:23:55,300 --> 00:23:53,360

becomes very different at these low

621

00:23:56,950 --> 00:23:55,310

temperatures and so one of the things

622

00:24:00,760 --> 00:23:56,960

that we are trying to understand in the

623

00:24:02,920 --> 00:24:00,770

lab is what tools some sort of weird

624

00:24:04,740 --> 00:24:02,930

alien life might use in this very cold

625

00:24:07,690 --> 00:24:04,750

environment I'll give you an example

626

00:24:10,840 --> 00:24:07,700

earth life all earth life that we know

627

00:24:14,410 --> 00:24:10,850

of uses one energy molecule it's called

628

00:24:16,750 --> 00:24:14,420

ATP adenosine triphosphate and the way

629

00:24:19,630 --> 00:24:16,760

that your cells in your body and all

630

00:24:21,400 --> 00:24:19,640

microorganisms and giraffes and to worms

631

00:24:23,750 --> 00:24:21,410

and everyone uses the same energy

632

00:24:26,510 --> 00:24:23,760

molecule the way that you transfer that

633

00:24:29,120 --> 00:24:26,520

energy around is by making or breaking a

634

00:24:31,160 --> 00:24:29,130

covalent bond so you you add or subtract

635

00:24:33,560 --> 00:24:31,170

a phosphate that's a covalent bond that

636

00:24:35,420 --> 00:24:33,570

you used to do that well that's fine

637

00:24:37,430 --> 00:24:35,430

here on earth that you've got a dump

638

00:24:39,860 --> 00:24:37,440

some energy into break the bond but then

639

00:24:43,430 --> 00:24:39,870

you get some energy out at the same time

640

00:24:45,680 --> 00:24:43,440

but on Titan a covalent bond is really

641

00:24:48,380 --> 00:24:45,690

really tough to make or break it

642

00:24:50,140 --> 00:24:48,390

requires sort of the equivalent of a lot

643

00:24:53,600 --> 00:24:50,150

more energy at those low temperatures

644

00:24:56,030 --> 00:24:53,610

now on earth we have different types of

645

00:24:57,410 --> 00:24:56,040

bonds we have hydrogen bonds things

646

00:24:59,810 --> 00:24:57,420

called van der Waals forces or

647

00:25:01,610 --> 00:24:59,820

dipole-dipole interactions fancy words

648

00:25:04,190 --> 00:25:01,620

for basically bombs that are a lot

649

00:25:07,280 --> 00:25:04,200

weaker now here on earth they're not

650

00:25:09,470 --> 00:25:07,290

quite as useful for say trading energy

651  
00:25:11,300 --> 00:25:09,480  
around but on Titan maybe those weaker

652  
00:25:12,800 --> 00:25:11,310  
bonds would be much more important a

653  
00:25:15,560 --> 00:25:12,810  
weaker bond might be the equivalent

654  
00:25:17,210 --> 00:25:15,570  
about covalent bonds here on earth and

655  
00:25:20,000 --> 00:25:17,220  
so we sort of have to take a step back

656  
00:25:23,800 --> 00:25:20,010  
and rethink how we might look for life

657  
00:25:26,870 --> 00:25:23,810  
or the basic tools life might use to

658  
00:25:29,210 --> 00:25:26,880  
make bonds break bonds and form the

659  
00:25:30,440 --> 00:25:29,220  
molecular machinery to be alive so those

660  
00:25:32,990 --> 00:25:30,450  
those are some of the questions that

661  
00:25:33,410 --> 00:25:33,000  
we're trying to address in this alien

662  
00:25:37,880 --> 00:25:33,420  
world

663  
00:25:40,250 --> 00:25:37,890

that's Titan so it just shows the danger

664

00:25:41,600 --> 00:25:40,260

of having an anthropomorphic view of

665

00:25:43,640 --> 00:25:41,610

life in the universe like just knowing

666

00:25:46,250 --> 00:25:43,650

the only kind of life that we do know it

667

00:25:48,560 --> 00:25:46,260

is earth life so awesome that you think

668

00:25:50,540 --> 00:25:48,570

about these new chemical ways that that

669

00:25:51,740 --> 00:25:50,550

chemical systems could perhaps evolve

670

00:25:53,540 --> 00:25:51,750

into something biological

671

00:25:55,610 --> 00:25:53,550

really cool speaking of planetary

672

00:25:57,680 --> 00:25:55,620

surfaces you're also involved in the

673

00:26:00,290 --> 00:25:57,690

exploration of another planetary surface

674

00:26:03,200 --> 00:26:00,300

on a moon around Saturn and that is the

675

00:26:05,660 --> 00:26:03,210

surface of Enceladus right no Europa

676  
00:26:06,470 --> 00:26:05,670  
Lander are on Jupiter I'm sorry but tell

677  
00:26:09,020 --> 00:26:06,480  
us a little bit about your involvement

678  
00:26:12,890 --> 00:26:09,030  
in the in the lander that's gonna

679  
00:26:13,400 --> 00:26:12,900  
explore the surface of Jupiter of Europa

680  
00:26:15,920 --> 00:26:13,410  
hopefully

681  
00:26:17,960 --> 00:26:15,930  
door yeah and I would love to talk about

682  
00:26:20,720 --> 00:26:17,970  
and sell it as - that's an amazing world

683  
00:26:23,660 --> 00:26:20,730  
like you said Europe was a fascinating

684  
00:26:25,210 --> 00:26:23,670  
place also currently nASA has one

685  
00:26:27,350 --> 00:26:25,220  
mission that's definitely going to

686  
00:26:29,810 --> 00:26:27,360  
Europa that's called the Europa clipper

687  
00:26:31,640 --> 00:26:29,820  
mission I'm a collaborator on one of

688  
00:26:33,980 --> 00:26:31,650

those instruments aboard that mission

689

00:26:37,130 --> 00:26:33,990

that one is going to do orbits around

690

00:26:39,200 --> 00:26:37,140

Jupiter and then flybys of Europa and

691

00:26:40,640 --> 00:26:39,210

it's gonna map the surface and higher

692

00:26:43,070 --> 00:26:40,650

resolution than we've ever done before

693

00:26:46,250 --> 00:26:43,080

the instrument that I'm a part of is

694

00:26:48,650 --> 00:26:46,260

called my's mapping imaging spectrometer

695

00:26:50,780 --> 00:26:48,660

for Europa and that will help us get at

696

00:26:52,970 --> 00:26:50,790

the composition of the surface we're

697

00:26:55,400 --> 00:26:52,980

still not sure if there are some places

698

00:26:57,890 --> 00:26:55,410

that are rich in salts like magnesium

699

00:26:59,690 --> 00:26:57,900

sulfate or if they're rich in things

700

00:27:02,150 --> 00:26:59,700

like sulfuric acid which might not be as

701  
00:27:04,160 --> 00:27:02,160  
useful for life so there are all sorts

702  
00:27:05,600 --> 00:27:04,170  
of interesting questions that the Europa

703  
00:27:09,350 --> 00:27:05,610  
clipper mission will address about

704  
00:27:12,080 --> 00:27:09,360  
Europa is history its habitability its

705  
00:27:14,600 --> 00:27:12,090  
potential to hold life in its subsurface

706  
00:27:16,130 --> 00:27:14,610  
liquid water ocean so that mission is

707  
00:27:18,770 --> 00:27:16,140  
really exciting and that one's moving

708  
00:27:20,930 --> 00:27:18,780  
forward I'm also part of another mission

709  
00:27:22,250 --> 00:27:20,940  
concept that would actually land like

710  
00:27:24,470 --> 00:27:22,260  
you said this is called the Europa

711  
00:27:26,630 --> 00:27:24,480  
Lander it's still in what we call pre

712  
00:27:28,940 --> 00:27:26,640  
phase a so it's not a real mission yet

713  
00:27:31,190 --> 00:27:28,950

it's still a concept study but we've

714

00:27:33,770 --> 00:27:31,200

done a lot of work on it our colleagues

715

00:27:36,410 --> 00:27:33,780

at JPL and elsewhere to develop the

716

00:27:38,900 --> 00:27:36,420

ideas that this mission would would try

717

00:27:41,180 --> 00:27:38,910

to address and the goal here I mean this

718

00:27:42,800 --> 00:27:41,190

would be the first time we would land on

719

00:27:44,840 --> 00:27:42,810

an ocean world without an atmosphere

720

00:27:47,210 --> 00:27:44,850

right the Huygens probe the

721

00:27:49,160 --> 00:27:47,220

collaboration with ista landed on Titan

722

00:27:50,720 --> 00:27:49,170

that had a very thick atmosphere it's a

723

00:27:52,010 --> 00:27:50,730

much different landing architecture

724

00:27:53,960 --> 00:27:52,020

because you can use parachutes and

725

00:27:56,630 --> 00:27:53,970

things like that on a place like you

726

00:27:58,880 --> 00:27:56,640

wrote by you can't so we're working on

727

00:28:01,880 --> 00:27:58,890

some creative ways to be able to safely

728

00:28:03,800 --> 00:28:01,890

land a payload in this alien environment

729

00:28:06,110 --> 00:28:03,810

where the highest resolution image we

730

00:28:08,150 --> 00:28:06,120

have right now is only six meters per

731

00:28:10,490 --> 00:28:08,160

pixel now it turns out we've done some

732

00:28:12,230 --> 00:28:10,500

similar things on Mars where we didn't

733

00:28:14,810 --> 00:28:12,240

have very good imagery of the surface

734

00:28:16,670 --> 00:28:14,820

but we're still able to land safely so

735

00:28:18,770 --> 00:28:16,680

we're taking a lot of those those tools

736

00:28:21,680 --> 00:28:18,780

and that knowledge and experience from

737

00:28:24,140 --> 00:28:21,690

the Mars community and applying that to

738

00:28:26,600 --> 00:28:24,150

Europa it's a really exciting time I

739

00:28:28,520 --> 00:28:26,610

mean could you imagine what if we land

740

00:28:30,440 --> 00:28:28,530

on the surface and we cut into that ice

741

00:28:32,570 --> 00:28:30,450

and we collect a sample and we find

742

00:28:35,870 --> 00:28:32,580

evidence of life there how amazing would

743

00:28:37,490 --> 00:28:35,880

that be that's incredible yeah so you're

744

00:28:39,710 --> 00:28:37,500

involved in exploring the entire solar

745

00:28:41,900 --> 00:28:39,720

system it seems what a career well there

746

00:28:43,490 --> 00:28:41,910

are so many amazing places to go I mean

747

00:28:44,490 --> 00:28:43,500

it's it's hard to say no when someone

748

00:28:46,620 --> 00:28:44,500

says hey we're we're

749

00:28:48,450 --> 00:28:46,630

on a mission concept to go to tighten

750

00:28:50,310 --> 00:28:48,460

her to go to Enceladus you know what am

751  
00:28:51,900 --> 00:28:50,320  
I gonna do oh no I'm too busy that's not

752  
00:28:54,270 --> 00:28:51,910  
a very exciting place of course I'm not

753  
00:28:57,600 --> 00:28:54,280  
gonna say that but it is hard you know

754  
00:29:00,540 --> 00:28:57,610  
you want to not see us everything but

755  
00:29:03,240 --> 00:29:00,550  
yes in particular Titan Enceladus in

756  
00:29:05,340 --> 00:29:03,250  
Europa those three are just they're so

757  
00:29:08,070 --> 00:29:05,350  
fascinating and they're so deserving of

758  
00:29:11,010 --> 00:29:08,080  
more exploration I really hope we get to

759  
00:29:12,840 --> 00:29:11,020  
do as much science as we can you know in

760  
00:29:14,820 --> 00:29:12,850  
our lifetime and preparing the next

761  
00:29:17,760 --> 00:29:14,830  
generation for making the discoveries

762  
00:29:19,740 --> 00:29:17,770  
there if anything Cassini and Galileo

763  
00:29:22,500 --> 00:29:19,750

these missions to these outer planets

764

00:29:24,210 --> 00:29:22,510

they've taught us that you know every

765

00:29:26,340 --> 00:29:24,220

time you go there you find something new

766

00:29:28,350 --> 00:29:26,350

something fascinating that you want to

767

00:29:30,330 --> 00:29:28,360

explore further and it really helps us

768

00:29:32,160 --> 00:29:30,340

hone our science and the questions we

769

00:29:35,910 --> 00:29:32,170

want to ask for next time but we only

770

00:29:37,530 --> 00:29:35,920

come up with new questions to Yasim just

771

00:29:42,690 --> 00:29:37,540

oozing out of the screen in front of me

772

00:29:44,760 --> 00:29:42,700

it's fantastic many of our younger

773

00:29:47,040 --> 00:29:44,770

viewers are wondering how does one

774

00:29:49,200 --> 00:29:47,050

become a scientist at JPL you have some

775

00:29:52,800 --> 00:29:49,210

some words of advice for them oh sure

776

00:29:55,170 --> 00:29:52,810

that's a great question I think in

777

00:29:57,720 --> 00:29:55,180

addition to like studying a science one

778

00:30:01,590 --> 00:29:57,730

of the most important things is to stay

779

00:30:03,060 --> 00:30:01,600

curious and be motivated because

780

00:30:05,970 --> 00:30:03,070

planetary science is such an

781

00:30:08,880 --> 00:30:05,980

interdisciplinary through fields you can

782

00:30:12,330 --> 00:30:08,890

study anything from biology to chemistry

783

00:30:15,000 --> 00:30:12,340

to geology astrophysics all of these

784

00:30:17,100 --> 00:30:15,010

things you can apply to the planetary

785

00:30:20,520 --> 00:30:17,110

science and become a scientist and a

786

00:30:22,920 --> 00:30:20,530

NASA center like JPL one day so don't

787

00:30:25,290 --> 00:30:22,930

pick a major because you think that's

788

00:30:26,820 --> 00:30:25,300

what they want pick something that you

789

00:30:29,430 --> 00:30:26,830

enjoy but you're passionate about

790

00:30:31,830 --> 00:30:29,440

something that you would do for free but

791

00:30:34,110 --> 00:30:31,840

you didn't even need to be paid for that

792

00:30:36,570 --> 00:30:34,120

passion is going to follow you

793

00:30:38,460 --> 00:30:36,580

throughout your entire career and if

794

00:30:40,680 --> 00:30:38,470

it's something that you can tie in to

795

00:30:43,050 --> 00:30:40,690

planetary science or astrobiology all

796

00:30:44,640 --> 00:30:43,060

the better but we have not just

797

00:30:46,470 --> 00:30:44,650

scientists we have engineers that work

798

00:30:49,410 --> 00:30:46,480

on these missions of course we have

799

00:30:51,270 --> 00:30:49,420

journalists people who helped us with

800

00:30:53,880 --> 00:30:51,280

our media campaigns and help us

801  
00:30:56,100 --> 00:30:53,890  
communicate to the world we have artists

802  
00:30:58,380 --> 00:30:56,110  
JPL has a few resident artists that help

803  
00:31:00,330 --> 00:30:58,390  
us with our outreach

804  
00:31:02,610 --> 00:31:00,340  
they'll help us with mission proposals

805  
00:31:05,040 --> 00:31:02,620  
and all of the beautiful artwork you see

806  
00:31:06,660 --> 00:31:05,050  
on our websites that's thanks to them so

807  
00:31:09,450 --> 00:31:06,670  
there are a lot of different career

808  
00:31:10,620 --> 00:31:09,460  
paths that will take you to NASA now

809  
00:31:12,480 --> 00:31:10,630  
there's something else I mentioned

810  
00:31:14,490 --> 00:31:12,490  
earlier on remember how I said I did an

811  
00:31:16,860 --> 00:31:14,500  
internship that I think is really

812  
00:31:19,140 --> 00:31:16,870  
important to NASA has a bunch of

813  
00:31:21,840 --> 00:31:19,150

internship programs and they're a great

814

00:31:23,940 --> 00:31:21,850

way for you to get a taste for what this

815

00:31:26,040 --> 00:31:23,950

work is actually like figure out if it's

816

00:31:28,170 --> 00:31:26,050

really for you or not and then expand

817

00:31:30,840 --> 00:31:28,180

that network it's a lot harder to ignore

818

00:31:32,420 --> 00:31:30,850

an application from someone when you

819

00:31:35,220 --> 00:31:32,430

know who they are they've already

820

00:31:37,140 --> 00:31:35,230

demonstrated their capabilities because

821

00:31:39,240 --> 00:31:37,150

you've seen them to do some work and

822

00:31:41,160 --> 00:31:39,250

you've built that reputation already so

823

00:31:44,370 --> 00:31:41,170

I really encourage applying for

824

00:31:46,740 --> 00:31:44,380

internships fantastic and you're almost

825

00:31:48,360 --> 00:31:46,750

time to open up the conversation to our

826  
00:31:50,160 --> 00:31:48,370  
guest to ask questions but I do want to

827  
00:31:52,920 --> 00:31:50,170  
ask you about your hobby which is

828  
00:31:53,820 --> 00:31:52,930  
mountain biking on a unicycle how did

829  
00:31:56,730 --> 00:31:53,830  
you get into that

830  
00:31:58,680 --> 00:31:56,740  
we call it Mountain unicycling or Muni

831  
00:32:00,060 --> 00:31:58,690  
for short and we basically just got rid

832  
00:32:02,430 --> 00:32:00,070  
of all the stuff you don't need you know

833  
00:32:02,790 --> 00:32:02,440  
the handlebars the brakes the training

834  
00:32:04,700 --> 00:32:02,800  
wheel

835  
00:32:08,820 --> 00:32:04,710  
oh that just you don't really need it

836  
00:32:11,610 --> 00:32:08,830  
but but seriously though when I was

837  
00:32:13,620 --> 00:32:11,620  
doing my internship at JPL so I was

838  
00:32:16,170 --> 00:32:13,630

still an undergraduate student I met

839

00:32:18,120 --> 00:32:16,180

this really cute guy who was riding a

840

00:32:20,070 --> 00:32:18,130

unicycle around Kyle Petty so I went up

841

00:32:22,260 --> 00:32:20,080

and talked to him and asked him about it

842

00:32:24,900 --> 00:32:22,270

because it was a really unusual looking

843

00:32:27,210 --> 00:32:24,910

unicycle it had a big gnarly tired like

844

00:32:29,460 --> 00:32:27,220

nubs on it it was really like beefy

845

00:32:32,010 --> 00:32:29,470

looking and it turns out that he had

846

00:32:34,230 --> 00:32:32,020

done mountain unicycling and a few years

847

00:32:38,130 --> 00:32:34,240

later I kind of married him and now we

848

00:32:40,950 --> 00:32:38,140

go riding pretty often but I love that

849

00:32:43,260 --> 00:32:40,960

sport because it forces me to be

850

00:32:45,060 --> 00:32:43,270

completely focused like I can't let my

851  
00:32:46,920 --> 00:32:45,070  
thoughts drift off to the work I need to

852  
00:32:48,870 --> 00:32:46,930  
do or the proposal I need to write or

853  
00:32:50,430 --> 00:32:48,880  
the papers I'm working on like you have

854  
00:32:51,960 --> 00:32:50,440  
to be completely focused on what you're

855  
00:32:53,730 --> 00:32:51,970  
doing because if you let your thoughts

856  
00:32:56,760 --> 00:32:53,740  
drift you're gonna hit a rock in base

857  
00:32:57,900 --> 00:32:56,770  
and that's not so good so I like it for

858  
00:33:01,260 --> 00:32:57,910  
that I like it because it's really

859  
00:33:03,780 --> 00:33:01,270  
challenging and yeah it's sort of like

860  
00:33:05,820 --> 00:33:03,790  
meditation and motion for me one of the

861  
00:33:07,950 --> 00:33:05,830  
things I've noticed about all of my

862  
00:33:09,720 --> 00:33:07,960  
colleagues at JPL and in other NASA

863  
00:33:12,150 --> 00:33:09,730

centers as well you said joy or a good

864

00:33:14,430 --> 00:33:12,160

example too we tend to have hobbies

865

00:33:16,470 --> 00:33:14,440

where you know we'll be passionate and

866

00:33:19,140 --> 00:33:16,480

push push ourselves as well

867

00:33:21,600 --> 00:33:19,150

in hobbies just like we do in work and I

868

00:33:23,790 --> 00:33:21,610

really love that because we're all such

869

00:33:25,410 --> 00:33:23,800

dynamic people and it's great to see the

870

00:33:27,660 --> 00:33:25,420

different outlets that we push our

871

00:33:31,440 --> 00:33:27,670

energy into you do you do what is it

872

00:33:33,720 --> 00:33:31,450

it's Navin navigating know doing my

873

00:33:35,100 --> 00:33:33,730

interior yeah we're you like get a map

874

00:33:36,480 --> 00:33:35,110

and then you go that's a really useful

875

00:33:38,340 --> 00:33:36,490

skill for all sorts of different reasons

876

00:33:41,520 --> 00:33:38,350

and then you race you like run around

877

00:33:43,020 --> 00:33:41,530

that's awesome yeah it's something I'd

878

00:33:44,970 --> 00:33:43,030

like to do all you don't know the course

879

00:33:46,980 --> 00:33:44,980

prior to the race the race starts you're

880

00:33:51,230 --> 00:33:46,990

given a map and the compass and let go

881

00:33:53,310 --> 00:33:51,240

like where am i hey I think it's awesome

882

00:33:54,420 --> 00:33:53,320

let's not not talk about me let's talk

883

00:33:57,210 --> 00:33:54,430

about you but it's time for questions

884

00:33:59,250 --> 00:33:57,220

which is my favorite part of the show so

885

00:34:01,350 --> 00:33:59,260

please ask your questions using hashtag

886

00:34:02,640 --> 00:34:01,360

ask Astro bio on Twitter or put them in

887

00:34:04,920 --> 00:34:02,650

a cigarette chat if you're watching on

888

00:34:06,390 --> 00:34:04,930

cigarette butt org or put them in

889

00:34:09,060 --> 00:34:06,400

comments if you're on Facebook live and

890

00:34:11,460 --> 00:34:09,070

the first question is from Marian Denton

891

00:34:13,530 --> 00:34:11,470

hello Marianne and she asks what is your

892

00:34:15,090 --> 00:34:13,540

favorite earth analog in other words if

893

00:34:17,790 --> 00:34:15,100

you can take a car and drive away where

894

00:34:20,040 --> 00:34:17,800

would you go okay my favorite earth

895

00:34:22,169 --> 00:34:20,050

analog well I've got one that I could

896

00:34:23,460 --> 00:34:22,179

drive to and one that I definitely would

897

00:34:26,280 --> 00:34:23,470

need to take a plane and then do some

898

00:34:28,530 --> 00:34:26,290

hiking so my favorite earth analog that

899

00:34:30,870 --> 00:34:28,540

I can drive to is probably Death Valley

900

00:34:32,909 --> 00:34:30,880

there's a place there called Devil's

901  
00:34:34,590 --> 00:34:32,919  
golf course which if you haven't seen

902  
00:34:37,290 --> 00:34:34,600  
one this looks like definitely Google it

903  
00:34:39,180 --> 00:34:37,300  
it's really gnarly looking it's it's a

904  
00:34:41,610 --> 00:34:39,190  
salt pan that has gone through many

905  
00:34:43,350 --> 00:34:41,620  
cycles it was getting wet and then the

906  
00:34:45,210 --> 00:34:43,360  
liquid evaporating away and since it's

907  
00:34:46,710 --> 00:34:45,220  
in Death Valley it's so salt rich that

908  
00:34:48,150 --> 00:34:46,720  
you end up with these like they look

909  
00:34:50,669 --> 00:34:48,160  
like rocks but they're made out of salt

910  
00:34:52,200 --> 00:34:50,679  
and they're very sharp and you know if

911  
00:34:53,730 --> 00:34:52,210  
you tried to hike on them you care if

912  
00:34:56,010 --> 00:34:53,740  
your boots and probably get some scrapes

913  
00:34:59,010 --> 00:34:56,020

and scratches the cool thing about this

914

00:35:00,870 --> 00:34:59,020

place is that from a very low resolution

915

00:35:02,820 --> 00:35:00,880

if you were just to fly over it with a

916

00:35:04,980 --> 00:35:02,830

low resolution camera it would look

917

00:35:07,350 --> 00:35:04,990

smoothest soaked like the safest place

918

00:35:08,970 --> 00:35:07,360

you could possibly land but then when

919

00:35:11,160 --> 00:35:08,980

you actually get down there or get some

920

00:35:13,500 --> 00:35:11,170

high-resolution imagery it's kind of

921

00:35:15,630 --> 00:35:13,510

it's got some some crags and some some

922

00:35:17,220 --> 00:35:15,640

drops and dips and scary stuff that you

923

00:35:20,010 --> 00:35:17,230

might not necessarily be okay with

924

00:35:21,780 --> 00:35:20,020

sticking a lander on so it's a good use

925

00:35:23,820 --> 00:35:21,790

case for us to try to test some of our

926

00:35:25,480 --> 00:35:23,830

our landing capability for things like

927

00:35:27,070 --> 00:35:25,490

the Europa land

928

00:35:29,560 --> 00:35:27,080

that's the one I would drive - the one I

929

00:35:32,830 --> 00:35:29,570

would fly to is probably the summit of

930

00:35:34,960 --> 00:35:32,840

Mount Kilimanjaro when I was a graduate

931

00:35:37,480 --> 00:35:34,970

student I was fortunate enough to be

932

00:35:39,250 --> 00:35:37,490

added on to a team where we got to hike

933

00:35:41,740 --> 00:35:39,260

up to the top of that mountain and camp

934

00:35:44,350 --> 00:35:41,750

at the summit for four nights and it was

935

00:35:47,500 --> 00:35:44,360

one of the most amazing experiences I've

936

00:35:49,600 --> 00:35:47,510

ever had I mean you feel like you're

937

00:35:51,280 --> 00:35:49,610

that much closer to space I can't

938

00:35:53,560 --> 00:35:51,290

remember what exactly the pressure is at

939

00:35:57,250 --> 00:35:53,570

20,000 feet that's the altitude at the

940

00:35:58,990 --> 00:35:57,260

top but it's just it's amazing and our

941

00:36:00,790 --> 00:35:59,000

sample site was like this very short

942

00:36:02,620 --> 00:36:00,800

walk away from camp it was near one of

943

00:36:04,270 --> 00:36:02,630

the the glaciers ice fields like the

944

00:36:06,670 --> 00:36:04,280

edge of this glacier and it was up this

945

00:36:08,080 --> 00:36:06,680

really gentle incline but since it's at

946

00:36:10,900 --> 00:36:08,090

20,000 feet you don't have as much

947

00:36:12,370 --> 00:36:10,910

option oxygen and I remember like just

948

00:36:15,220 --> 00:36:12,380

going up that tiny hill you're totally

949

00:36:17,020 --> 00:36:15,230

winded by the end you're like man I'm

950

00:36:19,870 --> 00:36:17,030

not a shape and then you remember oh no

951  
00:36:23,050 --> 00:36:19,880  
we're not like ridiculously high 3/5

952  
00:36:24,730 --> 00:36:23,060  
it's nuts but beautiful place yeah thank

953  
00:36:28,510 --> 00:36:24,740  
you pressure at the top is like half of

954  
00:36:33,730 --> 00:36:28,520  
what we have on the under it's pretty

955  
00:36:36,130 --> 00:36:33,740  
intense very windy so one of the key

956  
00:36:38,080 --> 00:36:36,140  
elements for life is phosphorus at least

957  
00:36:40,030 --> 00:36:38,090  
for life on Earth and Tom Caruso via

958  
00:36:42,130 --> 00:36:40,040  
Facebook asks can you explain the

959  
00:36:43,960 --> 00:36:42,140  
possible phosphorous cycle on titan and

960  
00:36:46,300 --> 00:36:43,970  
possible sources of phosphorous outside

961  
00:36:47,710 --> 00:36:46,310  
of the moon such as meteors or dust

962  
00:36:49,330 --> 00:36:47,720  
during particulates over time that could

963  
00:36:54,310 --> 00:36:49,340

influence the development of life on

964

00:36:56,680 --> 00:36:54,320

Titan or any of the moons nearby yeah so

965

00:36:58,120 --> 00:36:56,690

life is we know it includes phosphorus

966

00:37:01,140 --> 00:36:58,130

as one of its key elements like we

967

00:37:03,220 --> 00:37:01,150

talked about ATP adenosine triphosphate

968

00:37:05,650 --> 00:37:03,230

phosphorus is a key part of that energy

969

00:37:08,020 --> 00:37:05,660

transferring molecule that all life uses

970

00:37:10,390 --> 00:37:08,030

now as you get further out into the

971

00:37:13,240 --> 00:37:10,400

solar system further away from the Sun

972

00:37:15,340 --> 00:37:13,250

you end up getting enriched less in

973

00:37:18,040 --> 00:37:15,350

metals like mercury is sort of the most

974

00:37:19,510 --> 00:37:18,050

metal containing planet as you March

975

00:37:22,600 --> 00:37:19,520

further out you get less of that and

976

00:37:26,440 --> 00:37:22,610

more of volatile condensing so things

977

00:37:29,230 --> 00:37:26,450

like ammonia nitrogen methane water co2

978

00:37:32,590 --> 00:37:29,240

stuff like that now Titan still has a

979

00:37:34,870 --> 00:37:32,600

rocky core so if there were to be life

980

00:37:36,640 --> 00:37:34,880

you know in that surface ocean it's

981

00:37:38,470 --> 00:37:36,650

possible that there could be some

982

00:37:40,150 --> 00:37:38,480

phosphate that you could get

983

00:37:41,770 --> 00:37:40,160

from that environment there are some

984

00:37:44,890 --> 00:37:41,780

models that may have an ice layer

985

00:37:46,780 --> 00:37:44,900

between that rocky mantle and the ocean

986

00:37:48,160 --> 00:37:46,790

but I think a few studies have come out

987

00:37:49,600 --> 00:37:48,170

that show that even if there is ice

988

00:37:52,930 --> 00:37:49,610

there you can still get exchanged

989

00:37:55,210 --> 00:37:52,940

overtime and so that could be something

990

00:37:57,760 --> 00:37:55,220

that could exist there's also like your

991

00:37:59,260 --> 00:37:57,770

your person who asked the question

992

00:38:01,990 --> 00:37:59,270

mentioned there could be meteoritic

993

00:38:04,000 --> 00:38:02,000

involved that could deposit certain

994

00:38:06,610 --> 00:38:04,010

minerals and things like phosphates as

995

00:38:08,800 --> 00:38:06,620

well so there are a few sources they're

996

00:38:10,810 --> 00:38:08,810

not going to be quite as abundant but

997

00:38:12,990 --> 00:38:10,820

that just may give us some ideas in

998

00:38:16,660 --> 00:38:13,000

terms of life as we know it and what the

999

00:38:19,270 --> 00:38:16,670

metabolic limits might be there might be

1000

00:38:22,590 --> 00:38:19,280

a more energy constrained environment

1001

00:38:26,020 --> 00:38:22,600

because of resources like that or life

1002

00:38:28,210 --> 00:38:26,030

might find a way like some people might

1003

00:38:30,820 --> 00:38:28,220

have said in Jurassic Park and we may

1004

00:38:32,380 --> 00:38:30,830

end up utilizing different energy

1005

00:38:34,540 --> 00:38:32,390

transfer molecules and things like that

1006

00:38:38,230 --> 00:38:34,550

there was that controversial paper a few

1007

00:38:40,960 --> 00:38:38,240

years ago about the lake Mono Lake in

1008

00:38:43,000 --> 00:38:40,970

the arsenic that could potentially take

1009

00:38:44,470 --> 00:38:43,010

the place for phosphate now I urged

1010

00:38:46,630 --> 00:38:44,480

temperatures and pressures that's not

1011

00:38:49,930 --> 00:38:46,640

very likely the reason arsenic is a

1012

00:38:52,480 --> 00:38:49,940

poison is because it is not very stable

1013

00:38:54,700 --> 00:38:52,490

in liquid water at our temperatures it

1014

00:38:56,260 --> 00:38:54,710

tends to undergo hydrolysis and so why

1015

00:38:58,720 --> 00:38:56,270

don't do is it will replace the

1016

00:39:00,670 --> 00:38:58,730

phosphate backbone with some arsenic and

1017

00:39:02,770 --> 00:39:00,680

then just kind of chew it up that's why

1018

00:39:04,900 --> 00:39:02,780

arsenic is so dangerous for us but think

1019

00:39:07,150 --> 00:39:04,910

about really low temperatures well then

1020

00:39:08,920 --> 00:39:07,160

the hydrolysis will be slowed down a lot

1021

00:39:10,210 --> 00:39:08,930

and let's say you're not even exposed to

1022

00:39:12,550 --> 00:39:10,220

water what if you're in methane or

1023

00:39:15,820 --> 00:39:12,560

ethane as your solvent well then those

1024

00:39:18,400 --> 00:39:15,830

types of minerals and other things that

1025

00:39:20,500 --> 00:39:18,410

are different but could behave like

1026

00:39:22,690 --> 00:39:20,510

phosphate might become more important I

1027

00:39:25,120 --> 00:39:22,700

think right now we're at the cusp of

1028

00:39:26,980 --> 00:39:25,130

just trying to understand basic

1029

00:39:29,440 --> 00:39:26,990

interactions between very simple

1030

00:39:31,480 --> 00:39:29,450

combinations of organic molecules on

1031

00:39:33,370 --> 00:39:31,490

Titan ultimately we'd like to get to a

1032

00:39:35,020 --> 00:39:33,380

point where we're testing more complex

1033

00:39:37,060 --> 00:39:35,030

systems and we can really start to

1034

00:39:38,920 --> 00:39:37,070

address these questions of what would be

1035

00:39:40,870 --> 00:39:38,930

the analogue for phosphate on Titan

1036

00:39:43,060 --> 00:39:40,880

we're not there yet but it's an exciting

1037

00:39:44,920 --> 00:39:43,070

time and I encourage any of your younger

1038

00:39:47,650 --> 00:39:44,930

viewers to think about that as a

1039

00:39:51,520 --> 00:39:47,660

potential area of research for a future

1040

00:39:52,330 --> 00:39:51,530

career very exciting the next question

1041

00:39:54,940 --> 00:39:52,340

comes from which would

1042

00:39:57,310 --> 00:39:54,950

who asks it via sega net hi richard and

1043

00:39:59,230 --> 00:39:57,320

his question is really cool because he

1044

00:40:00,910 --> 00:39:59,240

cites the work of a meteorologist

1045

00:40:03,430 --> 00:40:00,920

robert hazen works at carnegie in

1046

00:40:05,230 --> 00:40:03,440

washington DC and Bob Hazen has made the

1047

00:40:07,810 --> 00:40:05,240

argument that the diversity of minerals

1048

00:40:09,430 --> 00:40:07,820

on earth's surface corresponds to the

1049

00:40:11,230 --> 00:40:09,440

increase in diversity of life that has

1050

00:40:13,510 --> 00:40:11,240

taken over the planet in other words a

1051  
00:40:17,110 --> 00:40:13,520  
lot of minerals means life has taken a

1052  
00:40:18,490 --> 00:40:17,120  
over place can we use the do we know

1053  
00:40:20,230 --> 00:40:18,500  
enough about the mineralogy on the

1054  
00:40:22,300 --> 00:40:20,240  
surface of Mars to kind of use that as a

1055  
00:40:24,490 --> 00:40:22,310  
proxy for whether or not life is on the

1056  
00:40:30,040 --> 00:40:24,500  
surface that's a really interesting

1057  
00:40:32,740 --> 00:40:30,050  
question I don't know but I think that

1058  
00:40:35,080 --> 00:40:32,750  
line of thinking of finding a place that

1059  
00:40:37,600 --> 00:40:35,090  
is not bland and purely composed of one

1060  
00:40:40,120 --> 00:40:37,610  
whether it's a mineral like on Mars or

1061  
00:40:41,890 --> 00:40:40,130  
Earth or an organic mineral on Titan I

1062  
00:40:44,650 --> 00:40:41,900  
agree we want to go to the interesting

1063  
00:40:46,540 --> 00:40:44,660

places where there seem to be chemical

1064

00:40:48,190 --> 00:40:46,550

gradients physical gradients things like

1065

00:40:50,680 --> 00:40:48,200

that because that's what life tends to

1066

00:40:54,090 --> 00:40:50,690

muse the other lesson that I think we

1067

00:40:57,010 --> 00:40:54,100

can take so far in our astrobiological

1068

00:40:59,290 --> 00:40:57,020

investigations at this stage is that no

1069

00:41:01,780 --> 00:40:59,300

one test is going to tell us whether or

1070

00:41:04,870 --> 00:41:01,790

not life exists unless let's say some

1071

00:41:06,760 --> 00:41:04,880

squid emerges from a crack in Europa

1072

00:41:08,800 --> 00:41:06,770

surface and waves is noodley appendage

1073

00:41:10,930 --> 00:41:08,810

at us okay then we might say we've just

1074

00:41:13,060 --> 00:41:10,940

need one test but typically especially

1075

00:41:15,670 --> 00:41:13,070

for micro organisms we're probably going

1076

00:41:18,760 --> 00:41:15,680

to need multiple independent lines of

1077

00:41:20,710 --> 00:41:18,770

evidence that lead us towards ultimately

1078

00:41:23,950 --> 00:41:20,720

the final conclusion that there is life

1079

00:41:26,200 --> 00:41:23,960

Carl Sagan once said that life has to be

1080

00:41:28,570 --> 00:41:26,210

the hypothesis of last resort so you

1081

00:41:30,940 --> 00:41:28,580

must have eliminated all other possible

1082

00:41:34,510 --> 00:41:30,950

explanations and you're only left with

1083

00:41:36,730 --> 00:41:34,520

life then that's the you know the most

1084

00:41:39,820 --> 00:41:36,740

convincing way you can approach that

1085

00:41:43,330 --> 00:41:39,830

question and so this mineralogical

1086

00:41:44,620 --> 00:41:43,340

diversity idea could be very well one of

1087

00:41:46,060 --> 00:41:44,630

those lines of evidence but I don't

1088

00:41:50,620 --> 00:41:46,070

think it would be convincing enough if

1089

00:41:53,200 --> 00:41:50,630

it was the only one cool very cool thank

1090

00:41:54,580 --> 00:41:53,210

you for that and Julia on sega net asks

1091

00:41:57,820 --> 00:41:54,590

about whether you could tell us a bit

1092

00:41:59,350 --> 00:41:57,830

more what cryovolcanoes are like it's

1093

00:42:02,560 --> 00:41:59,360

it's not intuitive we don't really have

1094

00:42:04,750 --> 00:42:02,570

them on earth or do we I sure know I

1095

00:42:07,600 --> 00:42:04,760

don't think we have any I mean you can

1096

00:42:10,330 --> 00:42:07,610

when in the lab pretty easily but just

1097

00:42:13,000 --> 00:42:10,340

like Earth's has a mantle where we've

1098

00:42:14,140 --> 00:42:13,010

got lava magma right it's magma when

1099

00:42:15,910 --> 00:42:14,150

it's underground and then when it comes

1100

00:42:18,070 --> 00:42:15,920

out it becomes lava right but that's the

1101  
00:42:20,560 --> 00:42:18,080  
difference and so just like magma and

1102  
00:42:22,960 --> 00:42:20,570  
lava here on earth you can have cryo

1103  
00:42:25,510 --> 00:42:22,970  
magma and cryo lava somewhere else

1104  
00:42:28,860 --> 00:42:25,520  
instead of being made of molten rock in

1105  
00:42:32,260 --> 00:42:28,870  
a place like Titan it would be made of

1106  
00:42:34,750 --> 00:42:32,270  
liquid water or a slurry of like water

1107  
00:42:36,730 --> 00:42:34,760  
ice but it's just barely liquidy and

1108  
00:42:38,920 --> 00:42:36,740  
kind of viscous because it might have

1109  
00:42:41,800 --> 00:42:38,930  
things like ammonia or other sort of

1110  
00:42:44,650 --> 00:42:41,810  
antifreeze type molecules that would

1111  
00:42:46,300 --> 00:42:44,660  
help to depress or lower the freezing

1112  
00:42:48,130 --> 00:42:46,310  
point so this is something that could

1113  
00:42:49,780 --> 00:42:48,140

exist below the freezing point of water

1114

00:42:52,050 --> 00:42:49,790

because it's got a lot of salts and

1115

00:42:55,390 --> 00:42:52,060

ammonia and other stuff in it it may be

1116

00:42:58,510 --> 00:42:55,400

really viscous and not super liquidy but

1117

00:43:00,540 --> 00:42:58,520

that type of cryo magma if it were to

1118

00:43:03,190 --> 00:43:00,550

exist in this environment there could be

1119

00:43:06,280 --> 00:43:03,200

different geological mechanisms that

1120

00:43:08,560 --> 00:43:06,290

could force that cryo magma up through

1121

00:43:11,680 --> 00:43:08,570

some sort of seizure in the surface

1122

00:43:14,350 --> 00:43:11,690

where it could spill out on the on the

1123

00:43:16,600 --> 00:43:14,360

top of Titan's surface and there are a

1124

00:43:18,670 --> 00:43:16,610

couple of papers Rosalee Lopez I know

1125

00:43:20,770 --> 00:43:18,680

she's a colleague at JPL has written

1126

00:43:22,480 --> 00:43:20,780

about a couple of places on Titan

1127

00:43:24,820 --> 00:43:22,490

surface there's an area called hotei

1128

00:43:27,460 --> 00:43:24,830

Reggio I think that's one I'm in so

1129

00:43:30,370 --> 00:43:27,470

trakula is is the name of another one

1130

00:43:31,930 --> 00:43:30,380

places where it looks like this process

1131

00:43:34,420 --> 00:43:31,940

might be happening and so we might have

1132

00:43:37,930 --> 00:43:34,430

a cryo volcanic flow and these are

1133

00:43:39,370 --> 00:43:37,940

exciting because a it might tell us if

1134

00:43:41,410 --> 00:43:39,380

we were to go and sample one of those

1135

00:43:43,300 --> 00:43:41,420

places we might have an easy way of

1136

00:43:45,550 --> 00:43:43,310

accessing some material from that ocean

1137

00:43:48,610 --> 00:43:45,560

that would be really hard to to drill

1138

00:43:51,640 --> 00:43:48,620

and sample ourselves and be this could

1139

00:43:54,070 --> 00:43:51,650

be a place where now you have liquid or

1140

00:43:56,200 --> 00:43:54,080

near liquid water interacting with all

1141

00:43:57,760 --> 00:43:56,210

of those fascinating organic molecules

1142

00:43:59,620 --> 00:43:57,770

they have been raining down from the

1143

00:44:02,560 --> 00:43:59,630

atmosphere now this is important because

1144

00:44:05,230 --> 00:44:02,570

here on earth when we make those complex

1145

00:44:07,330 --> 00:44:05,240

organic molecules we call them Dolan's

1146

00:44:08,830 --> 00:44:07,340

Carl Sagan named it it's named after the

1147

00:44:10,180 --> 00:44:08,840

Greek though loose which means muddy are

1148

00:44:11,950 --> 00:44:10,190

not clear I love that because they're

1149

00:44:13,000 --> 00:44:11,960

like brownish we also don't really know

1150

00:44:14,680 --> 00:44:13,010

what they're made of because it's like a

1151  
00:44:16,540 --> 00:44:14,690  
soup with all sorts of organic molecules

1152  
00:44:17,400 --> 00:44:16,550  
if you take those Solon's

1153  
00:44:19,740 --> 00:44:17,410  
and you dissolve

1154  
00:44:22,080 --> 00:44:19,750  
in water you make amino acids like that

1155  
00:44:23,900 --> 00:44:22,090  
like it's crazy and so any place on

1156  
00:44:26,460 --> 00:44:23,910  
Titan where we might find liquid water

1157  
00:44:28,560 --> 00:44:26,470  
interacting with these organics we might

1158  
00:44:28,860 --> 00:44:28,570  
find the ingredients for life as we know

1159  
00:44:30,840 --> 00:44:28,870  
it

1160  
00:44:33,210 --> 00:44:30,850  
so Craiova Kanak flows are a good place

1161  
00:44:35,640 --> 00:44:33,220  
if there's like an impact from a comet

1162  
00:44:36,840 --> 00:44:35,650  
or meteor the created melt pool that

1163  
00:44:38,910 --> 00:44:36,850

could be stable for a while that's

1164

00:44:41,330 --> 00:44:38,920

another big place things like this are

1165

00:44:45,210 --> 00:44:41,340

really fascinating targets for a future

1166

00:44:47,280 --> 00:44:45,220

Institute mission Titan indeed and this

1167

00:44:49,680 --> 00:44:47,290

leads to the next question by my co-host

1168

00:44:51,690 --> 00:44:49,690

Graham Lau who is curious about if you

1169

00:44:53,790 --> 00:44:51,700

had like an infinite of resources to

1170

00:44:55,860 --> 00:44:53,800

build your own mission to explore the

1171

00:44:58,050 --> 00:44:55,870

icy worlds of our solar system what

1172

00:45:00,330 --> 00:44:58,060

would you do what would you build oh boy

1173

00:45:02,400 --> 00:45:00,340

well I think that's a great question and

1174

00:45:04,500 --> 00:45:02,410

I think it would be a different answer

1175

00:45:07,140 --> 00:45:04,510

for a place like Titan then it would be

1176  
00:45:09,300 --> 00:45:07,150  
for a place like Europa or Enceladus let

1177  
00:45:11,130 --> 00:45:09,310  
me explain why I do two Titan's

1178  
00:45:13,710 --> 00:45:11,140  
atmosphere you can actually take

1179  
00:45:16,560 --> 00:45:13,720  
advantage of a couple of different ways

1180  
00:45:18,360 --> 00:45:16,570  
to transport or move your robotic

1181  
00:45:20,880 --> 00:45:18,370  
spacecraft around I'm actually a

1182  
00:45:23,040 --> 00:45:20,890  
co-investigator on one mission concept

1183  
00:45:27,210 --> 00:45:23,050  
called dragonfly that would do just that

1184  
00:45:29,580 --> 00:45:27,220  
the PIO zippy turtle out of APL and what

1185  
00:45:33,270 --> 00:45:29,590  
this is essentially a rotor craft

1186  
00:45:35,700 --> 00:45:33,280  
that could fly land basically do these

1187  
00:45:37,620 --> 00:45:35,710  
hops across the surface of Titan it

1188  
00:45:39,540 --> 00:45:37,630

turns out just like we were talking

1189

00:45:40,980 --> 00:45:39,550

about earlier where if you were standing

1190

00:45:43,320 --> 00:45:40,990

on the surface and you could flap your

1191

00:45:45,210 --> 00:45:43,330

wings you could fly on Titan it turns

1192

00:45:46,830 --> 00:45:45,220

out that transporting through air is

1193

00:45:49,620 --> 00:45:46,840

much more efficient than it would be to

1194

00:45:52,110 --> 00:45:49,630

use like a typical Mars rover kind of

1195

00:45:53,850 --> 00:45:52,120

design for an environment like Titan so

1196

00:45:55,770 --> 00:45:53,860

I think in terms of exploring Titan

1197

00:45:57,870 --> 00:45:55,780

that's the exact kind of architecture I

1198

00:46:00,360 --> 00:45:57,880

would use because then you can move to

1199

00:46:02,610 --> 00:46:00,370

different places so we could say we

1200

00:46:04,650 --> 00:46:02,620

found a cryo volcanic flow we could land

1201

00:46:06,150 --> 00:46:04,660

there collect some samples do some

1202

00:46:07,620 --> 00:46:06,160

science and then we could hop over to

1203

00:46:08,970 --> 00:46:07,630

the dunes and figure out what the heck

1204

00:46:10,560 --> 00:46:08,980

those are made of because we still don't

1205

00:46:12,930 --> 00:46:10,570

know and maybe we could hop all the way

1206

00:46:15,120 --> 00:46:12,940

over to a lake edge and collect a sample

1207

00:46:17,370 --> 00:46:15,130

there there are all sorts of things you

1208

00:46:19,500 --> 00:46:17,380

could do with that kind of platform so I

1209

00:46:22,530 --> 00:46:19,510

think that's what I do for Titan now for

1210

00:46:24,510 --> 00:46:22,540

Enceladus in Europa oh boy

1211

00:46:29,910 --> 00:46:24,520

it depends on how much money I had I

1212

00:46:30,450 --> 00:46:29,920

think if I could if I could um like

1213

00:46:33,420 --> 00:46:30,460

slice through

1214

00:46:35,970 --> 00:46:33,430

plume of Enceladus with a lot more

1215

00:46:37,890 --> 00:46:35,980

detailed instruments or instruments with

1216

00:46:41,849 --> 00:46:37,900

better resolution and sensitivity and

1217

00:46:43,950 --> 00:46:41,859

Cassini I definitely do that but you

1218

00:46:46,589 --> 00:46:43,960

know ultimately landing maybe digging

1219

00:46:48,630 --> 00:46:46,599

down drilling into the crust and getting

1220

00:46:50,520 --> 00:46:48,640

to the ocean and letting loose a

1221

00:46:52,980 --> 00:46:50,530

submersible that would ideally be what

1222

00:46:55,320 --> 00:46:52,990

I'd like to do swim around look for some

1223

00:46:57,660 --> 00:46:55,330

some - worms by those hydrothermal vents

1224

00:47:04,530 --> 00:46:57,670

and and officially collect my Nobel

1225

00:47:06,390 --> 00:47:04,540

Prize that's what I do a few episodes

1226  
00:47:08,910 --> 00:47:06,400  
ago and asking astrobiologists we had

1227  
00:47:10,530 --> 00:47:08,920  
ski vents we weren't doing Steve ants

1228  
00:47:13,109 --> 00:47:10,540  
and he was a science advisor for the

1229  
00:47:14,640 --> 00:47:13,119  
movie the Europa report so those of you

1230  
00:47:16,050 --> 00:47:14,650  
who are watching today like you haven't

1231  
00:47:17,250 --> 00:47:16,060  
seen that movie go ahead and which head

1232  
00:47:19,770 --> 00:47:17,260  
gives you a bit of an idea of what it

1233  
00:47:21,630 --> 00:47:19,780  
takes to explore Europa I'm so we're

1234  
00:47:23,160 --> 00:47:21,640  
getting close on time here but I want to

1235  
00:47:25,290 --> 00:47:23,170  
give Prieta the chance to ask her

1236  
00:47:27,690 --> 00:47:25,300  
questions which is very good and she

1237  
00:47:30,060 --> 00:47:27,700  
asks apart from Mars and the moons of

1238  
00:47:32,099 --> 00:47:30,070

Jupiter and Saturn what are the other

1239

00:47:36,420 --> 00:47:32,109

places in the solar system that are most

1240

00:47:38,730 --> 00:47:36,430

probably habitable oh okay

1241

00:47:41,490 --> 00:47:38,740

other than Mars and the moons of Jupiter

1242

00:47:43,410 --> 00:47:41,500

and Saturn okay well Triton which is a

1243

00:47:45,450 --> 00:47:43,420

moon around Neptune is really

1244

00:47:47,760 --> 00:47:45,460

fascinating and really weird right it's

1245

00:47:49,200 --> 00:47:47,770

orbiting backwards which means we think

1246

00:47:50,700 --> 00:47:49,210

it might be like a captured quick

1247

00:47:53,430 --> 00:47:50,710

rebelled object or something like that

1248

00:47:55,290 --> 00:47:53,440

it's got active cryovolcanoes it's the

1249

00:47:57,660 --> 00:47:55,300

one place that it's confirmed for sure

1250

00:48:00,329 --> 00:47:57,670

to have that thanks to the Voyager

1251  
00:48:01,740 --> 00:48:00,339  
missions we know about that so it looks

1252  
00:48:03,900 --> 00:48:01,750  
like that could be a really fascinating

1253  
00:48:06,480 --> 00:48:03,910  
place it's not clear if it also has a

1254  
00:48:09,030 --> 00:48:06,490  
liquid water ocean that would be one of

1255  
00:48:10,710 --> 00:48:09,040  
the main things to look at the next time

1256  
00:48:11,790 --> 00:48:10,720  
we send something there which boy I hope

1257  
00:48:14,970 --> 00:48:11,800  
is soon because that's a fascinating

1258  
00:48:18,120 --> 00:48:14,980  
place - there's been a lot of work with

1259  
00:48:19,710 --> 00:48:18,130  
Ceres and some of the larger dwarf

1260  
00:48:21,510 --> 00:48:19,720  
planets and things like that in the

1261  
00:48:23,760 --> 00:48:21,520  
asteroid belt that are really

1262  
00:48:26,130 --> 00:48:23,770  
fascinating there are these Trojan

1263  
00:48:28,890 --> 00:48:26,140

asteroids that that are further out that

1264

00:48:30,480 --> 00:48:28,900

also could host environments where maybe

1265

00:48:32,520 --> 00:48:30,490

liquid water could be stable for a

1266

00:48:34,710 --> 00:48:32,530

certain period of time now we still

1267

00:48:36,720 --> 00:48:34,720

don't even know how long you need to

1268

00:48:38,790 --> 00:48:36,730

have the right ingredients for life to

1269

00:48:40,800 --> 00:48:38,800

emerge to just sit and wait and have

1270

00:48:42,630 --> 00:48:40,810

life form we still don't know what what

1271

00:48:43,410 --> 00:48:42,640

that is is it 20 seconds is it 20

1272

00:48:46,589 --> 00:48:43,420

million years we

1273

00:48:48,359 --> 00:48:46,599

and so I think going and looking at all

1274

00:48:50,400 --> 00:48:48,369

of these places is really important

1275

00:48:52,589 --> 00:48:50,410

because like you said Sen join we only

1276

00:48:54,960 --> 00:48:52,599

have a sample size of one right we know

1277

00:48:56,940 --> 00:48:54,970

earth is the place we have life here

1278

00:48:59,099 --> 00:48:56,950

that's it that's all we know up and so

1279

00:49:01,049 --> 00:48:59,109

by studying all these other places where

1280

00:49:02,519 --> 00:49:01,059

liquid water may have existed for

1281

00:49:04,740 --> 00:49:02,529

different time scales where the

1282

00:49:06,960 --> 00:49:04,750

temperatures are the pH or the the

1283

00:49:09,509 --> 00:49:06,970

initial ingredients may be different all

1284

00:49:12,000 --> 00:49:09,519

of those things we can now bring into

1285

00:49:13,890 --> 00:49:12,010

our sample size and assess okay well in

1286

00:49:16,140 --> 00:49:13,900

this environment there's no life but it

1287

00:49:18,210 --> 00:49:16,150

had these conditions vs. earth which had

1288

00:49:20,700 --> 00:49:18,220

life time these conditions and this can

1289

00:49:22,559 --> 00:49:20,710

help inform our exploration and our

1290

00:49:25,620 --> 00:49:22,569

study of exoplanets and trying to find

1291

00:49:27,960 --> 00:49:25,630

life elsewhere as well that's so

1292

00:49:29,700 --> 00:49:27,970

fascinating but before we closed over

1293

00:49:32,130 --> 00:49:29,710

again I want to give you an entire

1294

00:49:34,230 --> 00:49:32,140

Cassini team a huge shout out for the

1295

00:49:35,670 --> 00:49:34,240

incredible mission that it's been and I

1296

00:49:37,049 --> 00:49:35,680

think we're still getting data and

1297

00:49:40,470 --> 00:49:37,059

analyzing trying to figure out what it

1298

00:49:42,289 --> 00:49:40,480

means but Cassini received an Emmy Award

1299

00:49:45,329 --> 00:49:42,299

right tell us about that that's awesome

1300

00:49:46,859 --> 00:49:45,339

yeah Cassini is any was for I want to

1301

00:49:49,859 --> 00:49:46,869

read it it was outstanding original

1302

00:49:52,980 --> 00:49:49,869

interactive program so this was right

1303

00:49:54,660 --> 00:49:52,990

near the grand finale we we had a unique

1304

00:49:57,059 --> 00:49:54,670

opportunity right the spacecraft was

1305

00:49:59,220 --> 00:49:57,069

working perfectly and we could actually

1306

00:50:00,299 --> 00:49:59,230

plan the end of the missions now you

1307

00:50:02,249 --> 00:50:00,309

don't always get to do this sometimes

1308

00:50:05,400 --> 00:50:02,259

things go wrong like with the Spirit

1309

00:50:06,839 --> 00:50:05,410

Mars rover where that was sort of out of

1310

00:50:09,240 --> 00:50:06,849

our control of when that mission might

1311

00:50:12,170 --> 00:50:09,250

end but with Cassini we knew we were

1312

00:50:15,120 --> 00:50:12,180

running out of gas and we didn't want to

1313

00:50:16,920 --> 00:50:15,130

have Cassini run out us completely and

1314

00:50:18,690 --> 00:50:16,930

then drift aimlessly in the Saturn

1315

00:50:20,549 --> 00:50:18,700

system where we couldn't control it

1316

00:50:22,529 --> 00:50:20,559

any more miss Cassini was kind of a

1317

00:50:24,799 --> 00:50:22,539

victim of its own success it discovered

1318

00:50:27,870 --> 00:50:24,809

liquid water on Enceladus and

1319

00:50:30,749 --> 00:50:27,880

underground on Titan - what if by chance

1320

00:50:32,490 --> 00:50:30,759

a thousand years from now 10,000 years

1321

00:50:35,190 --> 00:50:32,500

from now Cassini were to accidentally

1322

00:50:37,140 --> 00:50:35,200

crash in one of these places and deposit

1323

00:50:39,450 --> 00:50:37,150

one of its microbial hitchhikers there

1324

00:50:41,579 --> 00:50:39,460

we did our the best job we could to

1325

00:50:43,170 --> 00:50:41,589

clean Cassini but we didn't sterilize it

1326

00:50:44,999 --> 00:50:43,180

but we didn't think liquid water could

1327

00:50:47,970 --> 00:50:45,009

exist that far out when we built it and

1328

00:50:50,249 --> 00:50:47,980

launched it in 97 and so because of that

1329

00:50:52,319 --> 00:50:50,259

we had to dispose of Cassini somewhere

1330

00:50:54,509 --> 00:50:52,329

where we knew it could not contaminate

1331

00:50:56,340 --> 00:50:54,519

that place with earth life what would be

1332

00:50:58,140 --> 00:50:56,350

worse than finally finding life on

1333

00:51:00,870 --> 00:50:58,150

and realizing we accidentally put it

1334

00:51:03,360 --> 00:51:00,880

there so because of that we planned this

1335

00:51:05,880 --> 00:51:03,370

swan dive into Saturn's atmosphere we

1336

00:51:08,690 --> 00:51:05,890

collected data the entire way until we

1337

00:51:12,300 --> 00:51:08,700

lost signal and as part of that effort

1338

00:51:15,540 --> 00:51:12,310

our media department did a huge outreach

1339

00:51:18,870 --> 00:51:15,550

campaign you can still go to Saturn JPL

1340

00:51:21,270 --> 00:51:18,880

NASA gov and find a lot of those those

1341

00:51:23,220 --> 00:51:21,280

same outreach activities things that we

1342

00:51:26,850 --> 00:51:23,230

were monitoring we had some incredible

1343

00:51:28,980 --> 00:51:26,860

videos and then some live footage of the

1344

00:51:31,470 --> 00:51:28,990

Cassini grand finale plunge which is at

1345

00:51:34,560 --> 00:51:31,480

five o'clock in the morning here Pacific

1346

00:51:36,900 --> 00:51:34,570

time and it was an incredible Herculean

1347

00:51:39,090 --> 00:51:36,910

effort those media specialists that are

1348

00:51:41,340 --> 00:51:39,100

on our team were absolutely amazing and

1349

00:51:43,380 --> 00:51:41,350

very deserving of the emmy i mean they

1350

00:51:45,000 --> 00:51:43,390

were the ones who did the lion's share

1351  
00:51:47,640 --> 00:51:45,010  
of the work but everyone on Cassini

1352  
00:51:48,840 --> 00:51:47,650  
feels like the emmy is in part a little

1353  
00:51:50,790 --> 00:51:48,850  
bit you know it's shared amongst the

1354  
00:51:53,490 --> 00:51:50,800  
whole team because this mission was just

1355  
00:51:56,220 --> 00:51:53,500  
such an amazing success and it touched

1356  
00:51:58,440 --> 00:51:56,230  
so many lives and like you said the data

1357  
00:52:01,650 --> 00:51:58,450  
we're still gonna be analyzing that for

1358  
00:52:04,050 --> 00:52:01,660  
decades to come so it's an incredible

1359  
00:52:06,300 --> 00:52:04,060  
thing to be a part of and just can't be

1360  
00:52:08,580 --> 00:52:06,310  
more proud of my colleagues and friends

1361  
00:52:10,410 --> 00:52:08,590  
on the Cassini mission this particular

1362  
00:52:12,660 --> 00:52:10,420  
the the media teams that made that

1363  
00:52:14,160 --> 00:52:12,670

possible wonderful and that's a

1364

00:52:15,570 --> 00:52:14,170

beautiful place to close we're running

1365

00:52:17,460 --> 00:52:15,580

out of time which is so too bad I really

1366

00:52:18,960 --> 00:52:17,470

value this conversation Morgan I know

1367

00:52:21,090 --> 00:52:18,970

you're extremely busy and it's clear

1368

00:52:23,280 --> 00:52:21,100

that you are you do a lot of science you

1369

00:52:25,680 --> 00:52:23,290

even travel the world to outreach to

1370

00:52:27,180 --> 00:52:25,690

talk about how exciting Sciences you're

1371

00:52:28,920 --> 00:52:27,190

really excellent role model for many of

1372

00:52:30,480 --> 00:52:28,930

our young viewers just want to thank you

1373

00:52:32,670 --> 00:52:30,490

for the time you took to speak with us

1374

00:52:35,250 --> 00:52:32,680

today Thank You Sandra I feel really

1375

00:52:37,910 --> 00:52:35,260

lucky to be able to have fun I love

1376  
00:52:40,830 --> 00:52:37,920  
going to work every day and I hope that

1377  
00:52:43,170 --> 00:52:40,840  
we can potentially you and I and and all

1378  
00:52:44,460 --> 00:52:43,180  
of us who advocate for outreach and

1379  
00:52:46,170 --> 00:52:44,470  
science we can inspire the next

1380  
00:52:47,850 --> 00:52:46,180  
generation because I don't want the

1381  
00:52:49,380 --> 00:52:47,860  
science to end with us we've got to have

1382  
00:52:52,680 --> 00:52:49,390  
that next generation come up and

1383  
00:52:57,510 --> 00:52:52,690  
continue to do amazing things so thanks

1384  
00:52:59,040 --> 00:52:57,520  
and awesome so you are at at stars are

1385  
00:52:59,970 --> 00:52:59,050  
calling on Twitter so if you're on

1386  
00:53:02,910 --> 00:52:59,980  
Twitter and you're not you're not

1387  
00:53:05,070 --> 00:53:02,920  
following Morgan please do so folks this

1388  
00:53:07,020 --> 00:53:05,080

is it for this week I will see you next

1389

00:53:08,530 --> 00:53:07,030

month on ask an astrobiologist was gram

1390

00:53:09,910 --> 00:53:08,540

presenting and until then

1391

00:53:12,060 --> 00:53:09,920

it's good to see you all and stay