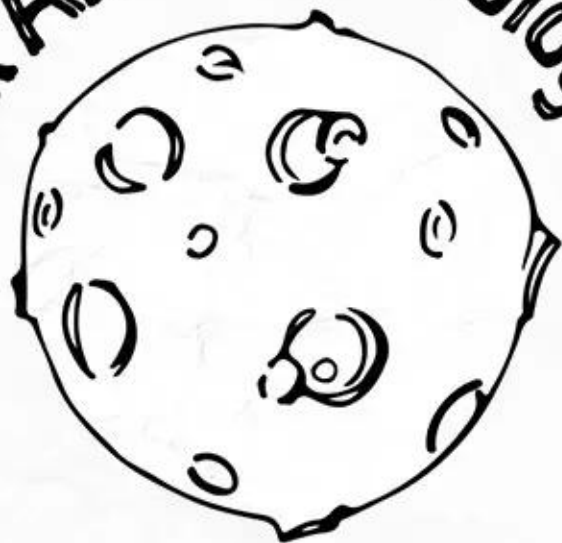


Ask An Astrobiologist



EPISODE 14: AUGUST 21ST, 2018

DR. STEVE VANCE



ASTROBIOLOGY PROGRAM

1
00:00:00,500 --> 00:00:29,740

[Music]

2
00:00:33,620 --> 00:00:31,730

greetings friends of astrobiology

3
00:00:35,750 --> 00:00:33,630

welcome to a brand new episode of ask

4
00:00:38,330 --> 00:00:35,760

mr. biologists a show where we celebrate

5
00:00:39,650 --> 00:00:38,340

science and celebrate scientists my name

6
00:00:41,510 --> 00:00:39,660

is Sanjay some and this program is made

7
00:00:43,639 --> 00:00:41,520

possible by contributions from the NASA

8
00:00:46,040 --> 00:00:43,649

Astrobiology program and a non profit

9
00:00:48,470 --> 00:00:46,050

blue bubble space today we're very lucky

10
00:00:50,900 --> 00:00:48,480

to have a special guest in dr. Steve

11
00:00:53,090 --> 00:00:50,910

Vance who works at the hallowed ground

12
00:00:55,549 --> 00:00:53,100

of planetary exploration the Jet

13
00:00:57,439 --> 00:00:55,559

Propulsion Laboratory in Pasadena which

14

00:01:03,070 --> 00:00:57,449

is near the city of Los Angeles in

15

00:01:07,100 --> 00:01:05,210

I'm so looking forward to our

16

00:01:09,130 --> 00:01:07,110

conversation but before we start it's

17

00:01:12,050 --> 00:01:09,140

time for your monthly background quiz

18

00:01:13,850 --> 00:01:12,060

behind me is a fascinating location and

19

00:01:15,679 --> 00:01:13,860

located on our beautiful planet the

20

00:01:17,899 --> 00:01:15,689

earth and it is your job you the

21

00:01:21,260 --> 00:01:17,909

audience to guess where it is for our

22

00:01:24,380 --> 00:01:21,270

next episode for prizes you get the

23

00:01:27,890 --> 00:01:24,390

third place winner gets the amazing NASA

24

00:01:30,200 --> 00:01:27,900

stickers here we go the second place

25

00:01:33,020 --> 00:01:30,210

will get the stickers and astrobiology

26

00:01:36,170 --> 00:01:33,030

graphic novels and the winner will get

27

00:01:40,010 --> 00:01:36,180

the stickers the graphic novel and the

28

00:01:43,160 --> 00:01:40,020

Signet org my class last month we had a

29

00:01:47,240 --> 00:01:43,170

beautiful image that Mike can put up for

30

00:01:49,310 --> 00:01:47,250

a few seconds congratulations to those

31

00:01:51,620 --> 00:01:49,320

of you who got the right answer it is

32

00:01:53,480 --> 00:01:51,630

the Bahamas blue holes those are many

33

00:01:55,010 --> 00:01:53,490

holes located in the Bahamas that gets

34

00:01:57,319 --> 00:01:55,020

flooded and they're really interesting

35

00:02:00,319 --> 00:01:57,329

because they get colonized by bacteria

36

00:02:02,149 --> 00:02:00,329

that do not depend on lights to survive

37

00:02:04,280 --> 00:02:02,159

that becomes important when thinking

38

00:02:06,469 --> 00:02:04,290

about life in extraterrestrial bodies

39

00:02:09,469 --> 00:02:06,479

like we'll talk about today on this very

40

00:02:10,210 --> 00:02:09,479

show so the third prize went to Evelina

41

00:02:12,240 --> 00:02:10,220

dual gear

42

00:02:14,770 --> 00:02:12,250

congratulations you get all the stickers

43

00:02:16,990 --> 00:02:14,780

who she connected from Garden City

44

00:02:18,370 --> 00:02:17,000

Michigan the second prize gets the

45

00:02:20,410 --> 00:02:18,380

stickers and a graphic novel

46

00:02:22,240 --> 00:02:20,420

Chad Mitchell congratulations connecting

47

00:02:24,790 --> 00:02:22,250

from Spanaway in the state of Washington

48

00:02:27,550 --> 00:02:24,800

and the winner of all three items is

49

00:02:29,470 --> 00:02:27,560

Omar al ID hi Omar congratulations is

50

00:02:32,260 --> 00:02:29,480

connecting from Cairo Egypt's

51
00:02:34,150 --> 00:02:32,270
congratulates to all of you so what is

52
00:02:38,140 --> 00:02:34,160
behind me we'll let you know next month

53
00:02:40,030 --> 00:02:38,150
on ask an astrobiologist I can say I'm

54
00:02:42,490 --> 00:02:40,040
excited about this particular episode

55
00:02:44,560 --> 00:02:42,500
Steve's because I'm personally a fan of

56
00:02:46,750 --> 00:02:44,570
the movie the Europa report that I know

57
00:02:49,600 --> 00:02:46,760
you are a scientist at scientific

58
00:02:51,010 --> 00:02:49,610
advisor for but before we get to that

59
00:02:52,540 --> 00:02:51,020
though like we like to do in this show

60
00:02:54,340 --> 00:02:52,550
is turn back the wheels of time a little

61
00:03:00,940 --> 00:02:54,350
bit and can you tell us how your

62
00:03:04,380 --> 00:03:00,950
interest in science first arose yeah so

63
00:03:07,840 --> 00:03:04,390

going back to elementary school and

64

00:03:10,840 --> 00:03:07,850

books on planets I remember distinctly

65

00:03:12,220 --> 00:03:10,850

an image of a fishbowl the size of the

66

00:03:14,979 --> 00:03:12,230

Sun showing how many earths you could

67

00:03:18,220 --> 00:03:14,989

fit in it and so I was intrigued by that

68

00:03:20,259 --> 00:03:18,230

I was also a fan of the cartoon Muppet

69

00:03:23,590 --> 00:03:20,269

Babies which I guess Bates me a little

70

00:03:26,949 --> 00:03:23,600

bit show all about the imagination and

71

00:03:30,370 --> 00:03:26,959

in the star wars episode the the Muffet

72

00:03:33,370 --> 00:03:30,380

baby kids made a star field I poked

73

00:03:35,440 --> 00:03:33,380

holes in paper and black cardboard so I

74

00:03:39,220 --> 00:03:35,450

was inspired to do that third grade for

75

00:03:42,729 --> 00:03:39,230

my report about Uranus and and so I made

76

00:03:44,410 --> 00:03:42,739

a shoebox star field and I actually had

77

00:03:47,830 --> 00:03:44,420

some accurate constellations on there

78

00:03:50,979 --> 00:03:47,840

and a little glow in the dark he's a

79

00:03:53,080 --> 00:03:50,989

plastic inside so I guess I can thank

80

00:03:56,289 --> 00:03:53,090

the Voyager mission for Earth's

81

00:03:57,940 --> 00:03:56,299

inspiring by my efforts of space very

82

00:04:01,300 --> 00:03:57,950

cool yeah I remember exactly where I was

83

00:04:02,920 --> 00:04:01,310

in 1989 when Voyager 2 passed Neptune I

84

00:04:05,830 --> 00:04:02,930

was very young boy and it's still very

85

00:04:07,930 --> 00:04:05,840

vivid in my mind so from a shoebox you

86

00:04:11,800 --> 00:04:07,940

then did your undergraduate in physics

87

00:04:14,350 --> 00:04:11,810

at UC Santa Cruz that is correct and

88

00:04:15,880 --> 00:04:14,360

yeah and like many undergraduates I

89

00:04:17,890 --> 00:04:15,890

wasn't sure exactly what I was going to

90

00:04:19,839 --> 00:04:17,900

be I was considering you know going into

91

00:04:22,420 --> 00:04:19,849

the lucrative field of semiconductor

92

00:04:24,070 --> 00:04:22,430

development but somehow that didn't

93

00:04:26,980 --> 00:04:24,080

excite me as much

94

00:04:29,499 --> 00:04:26,990

and as the idea of trying to figure out

95

00:04:32,409 --> 00:04:29,509

what's out there what is our place in

96

00:04:33,969 --> 00:04:32,419

the cosmos you know and I guess like

97

00:04:37,300 --> 00:04:33,979

many many people in our field I was

98

00:04:40,659 --> 00:04:37,310

inspired in high school by by Carl

99

00:04:43,510 --> 00:04:40,669

Sagan's Cosmos so I I had a VH set of

100

00:04:45,520 --> 00:04:43,520

VHS set of those and I watched my way

101
00:04:45,909 --> 00:04:45,530
through them so that that came back to

102
00:04:46,990 --> 00:04:45,919
me

103
00:04:49,899 --> 00:04:47,000
you know toward the end of undergrad

104
00:04:52,330 --> 00:04:49,909
when I was thinking about what I wanted

105
00:04:54,279 --> 00:04:52,340
to do and applying to grad schools and I

106
00:04:58,600 --> 00:04:54,289
had an internship of x-ray technology

107
00:05:02,170 --> 00:04:58,610
company near Santa Cruz so designing LED

108
00:05:06,659 --> 00:05:02,180
enclosures for testing x-ray tubes which

109
00:05:08,469 --> 00:05:06,669
was cool but what was even cooler

110
00:05:09,999 --> 00:05:08,479
sessions that I had with one of the

111
00:05:13,210 --> 00:05:10,009
employees there who had a master's

112
00:05:15,550 --> 00:05:13,220
degree in astrophysics and he had been

113
00:05:17,980 --> 00:05:15,560

his head you know the the plan for

114

00:05:19,950 --> 00:05:17,990

humanity's exploration of the universe

115

00:05:22,600 --> 00:05:19,960

and you know the first couple chapters

116

00:05:24,339 --> 00:05:22,610

in those discussions were basically

117

00:05:27,659 --> 00:05:24,349

astrobiology and this just happened to

118

00:05:30,850 --> 00:05:27,669

coincide with the discovery of alh84001

119

00:05:33,399 --> 00:05:30,860

the now famous meteorite that still has

120

00:05:33,760 --> 00:05:33,409

ambiguous signs of possible life from

121

00:05:36,339 --> 00:05:33,770

Mars

122

00:05:40,059 --> 00:05:36,349

which then kicked off at the beginning

123

00:05:43,990 --> 00:05:40,069

of astrobiology of the field so so

124

00:05:45,339 --> 00:05:44,000

following my regrets and that's where we

125

00:05:47,800 --> 00:05:45,349

met you went to the University of

126

00:05:50,589 --> 00:05:47,810

Washington and in Seattle and your

127

00:05:51,700 --> 00:05:50,599

doctoral thesis was in geophysics tell

128

00:05:53,769 --> 00:05:51,710

us a little bit about what you did I

129

00:05:58,420 --> 00:05:53,779

remember a big giant machine was a huge

130

00:06:00,820 --> 00:05:58,430

dial yeah well I'll get to that yeah so

131

00:06:02,170 --> 00:06:00,830

I was admitted to the geophysics program

132

00:06:05,200 --> 00:06:02,180

under the department that later became

133

00:06:07,240 --> 00:06:05,210

Earth and space science and I work with

134

00:06:09,670 --> 00:06:07,250

an advisor named J Michael Brown one of

135

00:06:11,890 --> 00:06:09,680

the many Mike Brown's of the world he's

136

00:06:13,899 --> 00:06:11,900

a famous mineral physicist so studies

137

00:06:15,339 --> 00:06:13,909

the interior of the earth and he was

138

00:06:16,689 --> 00:06:15,349

interested in applying some of his

139

00:06:19,029 --> 00:06:16,699

knowledge of thermodynamics and

140

00:06:20,890 --> 00:06:19,039

imparting for that knowledge to me in a

141

00:06:26,019 --> 00:06:20,900

way that would allow us to think about

142

00:06:27,969 --> 00:06:26,029

how the properties of water and salty

143

00:06:29,950 --> 00:06:27,979

fluids change at the really high

144

00:06:32,290 --> 00:06:29,960

pressures that were expected to occur in

145

00:06:34,930 --> 00:06:32,300

the ocean of Europa so Europe as a

146

00:06:37,029 --> 00:06:34,940

homonym Jupiter it's ocean had been just

147

00:06:37,959 --> 00:06:37,039

discovered at the time that I started

148

00:06:39,399 --> 00:06:37,969

grad school

149

00:06:41,649 --> 00:06:39,409

and we had hints that there were oceans

150

00:06:43,899 --> 00:06:41,659

elsewhere as well you know so there was

151
00:06:45,820 --> 00:06:43,909
there was a promising research direction

152
00:06:48,429 --> 00:06:45,830
in studying the chemistry of those food

153
00:06:53,950 --> 00:06:48,439
than the high-pressure and so to do that

154
00:06:58,119 --> 00:06:53,960
I built a device on wheels that allowed

155
00:07:00,820 --> 00:06:58,129
me to pressurize fluids to up to 8,000

156
00:07:02,799 --> 00:07:00,830
atmospheres and it had to be on wheels

157
00:07:04,209 --> 00:07:02,809
because it's an optical device so I

158
00:07:05,920 --> 00:07:04,219
shined a laser light through the

159
00:07:09,730 --> 00:07:05,930
high-pressure fluid like two laser

160
00:07:12,010 --> 00:07:09,740
lights and and created a pulse where

161
00:07:13,659 --> 00:07:12,020
that where the laser beams intersected

162
00:07:15,549 --> 00:07:13,669
and I and I looked at how that sound

163
00:07:16,689 --> 00:07:15,559

pulse evolved about measuring the

164

00:07:18,879 --> 00:07:16,699

diffraction of with this diffraction

165

00:07:21,399 --> 00:07:18,889

reading that I have created and so I

166

00:07:24,279 --> 00:07:21,409

measured Sound speed with light and and

167

00:07:26,409 --> 00:07:24,289

Sound speed then could be used to infer

168

00:07:28,049 --> 00:07:26,419

the density of the fluids so that was

169

00:07:32,049 --> 00:07:28,059

the beginning of our research program

170

00:07:33,089 --> 00:07:32,059

yeah the the frankenstein-looking was

171

00:07:35,499 --> 00:07:33,099

pretty impressive

172

00:07:39,129 --> 00:07:35,509

so that was a device to measure the

173

00:07:41,469 --> 00:07:39,139

properties of water or salty water under

174

00:07:43,269 --> 00:07:41,479

really really high pressures more than

175

00:07:46,360 --> 00:07:43,279

the pressures we see in Earth's oceans

176

00:07:48,100 --> 00:07:46,370

for the application of Europa and also

177

00:07:50,739 --> 00:07:48,110

other icy moons so perhaps let's take a

178

00:07:52,570 --> 00:07:50,749

step back now and why icy moons why is

179

00:07:56,290 --> 00:07:52,580

the interest in these icy moons also

180

00:07:57,939 --> 00:07:56,300

known as ocean worlds yeah well okay so

181

00:08:00,100 --> 00:07:57,949

at the beginning of astrobiology the

182

00:08:02,079 --> 00:08:00,110

mantra was follow the water we first

183

00:08:04,779 --> 00:08:02,089

wanted to just establish where there

184

00:08:08,260 --> 00:08:04,789

might be water because as is often said

185

00:08:11,110 --> 00:08:08,270

we were we find liquid water we find

186

00:08:12,339 --> 00:08:11,120

life so organisms are pretty good and

187

00:08:14,559 --> 00:08:12,349

making use of the resources that are

188

00:08:16,600 --> 00:08:14,569

available to them almost every loop of

189

00:08:18,670 --> 00:08:16,610

water environment and at the time that

190

00:08:22,869 --> 00:08:18,680

astrobiology started we didn't know of

191

00:08:24,249 --> 00:08:22,879

any liquid water on present day Mars and

192

00:08:26,589 --> 00:08:24,259

Mars continues to be a promising place

193

00:08:29,199 --> 00:08:26,599

to look for signs of past life and

194

00:08:31,959 --> 00:08:29,209

perhaps now that there's some evidence

195

00:08:33,759 --> 00:08:31,969

or subsurface water gargoyles to be a

196

00:08:36,159 --> 00:08:33,769

place to look for extant life so

197

00:08:39,790 --> 00:08:36,169

contrast that to Europa where you have

198

00:08:40,990 --> 00:08:39,800

very likely a more than twice the amount

199

00:08:43,089 --> 00:08:41,000

of liquid water that is in all of

200

00:08:45,850 --> 00:08:43,099

Earth's oceans in a moon the size of our

201
00:08:48,939 --> 00:08:45,860
Moon that makes Europa pretty compelling

202
00:08:51,700 --> 00:08:48,949
place to go if we can get to its

203
00:08:54,760 --> 00:08:51,710
subsurface water water that's under more

204
00:08:59,260 --> 00:08:54,770
three kilometres of heights and it was

205
00:09:01,420 --> 00:08:59,270
really exciting what's really exciting

206
00:09:04,780 --> 00:09:01,430
about Europa of course is that the water

207
00:09:07,030 --> 00:09:04,790
is most likely sitting above sea floor

208
00:09:09,190 --> 00:09:07,040
above Rock and we've had Alexis

209
00:09:11,530 --> 00:09:09,200
Templeton on on asking astrobiology in

210
00:09:13,750 --> 00:09:11,540
the past who is who's studying the

211
00:09:15,490 --> 00:09:13,760
process of serpentinization which is the

212
00:09:17,740 --> 00:09:15,500
process of reacting volcanic rock

213
00:09:20,020 --> 00:09:17,750

essentially seafloor rock with ocean

214

00:09:22,330 --> 00:09:20,030

water that creates chemical energy for

215

00:09:24,970 --> 00:09:22,340

biology again life that is independent

216

00:09:29,380 --> 00:09:24,980

of sun lights is that also an interest

217

00:09:31,660 --> 00:09:29,390

of yours it certainly is and yeah I can

218

00:09:34,660 --> 00:09:31,670

contrast Europa and Enceladus with the

219

00:09:37,030 --> 00:09:34,670

larger moons Europa Enceladus are in

220

00:09:38,650 --> 00:09:37,040

some ways earth-like in that at the sea

221

00:09:40,450 --> 00:09:38,660

floor of Europa you would have pressures

222

00:09:44,680 --> 00:09:40,460

that are comparable to the pressure of

223

00:09:45,850 --> 00:09:44,690

the Marianas Trench and and we think

224

00:09:48,100 --> 00:09:45,860

there's a good chance that the tidal

225

00:09:50,050 --> 00:09:48,110

activity on Europa the tidal heating can

226

00:09:53,350 --> 00:09:50,060

create hydrothermal systems and I'm

227

00:09:54,520 --> 00:09:53,360

interested in the reduced materials that

228

00:09:55,870 --> 00:09:54,530

might be produced in those systems that

229

00:09:58,090 --> 00:09:55,880

is materials that are rich in hydrogen

230

00:10:00,940 --> 00:09:58,100

which then provides the chemical energy

231

00:10:02,320 --> 00:10:00,950

for life and so the next thing from

232

00:10:05,350 --> 00:10:02,330

follow the water is follow the energy

233

00:10:07,510 --> 00:10:05,360

and and so yeah I like thinking of

234

00:10:09,850 --> 00:10:07,520

Europa as the earth-like target for

235

00:10:12,430 --> 00:10:09,860

looking for life elsewhere in forward

236

00:10:14,110 --> 00:10:12,440

system I'd like to talk about Ganymede

237

00:10:15,640 --> 00:10:14,120

and Titan in the larger man some point

238

00:10:18,580 --> 00:10:15,650

that's that's another set of challenges

239

00:10:20,500 --> 00:10:18,590

that I've also interested but yeah while

240

00:10:21,700 --> 00:10:20,510

I was building this giant Frankenstein

241

00:10:23,830 --> 00:10:21,710

apparatus but I wheeled around the

242

00:10:27,960 --> 00:10:23,840

hallways of our building congrat school

243

00:10:30,640 --> 00:10:27,970

I was also doing some modeling

244

00:10:33,100 --> 00:10:30,650

specifically considering how fractures

245

00:10:35,290 --> 00:10:33,110

might occur in rocks in Europa in

246

00:10:37,690 --> 00:10:35,300

particular but also in other worlds so

247

00:10:38,980 --> 00:10:37,700

the idea is that in order to have water

248

00:10:41,260 --> 00:10:38,990

rock interactions that generate this

249

00:10:43,330 --> 00:10:41,270

chemistry you need the water to get into

250

00:10:45,610 --> 00:10:43,340

the rock and so you need to know how

251
00:10:47,320 --> 00:10:45,620
fractures might form and so I developed

252
00:10:48,580 --> 00:10:47,330
this model based on some work some

253
00:10:50,950 --> 00:10:48,590
people were doing in the context of

254
00:10:53,380 --> 00:10:50,960
seafloor systems on earth to figure out

255
00:10:55,720 --> 00:10:53,390
how deep fluids can percolate and the

256
00:10:58,510 --> 00:10:55,730
simple outcome of that work was to to

257
00:11:00,310 --> 00:10:58,520
say well gee that the gravity is a lot

258
00:11:02,680 --> 00:11:00,320
lower and so the gradient and pressure

259
00:11:04,120 --> 00:11:02,690
is a lot smaller which means that you

260
00:11:05,500 --> 00:11:04,130
don't reach the pressure at which

261
00:11:07,780 --> 00:11:05,510
pressure clothes

262
00:11:10,449 --> 00:11:07,790
and to a much greater depth so in Europa

263
00:11:12,939 --> 00:11:10,459

you might have fluid rock interaction

264

00:11:14,680 --> 00:11:12,949

persisting to tens of kilometers whereas

265

00:11:17,710 --> 00:11:14,690

ten kilometers may be the upper limit on

266

00:11:19,600 --> 00:11:17,720

earth Wow very cool so by modeling you

267

00:11:21,340 --> 00:11:19,610

mean computer simulations without using

268

00:11:24,069 --> 00:11:21,350

the tools of mathematics and physics to

269

00:11:26,110 --> 00:11:24,079

predict how deep a fracture could go on

270

00:11:28,030 --> 00:11:26,120

Europa and where that water could travel

271

00:11:30,790 --> 00:11:28,040

to generate that chemical energy for

272

00:11:32,650 --> 00:11:30,800

life yes and since I can only go to

273

00:11:35,470 --> 00:11:32,660

Europa seafloor in my imagination

274

00:11:38,500 --> 00:11:35,480

currently I construct mathematical

275

00:11:39,970 --> 00:11:38,510

models allow me to do that very cool so

276

00:11:41,949 --> 00:11:39,980

we think a lot about water in the solar

277

00:11:43,900 --> 00:11:41,959

system we know of Europa the moon of

278

00:11:46,300 --> 00:11:43,910

Jupiter and Enceladus the moon of Saturn

279

00:11:47,769 --> 00:11:46,310

but there is water in more locations in

280

00:11:50,530 --> 00:11:47,779

our solar system can you do that give us

281

00:11:52,139 --> 00:11:50,540

a quick road trip across the solar

282

00:11:57,759 --> 00:11:52,149

system where you would find water

283

00:12:00,040 --> 00:11:57,769

so beyond beyond Mars there is water to

284

00:12:03,819 --> 00:12:00,050

be found and we amazingly we think that

285

00:12:06,400 --> 00:12:03,829

the planet Ceres the largest body in the

286

00:12:07,990 --> 00:12:06,410

asteroid belt is a watery object it's

287

00:12:10,389 --> 00:12:08,000

spherical it's twice the size of

288

00:12:13,090 --> 00:12:10,399

Enceladus and it probably had of muddy

289

00:12:15,030 --> 00:12:13,100

liquid interior or a significant part of

290

00:12:17,920 --> 00:12:15,040

its history if not into the present day

291

00:12:19,900 --> 00:12:17,930

the main the main ocean world's places

292

00:12:22,360 --> 00:12:19,910

where we believe there are extensive

293

00:12:24,370 --> 00:12:22,370

amounts of liquid water possibly more

294

00:12:24,910 --> 00:12:24,380

than put on are likely more than on

295

00:12:27,460 --> 00:12:24,920

earth

296

00:12:29,889 --> 00:12:27,470

the main one our Europa and then moving

297

00:12:33,250 --> 00:12:29,899

outward in Jupiter Ganymede and Callisto

298

00:12:35,800 --> 00:12:33,260

much larger moons basically the size of

299

00:12:37,780 --> 00:12:35,810

the planet Mercury and then at Saturn in

300

00:12:40,689 --> 00:12:37,790

addition to Enceladus which sits in the

301

00:12:43,090 --> 00:12:40,699

e-ring of Saturn beyond that farther

302

00:12:44,290 --> 00:12:43,100

from Saturn is the moon Titan which is

303

00:12:46,569 --> 00:12:44,300

also around the sides of the planet

304

00:12:48,430 --> 00:12:46,579

Mercury so in each of these we have

305

00:12:50,050 --> 00:12:48,440

different lines of evidence for loop

306

00:12:52,689 --> 00:12:50,060

with water under the icy surface and by

307

00:12:54,790 --> 00:12:52,699

under the exercise I mean hundreds of

308

00:12:56,439 --> 00:12:54,800

kilometers beneath the icy surface so

309

00:12:58,930 --> 00:12:56,449

you have you know basically Earth's

310

00:13:02,350 --> 00:12:58,940

supple upper mantle thickness of ice and

311

00:13:05,800 --> 00:13:02,360

then hundreds of kilometers of ocean

312

00:13:07,120 --> 00:13:05,810

so at low gravity but high pressure so

313

00:13:10,449 --> 00:13:07,130

it's weird to think of swimming around

314

00:13:12,670 --> 00:13:10,459

in this in this vast space of liquid

315

00:13:14,460 --> 00:13:12,680

water and because we don't know how

316

00:13:17,019 --> 00:13:14,470

these bodies have evolved through time

317

00:13:18,160 --> 00:13:17,029

we don't know their thermal evolution we

318

00:13:19,180 --> 00:13:18,170

don't know what the composition of the

319

00:13:21,790 --> 00:13:19,190

oceans is

320

00:13:22,960 --> 00:13:21,800

we know in the case of titan satan has

321

00:13:26,710 --> 00:13:22,970

the surface that's covered in liquid

322

00:13:29,050 --> 00:13:26,720

hydrocarbons some of those may make

323

00:13:31,360 --> 00:13:29,060

their way back in to the interior Titan

324

00:13:32,650 --> 00:13:31,370

that we think the source of the methane

325

00:13:34,180 --> 00:13:32,660

that makes up a lot of Titan's

326

00:13:35,740 --> 00:13:34,190

atmosphere and a source of nitrogen that

327

00:13:38,110 --> 00:13:35,750

makes up the majority of the atmosphere

328

00:13:40,420 --> 00:13:38,120

is from the interior so we expected a

329

00:13:41,800 --> 00:13:40,430

lot of organic in that ocean so it's

330

00:13:43,449 --> 00:13:41,810

interesting to think about what that

331

00:13:46,809 --> 00:13:43,459

those could service with the light in

332

00:13:50,470 --> 00:13:46,819

the urchin there when about four turn

333

00:13:52,569 --> 00:13:50,480

away maybe Pluto so yeah so going out

334

00:13:57,309 --> 00:13:52,579

beyond Saturn Uranus and Neptune of

335

00:13:59,350 --> 00:13:57,319

moons that might have promising moon of

336

00:14:00,850 --> 00:13:59,360

Neptune is Triton

337

00:14:02,949 --> 00:14:00,860

which appears to be a captured comet

338

00:14:04,360 --> 00:14:02,959

with orbiting the wrong direction it

339

00:14:05,530 --> 00:14:04,370

doesn't have the sense of things that

340

00:14:07,150 --> 00:14:05,540

were mentioned that all of the solar

341

00:14:09,610 --> 00:14:07,160

system has it's going in the opposite

342

00:14:11,650 --> 00:14:09,620

direction and so we think that it was

343

00:14:13,389 --> 00:14:11,660

captured and that capture means a lot of

344

00:14:14,800 --> 00:14:13,399

tidal heating yeah and going even

345

00:14:16,720 --> 00:14:14,810

further beyond that the Kuiper belt

346

00:14:20,710 --> 00:14:16,730

contains many dwarf planets including

347

00:14:22,780 --> 00:14:20,720

Pluto and because Pluto has a letter

348

00:14:26,259 --> 00:14:22,790

it's orbital interaction with his binary

349

00:14:27,819 --> 00:14:26,269

neighbor Sharon it's possible that Pluto

350

00:14:30,160 --> 00:14:27,829

has an ocean in fact I guess the

351
00:14:33,879 --> 00:14:30,170
interpretation of the weird heart-shaped

352
00:14:35,920 --> 00:14:33,889
region on Pluto is that it's insulated

353
00:14:39,100 --> 00:14:35,930
by its nitrogen at the surface and if

354
00:14:40,780 --> 00:14:39,110
you and if you then model what is the

355
00:14:42,850 --> 00:14:40,790
temperature profile going into that

356
00:14:44,470 --> 00:14:42,860
highly insulating nitrogen layer the

357
00:14:48,009 --> 00:14:44,480
water underneath can be in a liquid

358
00:14:49,420 --> 00:14:48,019
phase wow that's amazing to think that

359
00:14:51,280 --> 00:14:49,430
water or something we thought was like

360
00:14:53,499 --> 00:14:51,290
uniquely to earth only a few decades ago

361
00:14:57,069 --> 00:14:53,509
is probably all over the solar system

362
00:14:59,019 --> 00:14:57,079
it's amazing your your t-shirt is making

363
00:15:00,309 --> 00:14:59,029

me very envious I'm seeing Europa

364

00:15:01,870 --> 00:15:00,319

clipper there which is an exciting

365

00:15:03,759 --> 00:15:01,880

mission that NASA is currently putting

366

00:15:04,600 --> 00:15:03,769

together I know you're involved with it

367

00:15:08,799 --> 00:15:04,610

could you tell us a little bit about

368

00:15:11,040 --> 00:15:08,809

neither Europa clipper mission yeah just

369

00:15:13,840 --> 00:15:11,050

a little bit about your permission the

370

00:15:17,230 --> 00:15:13,850

plan launches in June 2022

371

00:15:18,670 --> 00:15:17,240

like Juno that's currently orbiting

372

00:15:19,900 --> 00:15:18,680

Jupiter in an elliptical orbit

373

00:15:22,600 --> 00:15:19,910

stay out of Jupiter's radiation

374

00:15:25,420 --> 00:15:22,610

environment Europa clipper will orbit

375

00:15:28,210 --> 00:15:25,430

Jupiter and fly by Europa a bunch of

376

00:15:29,710 --> 00:15:28,220

times and so in order to stay out of the

377

00:15:33,129 --> 00:15:29,720

intense radiation environment at Europa

378

00:15:34,900 --> 00:15:33,139

surface will zoom by get

379

00:15:37,960 --> 00:15:34,910

a bunch of data and then send it back to

380

00:15:40,269 --> 00:15:37,970

her over the ensuing two weeks or so and

381

00:15:42,999 --> 00:15:40,279

then zoom by again and by doing that we

382

00:15:45,099 --> 00:15:43,009

can build up map and so this is our

383

00:15:47,229 --> 00:15:45,109

chance to go back to Europa with a suite

384

00:15:49,929 --> 00:15:47,239

of instruments much more powerful than

385

00:15:51,669 --> 00:15:49,939

what the Galileo spacecraft had and to

386

00:15:53,199 --> 00:15:51,679

map the surface at resolutions down to

387

00:15:56,710 --> 00:15:53,209

less than a meter per pixel in some

388

00:16:00,789 --> 00:15:56,720

places and to start either magnetic

389

00:16:02,829 --> 00:16:00,799

field around Europa to understand if to

390

00:16:05,939 --> 00:16:02,839

understand the oceans composition from

391

00:16:08,019 --> 00:16:05,949

the field that's induced by Jupiter and

392

00:16:10,629 --> 00:16:08,029

typically we'll be able to fly through

393

00:16:13,090 --> 00:16:10,639

Klum's if there are pollutants at Europa

394

00:16:15,669 --> 00:16:13,100

as there are facilities that is the

395

00:16:17,439 --> 00:16:15,679

emissions of water from the surface

396

00:16:18,999 --> 00:16:17,449

we have evidence to this that there may

397

00:16:20,499 --> 00:16:19,009

be plumes there may have been plumes

398

00:16:23,349 --> 00:16:20,509

actually when Galileo flew by there and

399

00:16:25,689 --> 00:16:23,359

so we have very high resolution mass

400

00:16:28,689 --> 00:16:25,699

spectrometers to sample those materials

401
00:16:30,909 --> 00:16:28,699
directly also by studying the surface in

402
00:16:33,909 --> 00:16:30,919
great detail we can understand Europe of

403
00:16:35,739 --> 00:16:33,919
geology and the overturning time it's

404
00:16:37,179 --> 00:16:35,749
important thing for me to note that one

405
00:16:40,840 --> 00:16:37,189
reason why Europa in particular is so

406
00:16:42,789 --> 00:16:40,850
exciting is that radiation it sounds

407
00:16:45,729 --> 00:16:42,799
like a bummer for life but it's actually

408
00:16:48,100 --> 00:16:45,739
a potential source of chemical energy

409
00:16:49,569 --> 00:16:48,110
for life in that you can imagine the

410
00:16:51,579 --> 00:16:49,579
radiation breaking up water at the

411
00:16:53,350 --> 00:16:51,589
surface hydrogen is lighter and so

412
00:16:55,059 --> 00:16:53,360
preferentially escapes so what you're

413
00:16:57,929 --> 00:16:55,069

left with is a lot of oxygen on the

414

00:17:01,809 --> 00:16:57,939

surface and we Italians saw signs of

415

00:17:03,699 --> 00:17:01,819

hydrogen peroxide sulfuric acid things

416

00:17:05,889 --> 00:17:03,709

that are very oxygen-rich things that

417

00:17:08,019 --> 00:17:05,899

that by themselves also don't found so

418

00:17:09,819 --> 00:17:08,029

great for life but we could imagine ways

419

00:17:11,649 --> 00:17:09,829

in which those oxygen rich products

420

00:17:15,759 --> 00:17:11,659

break down into materials that could be

421

00:17:17,230 --> 00:17:15,769

useful for life and so but because the

422

00:17:18,669 --> 00:17:17,240

surface is very young it's expected that

423

00:17:20,559 --> 00:17:18,679

those oxygen rich materials make their

424

00:17:22,960 --> 00:17:20,569

way into the ocean and possibly even

425

00:17:25,389 --> 00:17:22,970

that the ocean is oxygen rich in such a

426

00:17:27,759 --> 00:17:25,399

way that it could support a lot of

427

00:17:30,399 --> 00:17:27,769

microbes and possibly even larger forms

428

00:17:32,919 --> 00:17:30,409

of life as fascinating because this this

429

00:17:34,389 --> 00:17:32,929

you have at the body ocean floor you

430

00:17:36,730 --> 00:17:34,399

have this hydrogen being produced by

431

00:17:38,350 --> 00:17:36,740

this serpentinization process and these

432

00:17:40,840 --> 00:17:38,360

oxidants being produced at the surface

433

00:17:43,269 --> 00:17:40,850

traveling down and so life loves this

434

00:17:44,619 --> 00:17:43,279

thermodynamic disequilibrium of species

435

00:17:46,350 --> 00:17:44,629

in fact it's probably a universal

436

00:17:47,640 --> 00:17:46,360

properties of life and so

437

00:17:49,289 --> 00:17:47,650

fact that that could exist on Europa

438

00:17:52,110 --> 00:17:49,299

makes it a very compelling place to

439

00:17:54,450 --> 00:17:52,120

explore um for those of us here watching

440

00:17:56,940 --> 00:17:54,460

don't forget you can ask questions live

441

00:17:59,070 --> 00:17:56,950

on the Signet or chat or if you're on

442

00:18:00,840 --> 00:17:59,080

Twitter please use hash tag ask Astro

443

00:18:02,789 --> 00:18:00,850

bio I will ask those questions to Steve

444

00:18:04,890 --> 00:18:02,799

in a little bit but first I want to

445

00:18:06,270 --> 00:18:04,900

focus a little bit on two recent papers

446

00:18:08,190 --> 00:18:06,280

you published one in the journal of

447

00:18:10,380 --> 00:18:08,200

geophysical research planets and one in

448

00:18:12,270 --> 00:18:10,390

astrobiology where you advocate for the

449

00:18:13,799 --> 00:18:12,280

use of a seismometer sun instruments

450

00:18:16,020 --> 00:18:13,809

that measures the waves that propagate

451

00:18:17,280 --> 00:18:16,030

inside the plant or interiors to say

452

00:18:19,310 --> 00:18:17,290

something about what it's made out of

453

00:18:20,970 --> 00:18:19,320

that could complement existing

454

00:18:22,560 --> 00:18:20,980

instrumentation or rather

455

00:18:24,840 --> 00:18:22,570

instrumentation that clipper will have

456

00:18:26,940 --> 00:18:24,850

in orbit such as ice penetrating

457

00:18:28,980 --> 00:18:26,950

penetrating radar which don't have as

458

00:18:30,180 --> 00:18:28,990

high of a resolution could tell us more

459

00:18:34,380 --> 00:18:30,190

about these and how they can be useful

460

00:18:36,419 --> 00:18:34,390

in astrobiology yeah so one of the

461

00:18:38,610 --> 00:18:36,429

papers in the journal astrobiology and

462

00:18:41,610 --> 00:18:38,620

it's meant to be an overview so the the

463

00:18:44,100 --> 00:18:41,620

questions you might ask are would

464

00:18:47,490 --> 00:18:44,110

seismology be useful in the first place

465

00:18:49,560 --> 00:18:47,500

in the way that it's useful on earth and

466

00:18:53,159 --> 00:18:49,570

so the question is would any of these

467

00:18:56,640 --> 00:18:53,169

bodies Europa Enceladus Titan Ganymede

468

00:18:58,140 --> 00:18:56,650

Callisto generate seismic signatures on

469

00:19:01,200 --> 00:18:58,150

a time scale that you'd be able to emit

470

00:19:03,390 --> 00:19:01,210

to pick them up and could they be useful

471

00:19:05,580 --> 00:19:03,400

for determining what's underneath so on

472

00:19:07,770 --> 00:19:05,590

earth we know about Earth's interior and

473

00:19:09,900 --> 00:19:07,780

we live on the soup skin of the very

474

00:19:12,020 --> 00:19:09,910

surface of the earth all of what we know

475

00:19:15,180 --> 00:19:12,030

of the earth is just a very thin layer

476
00:19:17,610 --> 00:19:15,190
and we know of what's underneath that

477
00:19:20,070 --> 00:19:17,620
because of seismic measurements we know

478
00:19:21,690 --> 00:19:20,080
how big earth metallic core is and we

479
00:19:23,460 --> 00:19:21,700
know basically what the mantle is made

480
00:19:25,200 --> 00:19:23,470
of and that mantle convection occurs and

481
00:19:26,669 --> 00:19:25,210
it's really important for me to mention

482
00:19:28,320 --> 00:19:26,679
that these hydrothermal systems that

483
00:19:30,000 --> 00:19:28,330
we're talking about on earth are driven

484
00:19:31,230 --> 00:19:30,010
by Earth's internal heat and the

485
00:19:32,940 --> 00:19:31,240
composition of those systems is

486
00:19:38,070 --> 00:19:32,950
determined by the interior activity or

487
00:19:39,570 --> 00:19:38,080
hurt so this student honor is by

488
00:19:41,460 --> 00:19:39,580

permission of all these activities that

489

00:19:43,590 --> 00:19:41,470

are happening inside of her and so

490

00:19:46,140 --> 00:19:43,600

understanding Earth's affability is

491

00:19:48,690 --> 00:19:46,150

enabled by seismology and so in a

492

00:19:50,730 --> 00:19:48,700

similar way because everything that's of

493

00:19:53,370 --> 00:19:50,740

interest for life where the like would

494

00:19:55,560 --> 00:19:53,380

be in these ocean worlds is in the

495

00:19:57,750 --> 00:19:55,570

interiors in the ocean we need a way to

496

00:20:00,180 --> 00:19:57,760

peer into the interior and understand

497

00:20:01,740 --> 00:20:00,190

what's happening so

498

00:20:04,290 --> 00:20:01,750

so getting back to the first question

499

00:20:07,320 --> 00:20:04,300

about seismology the answer to whether

500

00:20:10,169 --> 00:20:07,330

there could be seismic sources seems to

501
00:20:12,299 --> 00:20:10,179
be a strong yes the reason I feel

502
00:20:14,790 --> 00:20:12,309
confident about this is that the Apollo

503
00:20:17,130 --> 00:20:14,800
astronauts put seismometers on the moon

504
00:20:19,020 --> 00:20:17,140
so there are still seismometers on the

505
00:20:21,419 --> 00:20:19,030
moon albeit really low resolution of

506
00:20:23,280 --> 00:20:21,429
seismometers but from the first instance

507
00:20:25,500 --> 00:20:23,290
the time that pedometers were put down a

508
00:20:28,010 --> 00:20:25,510
continuous background of seismic norms

509
00:20:31,950 --> 00:20:28,020
was detected but our movement is humming

510
00:20:35,190 --> 00:20:31,960
because of its it's flexing from tidal

511
00:20:36,690 --> 00:20:35,200
tidal activity so the strength of the

512
00:20:41,280 --> 00:20:36,700
title signal on the moon are correlated

513
00:20:43,049 --> 00:20:41,290

with the title the title cycle and and

514

00:20:46,500 --> 00:20:43,059

so if you think about the likely tidal

515

00:20:48,660 --> 00:20:46,510

energy on Europa its many factors more

516

00:20:51,570 --> 00:20:48,670

than it is on the moon and so just on

517

00:20:54,180 --> 00:20:51,580

that basis you would expect for seismic

518

00:20:55,799 --> 00:20:54,190

activity and you can add to that the

519

00:20:57,570 --> 00:20:55,809

fact that Europa has a thin ice shell

520

00:21:00,570 --> 00:20:57,580

sitting on an ocean so it's free to move

521

00:21:03,930 --> 00:21:00,580

and the ice is more likely to fracture

522

00:21:05,730 --> 00:21:03,940

or easily than the rock so we should

523

00:21:07,799 --> 00:21:05,740

expect that fracturing within the ice

524

00:21:10,260 --> 00:21:07,809

should be a source of cytoplasmic

525

00:21:12,060 --> 00:21:10,270

information we could use that how thick

526

00:21:14,820 --> 00:21:12,070

the ice is also what is the composition

527

00:21:17,120 --> 00:21:14,830

of the ice so many different ways what

528

00:21:20,100 --> 00:21:17,130

are the what is the working of the ice

529

00:21:21,600 --> 00:21:20,110

in addition to that there there are

530

00:21:24,450 --> 00:21:21,610

suggestions that there might be fluids

531

00:21:26,669 --> 00:21:24,460

within the ice and we have examples of

532

00:21:30,180 --> 00:21:26,679

this sort of behaviour in Antarctica in

533

00:21:31,740 --> 00:21:30,190

Greenland where you have lakes that form

534

00:21:33,690 --> 00:21:31,750

at the surface of the ice that due to

535

00:21:35,310 --> 00:21:33,700

eating from the Sun you wouldn't have

536

00:21:37,410 --> 00:21:35,320

that happening at Europa where you kind

537

00:21:40,440 --> 00:21:37,420

of other factors materials within the

538

00:21:42,330 --> 00:21:40,450

ice helping the ice to melt and you can

539

00:21:45,240 --> 00:21:42,340

use seismic signals to listen to the

540

00:21:48,180 --> 00:21:45,250

fluids flowing through the ice we also

541

00:21:50,370 --> 00:21:48,190

think that as the ocean is churning

542

00:21:52,290 --> 00:21:50,380

underneath the ice we might be able to

543

00:21:54,450 --> 00:21:52,300

hear internal waves breaking against the

544

00:21:56,040 --> 00:21:54,460

ice as we've modeled some of that in

545

00:21:58,860 --> 00:21:56,050

related papers for the ones that you

546

00:22:01,320 --> 00:21:58,870

described yeah you can have sounds of

547

00:22:04,650 --> 00:22:01,330

Europa that we've modeled using our

548

00:22:06,690 --> 00:22:04,660

computers and you know I'm excited from

549

00:22:09,450 --> 00:22:06,700

my foundational work at the grad student

550

00:22:11,310 --> 00:22:09,460

in whether we can use seismic signals

551
00:22:13,000 --> 00:22:11,320
determine what is the composition of the

552
00:22:16,120 --> 00:22:13,010
ocean so you can imagine

553
00:22:17,830 --> 00:22:16,130
magnesium sulfate rich ocean would have

554
00:22:19,720 --> 00:22:17,840
a different seismic signature than a

555
00:22:21,640 --> 00:22:19,730
sodium chloride rich ocean and we're

556
00:22:25,450 --> 00:22:21,650
measuring those sound speed properties

557
00:22:26,770 --> 00:22:25,460
directly in the lab so it's like you're

558
00:22:28,960 --> 00:22:26,780
a doctor and putting like a stethoscope

559
00:22:30,490 --> 00:22:28,970
on the planet and listening to the

560
00:22:31,300 --> 00:22:30,500
planet's heartbeat to tell its health

561
00:22:34,150 --> 00:22:31,310
and what it's up to

562
00:22:35,680 --> 00:22:34,160
that's so cool so and you know you can

563
00:22:38,080 --> 00:22:35,690

imagine having a seismic network and

564

00:22:41,320 --> 00:22:38,090

being a doctor plating an ultrasound to

565

00:22:44,310 --> 00:22:41,330

listen for the baby kicking that's a

566

00:22:47,830 --> 00:22:44,320

great analogy so ocean worlds are also

567

00:22:49,600 --> 00:22:47,840

interesting analogues to exoplanets

568

00:22:51,850 --> 00:22:49,610

right planets that are orbiting far away

569

00:22:54,160 --> 00:22:51,860

from our Sun could you tell us a little

570

00:22:55,570 --> 00:22:54,170

bit about the weirdnesses that ocean

571

00:22:58,300 --> 00:22:55,580

worlds have in our solar system and how

572

00:22:59,440 --> 00:22:58,310

to think about dozens exoplanets yeah I

573

00:23:00,940 --> 00:22:59,450

think you know I think one of the most

574

00:23:03,220 --> 00:23:00,950

exciting parts of being in

575

00:23:05,290 --> 00:23:03,230

astrobiologists currently is thinking

576

00:23:06,670 --> 00:23:05,300

about the prospects for finding like in

577

00:23:08,080 --> 00:23:06,680

our solar system and where those places

578

00:23:09,700 --> 00:23:08,090

might being there are many differences

579

00:23:11,950 --> 00:23:09,710

that we're considering you know like

580

00:23:14,500 --> 00:23:11,960

past life on Mars life in ocean worlds

581

00:23:15,760 --> 00:23:14,510

it's interesting to see this field

582

00:23:18,340 --> 00:23:15,770

developing over the time that you and I

583

00:23:20,920 --> 00:23:18,350

have been professionals at the same time

584

00:23:22,330 --> 00:23:20,930

that exoplanets are coming into their

585

00:23:23,620 --> 00:23:22,340

own as a field the term ends with

586

00:23:25,450 --> 00:23:23,630

planets isn't either really all the

587

00:23:26,350 --> 00:23:25,460

mixture of solar planets when we first

588

00:23:28,840 --> 00:23:26,360

started grad school and that was a

589

00:23:30,880 --> 00:23:28,850

mouthful so it's nice that things are

590

00:23:32,200 --> 00:23:30,890

getting a little more streamlined but

591

00:23:33,640 --> 00:23:32,210

you know it's understandable that the

592

00:23:37,330 --> 00:23:33,650

search there is focused mainly on

593

00:23:38,800 --> 00:23:37,340

finding earth 2.0 like we have as we

594

00:23:41,110 --> 00:23:38,810

have a good chance of doing that in our

595

00:23:42,730 --> 00:23:41,120

lifetimes but I think there's a good

596

00:23:46,120 --> 00:23:42,740

reason to think that there will be a far

597

00:23:47,950 --> 00:23:46,130

greater abundance of planets that are

598

00:23:50,140 --> 00:23:47,960

roughly earth sized and are covered in

599

00:23:54,640 --> 00:23:50,150

water maybe they're farther away from

600

00:23:56,290 --> 00:23:54,650

their parent star and are more Ganymede

601
00:23:58,660 --> 00:23:56,300
light or Europa light

602
00:24:00,820 --> 00:23:58,670
I think that super Ganymede's are

603
00:24:04,150 --> 00:24:00,830
actually a really important thing to

604
00:24:06,520 --> 00:24:04,160
consider or super titans worlds that

605
00:24:08,650 --> 00:24:06,530
have you know the reducing atmosphere

606
00:24:11,170 --> 00:24:08,660
but then a icy surface and ocean

607
00:24:13,750 --> 00:24:11,180
underneath and a an important thing

608
00:24:15,940 --> 00:24:13,760
there and thinking about earth sized

609
00:24:18,100 --> 00:24:15,950
planets that are covered in water is

610
00:24:21,370 --> 00:24:18,110
that for an earth-sized planet if you

611
00:24:24,160 --> 00:24:21,380
had you know tens 800 kilometres of

612
00:24:26,320 --> 00:24:24,170
ocean the pressures at the bottom of the

613
00:24:26,799 --> 00:24:26,330

ocean would be so high that you create a

614

00:24:29,909 --> 00:24:26,809

different

615

00:24:32,680 --> 00:24:29,919

days of ice so-called high-pressure Isis

616

00:24:34,810 --> 00:24:32,690

there are many of them the ones that I'm

617

00:24:38,230 --> 00:24:34,820

most concerned about are ice three five

618

00:24:40,029 --> 00:24:38,240

and six the Roman numerals applied to

619

00:24:42,519 --> 00:24:40,039

the ice phase is really just no

620

00:24:44,529 --> 00:24:42,529

different crystallographic structure so

621

00:24:46,930 --> 00:24:44,539

you can think of the familiar ice that

622

00:24:50,110 --> 00:24:46,940

we put in our drinks that we skate on

623

00:24:52,389 --> 00:24:50,120

it's called one H the H is for hexagonal

624

00:24:55,840 --> 00:24:52,399

so it's a it's a hexagonal structure of

625

00:24:58,149 --> 00:24:55,850

ice that has a certain figuration of the

626

00:25:01,570 --> 00:24:58,159

way the atoms make up the crystalline

627

00:25:03,970 --> 00:25:01,580

matrix these other ice phases are more

628

00:25:06,600 --> 00:25:03,980

compact so high pressures the molecules

629

00:25:10,480 --> 00:25:06,610

are convinced to form a more compressed

630

00:25:13,299 --> 00:25:10,490

state because that kept a lower energy

631

00:25:15,039 --> 00:25:13,309

state at those high pressures and so

632

00:25:16,720 --> 00:25:15,049

being more compressed means that these

633

00:25:19,210 --> 00:25:16,730

ice phases are denser than liquid water

634

00:25:22,320 --> 00:25:19,220

and so they sink as need to make these

635

00:25:24,669 --> 00:25:22,330

in the lab and you can see them sink and

636

00:25:27,549 --> 00:25:24,679

there's been some some great works and

637

00:25:30,129 --> 00:25:27,559

modeling work recently looking at the

638

00:25:33,279 --> 00:25:30,139

rheological properties that is how these

639

00:25:34,149 --> 00:25:33,289

Isis flow how viscous they are at

640

00:25:35,980 --> 00:25:34,159

different temperature and pressure

641

00:25:38,680 --> 00:25:35,990

conditions making available information

642

00:25:40,779 --> 00:25:38,690

on that and then consider followed

643

00:25:42,970 --> 00:25:40,789

section looks like considering the role

644

00:25:45,789 --> 00:25:42,980

of melting in those ices and you can

645

00:25:47,499 --> 00:25:45,799

think of these thick high-pressure ice

646

00:25:48,869 --> 00:25:47,509

layers in ganymede for hundreds of

647

00:25:52,029 --> 00:25:48,879

fathers of id6

648

00:25:53,499 --> 00:25:52,039

as places that are that are active on

649

00:25:55,570 --> 00:25:53,509

our very pretty shortly logical time

650

00:25:58,239 --> 00:25:55,580

scales and move fluids around and you

651

00:26:00,519 --> 00:25:58,249

can ask whether there might be a in

652

00:26:02,259 --> 00:26:00,529

ocean underneath the high-pressure it's

653

00:26:04,029 --> 00:26:02,269

in addition to the the ocean on top of

654

00:26:07,359 --> 00:26:04,039

the high pressure Heights it's a part of

655

00:26:09,399 --> 00:26:07,369

our considering salts pointing out that

656

00:26:10,600 --> 00:26:09,409

when you add salt you make the liquids

657

00:26:12,249 --> 00:26:10,610

more dense and liquids are more

658

00:26:14,470 --> 00:26:12,259

compressible so you can actually create

659

00:26:15,549 --> 00:26:14,480

fluids that are you can create salty

660

00:26:17,560 --> 00:26:15,559

fluids that are denser than high

661

00:26:18,909 --> 00:26:17,570

pressure ice so you might have a dilute

662

00:26:21,820 --> 00:26:18,919

ocean on top of the high pressure ice

663

00:26:23,649 --> 00:26:21,830

and a salty ocean underneath so we're

664

00:26:25,359 --> 00:26:23,659

gathering those data very actively I

665

00:26:26,799 --> 00:26:25,369

continue to work with we group up in

666

00:26:28,239 --> 00:26:26,809

Seattle and we've got two really

667

00:26:31,629 --> 00:26:28,249

talented postdocs currently working with

668

00:26:34,180 --> 00:26:31,639

us gathering these data so we can put

669

00:26:35,529 --> 00:26:34,190

those into models to think about under

670

00:26:39,879 --> 00:26:35,539

what conditions you might have layered

671

00:26:40,660 --> 00:26:39,889

oceans and I like to say you think of

672

00:26:44,140 --> 00:26:40,670

the

673

00:26:48,760 --> 00:26:44,150

habitability scenario in which you have

674

00:26:50,500 --> 00:26:48,770

ice ocean ice as a sandwich ocean the

675

00:26:53,740 --> 00:26:50,510

layer at ocean we have multiple local

676

00:26:55,660 --> 00:26:53,750

illusions is a Dagwood sandwich so for

677

00:26:58,960 --> 00:26:55,670

those not familiar with old comics

678

00:27:01,870 --> 00:26:58,970

Dagwood was a zany guy who like to make

679

00:27:03,630 --> 00:27:01,880

really tall psycho to just you know read

680

00:27:10,000 --> 00:27:03,640

me Freddie

681

00:27:15,880 --> 00:27:10,010

so why is why is ice ocean ice less

682

00:27:18,180 --> 00:27:15,890

interesting for habitability yeah so at

683

00:27:20,800 --> 00:27:18,190

the beginning of this session about

684

00:27:23,350 --> 00:27:20,810

hydrothermal systems and water rock

685

00:27:26,770 --> 00:27:23,360

interactions providing food for life

686

00:27:30,670 --> 00:27:26,780

well you can't pump reductants into the

687

00:27:32,020 --> 00:27:30,680

ocean if if you have ice preventing

688

00:27:35,620 --> 00:27:32,030

water rock interactions from happening

689

00:27:36,730 --> 00:27:35,630

it seems from this recent work on fluids

690

00:27:38,410 --> 00:27:36,740

flowing within the high-pressure ice

691

00:27:41,080 --> 00:27:38,420

that even if you don't have an ocean

692

00:27:42,370 --> 00:27:41,090

underneath the ice water rocky

693

00:27:44,740 --> 00:27:42,380

interactions will create some of them

694

00:27:46,660 --> 00:27:44,750

out of melt and fluids will make their

695

00:27:48,280 --> 00:27:46,670

way through the ice regardless because

696

00:27:50,590 --> 00:27:48,290

the fluids that are formed will be less

697

00:27:51,820 --> 00:27:50,600

dense than the ice so maybe this is less

698

00:27:53,590 --> 00:27:51,830

of a problem than when people first

699

00:27:55,540 --> 00:27:53,600

thought but when we first discovered

700

00:27:57,520 --> 00:27:55,550

Europa's ocean and then discovered

701
00:27:58,900 --> 00:27:57,530
enemies ocean around the same time the

702
00:27:59,950 --> 00:27:58,910
discussion on habitability was well

703
00:28:01,420 --> 00:27:59,960
obviously Europe is much more

704
00:28:03,610 --> 00:28:01,430
interesting we can't even think of life

705
00:28:05,980 --> 00:28:03,620
on Ganymede because the pressures are so

706
00:28:08,110 --> 00:28:05,990
high at the base of course prejudice now

707
00:28:12,460 --> 00:28:08,120
at the base also present problems for

708
00:28:13,660 --> 00:28:12,470
life the high pressure environment the

709
00:28:15,790 --> 00:28:13,670
environment bottom of the Marianas

710
00:28:17,770 --> 00:28:15,800
Trench presents challenges or many

711
00:28:19,960 --> 00:28:17,780
organisms they have to adapt to those

712
00:28:22,780 --> 00:28:19,970
high pressures to make sure their

713
00:28:25,290 --> 00:28:22,790

proteins don't be nature and so there

714

00:28:27,160 --> 00:28:25,300

there's a set of obligate Barrow files

715

00:28:28,300 --> 00:28:27,170

organisms that are required to live at

716

00:28:30,870 --> 00:28:28,310

high pressure because most where they've

717

00:28:32,860 --> 00:28:30,880

adapted the web so we can imagine

718

00:28:35,170 --> 00:28:32,870

similar strategies perhaps being

719

00:28:36,490 --> 00:28:35,180

employed even at in the high pressure

720

00:28:38,890 --> 00:28:36,500

environment at the bottom of Europa's

721

00:28:43,150 --> 00:28:38,900

ocean but it's weird think we're gonna

722

00:28:44,320 --> 00:28:43,160

live it in high pressure ice and I think

723

00:28:47,530 --> 00:28:44,330

there's a lot more experimental work

724

00:28:48,610 --> 00:28:47,540

that needs to be done to understand what

725

00:28:51,130 --> 00:28:48,620

kind of limitations

726

00:28:54,159 --> 00:28:51,140

high pressure ices and high pressure

727

00:28:58,239 --> 00:28:54,169

environment to create for life so

728

00:29:01,810 --> 00:28:58,249

pressurize does not exist on earth so

729

00:29:07,599 --> 00:29:01,820

how do you create it in the lab you just

730

00:29:10,060 --> 00:29:07,609

squeeze really hard if you look at you

731

00:29:13,299 --> 00:29:10,070

look at the Wikipedia for water you can

732

00:29:14,739 --> 00:29:13,309

see a phase diagram or for water and you

733

00:29:16,239 --> 00:29:14,749

can see a region of pressure and

734

00:29:19,119 --> 00:29:16,249

temperature where water is liquid and

735

00:29:21,099 --> 00:29:19,129

then as you increase the pressure you

736

00:29:23,049 --> 00:29:21,109

get to this high pressure fit the reason

737

00:29:24,909 --> 00:29:23,059

you don't get high pressure phases on

738

00:29:26,109 --> 00:29:24,919

earth is that they form a relatively low

739

00:29:27,849 --> 00:29:26,119

temperature so they form at room

740

00:29:29,649 --> 00:29:27,859

temperature but by the time you get into

741

00:29:32,019 --> 00:29:29,659

Earth's interior to pressures where you

742

00:29:35,200 --> 00:29:32,029

put any high pressure ices you've gotten

743

00:29:36,310 --> 00:29:35,210

way above room temperature and so that's

744

00:29:37,930 --> 00:29:36,320

the only reason they don't form in

745

00:29:40,659 --> 00:29:37,940

nature in fact there have been

746

00:29:42,190 --> 00:29:40,669

suggestions that ice 3 is formed in

747

00:29:45,299 --> 00:29:42,200

certain places in Earth's mantle where

748

00:29:49,180 --> 00:29:45,309

you have subducting slabs and that

749

00:29:52,090 --> 00:29:49,190

nature paper recently it's not confirmed

750

00:29:54,669 --> 00:29:52,100

an interesting finding but but yeah it's

751
00:29:56,769 --> 00:29:54,679
easy enough easy enough to to create

752
00:29:59,409 --> 00:29:56,779
those pressures in the lab and to make

753
00:30:00,430 --> 00:29:59,419
pipe right there are things I just want

754
00:30:01,930 --> 00:30:00,440
to talk a little bit about that

755
00:30:04,869 --> 00:30:01,940
experiment because you have to take two

756
00:30:07,090 --> 00:30:04,879
small diamonds and compress them and

757
00:30:08,919 --> 00:30:07,100
it's that very small zone in between the

758
00:30:10,180 --> 00:30:08,929
diamond anvils that you can reach those

759
00:30:15,099 --> 00:30:10,190
really high pressures which is an

760
00:30:20,409 --> 00:30:15,109
awesome experiment the big Frankenstein

761
00:30:21,729 --> 00:30:20,419
thing that I built so there I had I

762
00:30:25,239 --> 00:30:21,739
didn't have diamonds I had sapphire

763
00:30:27,489 --> 00:30:25,249

windows and I had a series of overing

764

00:30:29,590 --> 00:30:27,499

they created the pressure seal and I

765

00:30:31,450 --> 00:30:29,600

pumped fluid into the food rod and one

766

00:30:33,519 --> 00:30:31,460

advantages in doing that and experiment

767

00:30:35,049 --> 00:30:33,529

the other Creators volume so you're less

768

00:30:37,419 --> 00:30:35,059

subject to errors and I bring out the

769

00:30:40,090 --> 00:30:37,429

chemistry and you're measuring the bulk

770

00:30:42,489 --> 00:30:40,100

properties of a bigger sample yes to be

771

00:30:45,519 --> 00:30:42,499

sure to make it make the higher pressure

772

00:30:48,849 --> 00:30:45,529

Isis or even 96 I was able to make an

773

00:30:51,879 --> 00:30:48,859

optical system I yeah I reliably did

774

00:30:54,909 --> 00:30:51,889

that but if you want to study conditions

775

00:30:59,710 --> 00:30:54,919

in Ganymede's deeper interior or

776

00:31:02,379 --> 00:30:59,720

occurring in Afghan Amit's you need

777

00:31:05,139 --> 00:31:02,389

diamond Endel sha and so that's taking

778

00:31:08,170 --> 00:31:05,149

two dem quality diamonds with very flat

779

00:31:09,790 --> 00:31:08,180

faces and making an anvil out of them

780

00:31:11,590 --> 00:31:09,800

yeah and you make this little basket

781

00:31:13,840 --> 00:31:11,600

with a space that a couple hundred

782

00:31:16,360 --> 00:31:13,850

microns across they made this very small

783

00:31:18,490 --> 00:31:16,370

volume of fluid and then you to squeeze

784

00:31:19,780 --> 00:31:18,500

you use their please screw the Diamonds

785

00:31:22,090 --> 00:31:19,790

together so they get closer together

786

00:31:23,980 --> 00:31:22,100

they pressurize the fluid and you can

787

00:31:26,110 --> 00:31:23,990

generate pressure if you don't put food

788

00:31:28,480 --> 00:31:26,120

then he put solids in it's the way the

789

00:31:38,980 --> 00:31:28,490

city brought you can he can reach 200

790

00:31:43,480 --> 00:31:38,990

EPA 40,000 atmosphere a lot of pressure

791

00:31:46,330 --> 00:31:43,490

very high yeah very high so with my unit

792

00:31:47,350 --> 00:31:46,340

current but yeah the pressures that

793

00:31:53,550 --> 00:31:47,360

we're concerned with her more than the

794

00:31:55,540 --> 00:31:53,560

one ETA 5 so 10,000 atmosphere above

795

00:31:57,640 --> 00:31:55,550

very cool well your job sounds

796

00:31:59,170 --> 00:31:57,650

absolutely awesome Steve we could talk

797

00:32:00,580 --> 00:31:59,180

forever as we usually do but I would

798

00:32:02,020 --> 00:32:00,590

like to open it up for questions from

799

00:32:04,630 --> 00:32:02,030

the audience so again if you're

800

00:32:07,000 --> 00:32:04,640

listening live and you're on Twitter

801
00:32:09,190 --> 00:32:07,010
please use hash tag ask Astro bio to ask

802
00:32:11,440 --> 00:32:09,200
us question and if you're on the

803
00:32:13,630 --> 00:32:11,450
signature org main chat room type it

804
00:32:16,930 --> 00:32:13,640
directly in chat window so the first

805
00:32:19,570 --> 00:32:16,940
question is by Michael Wong who asks via

806
00:32:21,640 --> 00:32:19,580
Twitter so life emerge on earth billions

807
00:32:24,310 --> 00:32:21,650
of years ago when our planet was a very

808
00:32:26,200 --> 00:32:24,320
different place that's very true can you

809
00:32:27,550 --> 00:32:26,210
steeply speculate on how Europe I would

810
00:32:29,650 --> 00:32:27,560
have been different four billion years

811
00:32:31,480 --> 00:32:29,660
ago and how that would have influenced

812
00:32:38,800 --> 00:32:31,490
its habitability and its potential for

813
00:32:43,780 --> 00:32:38,810

an origin of life so I think was very

814

00:32:45,240 --> 00:32:43,790

reducing four billion years ago and so

815

00:32:47,980 --> 00:32:45,250

oxygen was a later invention and that

816

00:32:51,940 --> 00:32:47,990

oxygen was a poison for every organism

817

00:32:54,880 --> 00:32:51,950

event we found submerged in it became

818

00:32:57,010 --> 00:32:54,890

more abundant on earth similarly it's

819

00:32:59,740 --> 00:32:57,020

expected that Europa formed as a

820

00:33:02,680 --> 00:32:59,750

reducing world perhaps similar to how

821

00:33:04,390 --> 00:33:02,690

Enceladus is today we have measurements

822

00:33:06,970 --> 00:33:04,400

of the plumes of them Selatan suggest

823

00:33:09,130 --> 00:33:06,980

the pH of those three the ocean and

824

00:33:13,410 --> 00:33:09,140

intelligence between nine and eleven so

825

00:33:16,480 --> 00:33:13,420

high pH means very basic fluids and

826

00:33:20,200 --> 00:33:16,490

pretty basic when it when it formed as

827

00:33:21,910 --> 00:33:20,210

well and to the extent that that

828

00:33:24,310 --> 00:33:21,920

provided conditions for my

829

00:33:27,370 --> 00:33:24,320

to arrive on earth perhaps that was also

830

00:33:30,610 --> 00:33:27,380

perfectly fine for Europa there's

831

00:33:33,040 --> 00:33:30,620

discussion and debate about how much

832

00:33:35,380 --> 00:33:33,050

oxygen rich material is imported to

833

00:33:37,480 --> 00:33:35,390

Europa's ocean from the surface and over

834

00:33:41,980 --> 00:33:37,490

time whether that would have outweighed

835

00:33:44,800 --> 00:33:41,990

the reducing materials and so the field

836

00:33:46,510 --> 00:33:44,810

of Europa system science or you consider

837

00:33:49,420 --> 00:33:46,520

the the fluxes of different reductants

838

00:33:51,880 --> 00:33:49,430

and oxidants you can construct scenarios

839

00:33:55,120 --> 00:33:51,890

where either Europa ended up oxygen-rich

840

00:33:59,680 --> 00:33:55,130

or stayed and introduced state

841

00:34:01,780 --> 00:33:59,690

I think either either of those outcomes

842

00:34:05,980 --> 00:34:01,790

would be amenable to different kinds of

843

00:34:07,450 --> 00:34:05,990

life it's just a question of what what

844

00:34:10,240 --> 00:34:07,460

types of what types of organisms you

845

00:34:12,580 --> 00:34:10,250

could imagine being in Europa I think

846

00:34:13,990 --> 00:34:12,590

it's safe to presume that the origin of

847

00:34:16,450 --> 00:34:14,000

life if it occurred on Europa might

848

00:34:18,550 --> 00:34:16,460

happen in a reducing environment that

849

00:34:21,430 --> 00:34:18,560

then gets into questions about whether

850

00:34:23,830 --> 00:34:21,440

hydrothermal systems were the plates

851
00:34:25,240 --> 00:34:23,840
that life could have emerged there are

852
00:34:30,220 --> 00:34:25,250
some in the field of origin of life who

853
00:34:31,810 --> 00:34:30,230
suppose at continents or at least some

854
00:34:34,800 --> 00:34:31,820
of the liquid gas interface is were

855
00:34:41,430 --> 00:34:34,810
required similar to what's behind Sanjoy

856
00:34:45,370 --> 00:34:41,440
and and so that that's an interesting

857
00:34:48,220 --> 00:34:45,380
topic of debate and and I guess to the

858
00:34:50,440 --> 00:34:48,230
extent that that's your hope it becomes

859
00:34:52,240 --> 00:34:50,450
a place to test that hypothesis if we

860
00:34:56,110 --> 00:34:52,250
can confirm but there wasn't independent

861
00:34:57,490 --> 00:34:56,120
origin of life on your perhaps we don't

862
00:34:59,230 --> 00:34:57,500
rule out those hypotheses that

863
00:35:01,210 --> 00:34:59,240

continents are a good place for life to

864

00:35:03,370 --> 00:35:01,220

form but we would probably provide

865

00:35:06,880 --> 00:35:03,380

support for a hydrothermal origin of

866

00:35:08,620 --> 00:35:06,890

life hypothesis Mary Cole thank you

867

00:35:11,890 --> 00:35:08,630

Michael for that question next one is by

868

00:35:14,230 --> 00:35:11,900

Andrew Smith who asked via Twitter when

869

00:35:18,150 --> 00:35:14,240

do you suspect we will find life on

870

00:35:22,770 --> 00:35:18,160

another planet so okay this is a wager

871

00:35:27,340 --> 00:35:22,780

and it's a wager for me between

872

00:35:29,320 --> 00:35:27,350

exoplanets and ocean worlds though I'm

873

00:35:31,360 --> 00:35:29,330

more confident lately that Mars might

874

00:35:32,860 --> 00:35:31,370

have entered the running if we believe

875

00:35:35,260 --> 00:35:32,870

the radar result it was published a

876

00:35:39,609 --> 00:35:35,270

couple weeks ago I mean

877

00:35:42,160 --> 00:35:39,619

so I'm hopeful that in the next 20 years

878

00:35:43,480 --> 00:35:42,170

we could we could find life and that's

879

00:35:45,150 --> 00:35:43,490

just speculating on the kinds of

880

00:35:47,170 --> 00:35:45,160

missions that might come from to bear

881

00:35:49,330 --> 00:35:47,180

there's a lot that can happen in 20

882

00:35:51,070 --> 00:35:49,340

years and having been involved with your

883

00:35:53,220 --> 00:35:51,080

OPA clipper for a while I understand

884

00:35:55,900 --> 00:35:53,230

that planning missions is complicated

885

00:35:57,370 --> 00:35:55,910

but you know but being involved Europa

886

00:35:59,070 --> 00:35:57,380

clipper I also have a lot of hope for

887

00:36:01,690 --> 00:35:59,080

the kinds of measurements we can make

888

00:36:03,430 --> 00:36:01,700

first and understanding the context or

889

00:36:07,480 --> 00:36:03,440

habitability better and ultimately in

890

00:36:09,370 --> 00:36:07,490

searching for light come on thank you

891

00:36:12,310 --> 00:36:09,380

for that next question again via

892

00:36:14,350 --> 00:36:12,320

Twitter's by Kochi who asks how do

893

00:36:16,900 --> 00:36:14,360

seismic systems work on the surface of

894

00:36:19,420 --> 00:36:16,910

ice such as on Europa where there might

895

00:36:20,890 --> 00:36:19,430

be no connection to a rocky core because

896

00:36:24,400 --> 00:36:20,900

the waves don't travel through water

897

00:36:27,490 --> 00:36:24,410

right well so leaves travel through

898

00:36:30,850 --> 00:36:27,500

water however so the different types of

899

00:36:34,540 --> 00:36:30,860

waves basically are compressional so

900

00:36:36,160 --> 00:36:34,550

like a slinky compressing so those are

901
00:36:37,660 --> 00:36:36,170
called P waves and then the other one is

902
00:36:42,550 --> 00:36:37,670
shear waves we can do this for this link

903
00:36:45,880 --> 00:36:42,560
here we can do it to the hose so the

904
00:36:48,400 --> 00:36:45,890
shear waves don't work in liquids and so

905
00:36:51,580 --> 00:36:48,410
yeah if you want to study the interior

906
00:36:53,170 --> 00:36:51,590
of Europa or another ocean world the

907
00:36:58,900 --> 00:36:53,180
ocean cuts out a lot of the information

908
00:37:00,970 --> 00:36:58,910
that you want but the the P waves that

909
00:37:03,190 --> 00:37:00,980
transmitted through the ice into the

910
00:37:06,160 --> 00:37:03,200
ocean into the rock and then convert

911
00:37:10,060 --> 00:37:06,170
into shear waves and to combinations of

912
00:37:12,640 --> 00:37:10,070
here and and professional waves and so

913
00:37:14,859 --> 00:37:12,650

it's a different type of seismology the

914

00:37:16,780 --> 00:37:14,869

technology generally works in the same

915

00:37:19,620 --> 00:37:16,790

way that it does on earth you just have

916

00:37:21,970 --> 00:37:19,630

to do a different type of predictive

917

00:37:23,859 --> 00:37:21,980

backtracking to understand what you're

918

00:37:26,680 --> 00:37:23,869

measuring and certainly measuring in one

919

00:37:27,730 --> 00:37:26,690

place is difficult but that's something

920

00:37:29,920 --> 00:37:27,740

that the insight mission will be doing

921

00:37:33,040 --> 00:37:29,930

at Mars starting when it lands in event

922

00:37:35,590 --> 00:37:33,050

on November 26 a little plug there and

923

00:37:36,550 --> 00:37:35,600

and I'll mention as part of these papers

924

00:37:38,500 --> 00:37:36,560

that Sanjaya mentioned we had a

925

00:37:42,790 --> 00:37:38,510

companion paper by it led by Simon's

926
00:37:44,440 --> 00:37:42,800
Taylor who is now at ETH Zurich there's

927
00:37:46,960 --> 00:37:44,450
a really great academic paper in terms

928
00:37:48,820 --> 00:37:46,970
of proposing naming conventions for the

929
00:37:49,060 --> 00:37:48,830
different types of seismic waves that

930
00:37:51,660 --> 00:37:49,070
would

931
00:37:54,370 --> 00:37:51,670
unique to ocean worlds because of this

932
00:37:56,470 --> 00:37:54,380
ice ocean solid interface that would

933
00:38:00,150 --> 00:37:56,480
occur and and I can point out

934
00:38:02,080 --> 00:38:00,160
furthermore if we want to understand the

935
00:38:04,120 --> 00:38:02,090
existence of high-pressure ices and

936
00:38:05,530 --> 00:38:04,130
layering and thickness of those ices I

937
00:38:07,390 --> 00:38:05,540
think in seismology is the only way

938
00:38:09,340 --> 00:38:07,400

we're gonna do that so I really look

939

00:38:11,980 --> 00:38:09,350

forward to to developing that in the

940

00:38:13,960 --> 00:38:11,990

future as well that's cool and dislike

941

00:38:15,580 --> 00:38:13,970

of transmission of P waves in liquids is

942

00:38:18,490 --> 00:38:15,590

how we discovered that Earth has a

943

00:38:20,050 --> 00:38:18,500

liquid core above the center core of

944

00:38:22,630 --> 00:38:20,060

course which is really cool so

945

00:38:27,580 --> 00:38:22,640

seismology is a very efficient way to

946

00:38:29,200 --> 00:38:27,590

probe the the deep interior of worlds on

947

00:38:31,900 --> 00:38:29,210

following on the on the seismology

948

00:38:34,390 --> 00:38:31,910

question and on the Martian Lake that

949

00:38:37,480 --> 00:38:34,400

was recently discovered Marian Denton

950

00:38:39,610 --> 00:38:37,490

via Facebook live asks you mentioned

951
00:38:41,500 --> 00:38:39,620
using a seismometer to sense wave action

952
00:38:43,630 --> 00:38:41,510
below ice sheets with the newly

953
00:38:45,670 --> 00:38:43,640
announced Lake at Mars a South South

954
00:38:47,320 --> 00:38:45,680
Pole be large enough to test that on and

955
00:38:49,900 --> 00:38:47,330
also has this been tested on earth

956
00:38:54,610 --> 00:38:49,910
analog sites for example Lake Vostok in

957
00:38:56,050 --> 00:38:54,620
Antarctica so the answer to the Mars

958
00:38:58,480 --> 00:38:56,060
questions I don't know

959
00:39:02,170 --> 00:38:58,490
and I I also don't know if this has been

960
00:39:04,810 --> 00:39:02,180
studied in the context of Lake Vostok or

961
00:39:09,610 --> 00:39:04,820
other sublation lakes what's really

962
00:39:11,680 --> 00:39:09,620
interesting about ocean acoustics or

963
00:39:12,970 --> 00:39:11,690

seismology this was recently

964

00:39:15,310 --> 00:39:12,980

demonstrated to me by a colleague here

965

00:39:17,890 --> 00:39:15,320

at JPL you take a modern sensitive

966

00:39:19,870 --> 00:39:17,900

hydrometer and put it on a tabletop at

967

00:39:22,840 --> 00:39:19,880

JPL or I saw it demonstrated or in

968

00:39:24,490 --> 00:39:22,850

Colorado the middle of the continent one

969

00:39:27,910 --> 00:39:24,500

of the persistent signals that you see

970

00:39:29,470 --> 00:39:27,920

is the transmission of breaking waves on

971

00:39:31,150 --> 00:39:29,480

the coast transmitting all the way

972

00:39:34,570 --> 00:39:31,160

across the continent so you can see

973

00:39:38,260 --> 00:39:34,580

Earth's ocean seismically anywhere and

974

00:39:41,110 --> 00:39:38,270

so and so our inspiration at Europa was

975

00:39:43,770 --> 00:39:41,120

to consider the analog of turbulent

976
00:39:45,970 --> 00:39:43,780
waves underneath underneath the ice and

977
00:39:49,600 --> 00:39:45,980
so the assumption in that that was in a

978
00:39:52,630 --> 00:39:49,610
paper by Mark Anning is that is that the

979
00:39:54,820 --> 00:39:52,640
oceans are the characteristic ocean wave

980
00:39:57,040 --> 00:39:54,830
speed can be close to a meter per second

981
00:39:58,930 --> 00:39:57,050
and the ocean is turbulent and has a lot

982
00:40:00,490 --> 00:39:58,940
of energy in it that's a discussion

983
00:40:02,710 --> 00:40:00,500
about fluid dynamics in your position

984
00:40:04,510 --> 00:40:02,720
that hasn't been fully resolved

985
00:40:05,710 --> 00:40:04,520
it's fun that our work is touching on a

986
00:40:08,410 --> 00:40:05,720
lot of different active fields of

987
00:40:11,440 --> 00:40:08,420
research in your robot yeah absolutely

988
00:40:13,839 --> 00:40:11,450

your board touches on what the plat the

989

00:40:15,910 --> 00:40:13,849

moon is made out of its talks about can

990

00:40:18,520 --> 00:40:15,920

contribute to the discussion on ocean

991

00:40:20,170 --> 00:40:18,530

convection on habitability or the

992

00:40:24,190 --> 00:40:20,180

essence of an astrobiologist is oozing

993

00:40:29,200 --> 00:40:26,050

the next question coming from the Signet

994

00:40:34,900 --> 00:40:29,210

main chat from richard gordon asks do

995

00:40:37,330 --> 00:40:34,910

all ices sinter that is a geology

996

00:40:41,710 --> 00:40:37,340

question and although i got a degree in

997

00:40:45,130 --> 00:40:41,720

a geology department i never did any any

998

00:40:47,859 --> 00:40:45,140

centering myself but so sin during is

999

00:40:50,890 --> 00:40:47,869

sorting out by grain sizes and to my

1000

00:40:54,930 --> 00:40:50,900

understanding or breaking off of

1001
00:40:56,920 --> 00:40:54,940
crystals into smaller fragments and I

1002
00:40:58,120 --> 00:40:56,930
don't know if that's been done with

1003
00:41:02,260 --> 00:40:58,130
high-pressure ices there were some

1004
00:41:04,990 --> 00:41:02,270
experiments in the 70s where a Canadian

1005
00:41:06,490 --> 00:41:05,000
group claimed to have created I six and

1006
00:41:08,890 --> 00:41:06,500
then rapidly be pressurized at low

1007
00:41:13,150 --> 00:41:08,900
temperature and had quenched I six I

1008
00:41:15,220 --> 00:41:13,160
suppose you could centre that I'm not

1009
00:41:17,050 --> 00:41:15,230
sure what the application would be and

1010
00:41:18,609 --> 00:41:17,060
it's important to emphasize that high

1011
00:41:20,320 --> 00:41:18,619
pressure ices where they would occur in

1012
00:41:23,140 --> 00:41:20,330
nature in the original worlds would

1013
00:41:27,520 --> 00:41:23,150

always be surrounded and so liquid would

1014

00:41:30,190 --> 00:41:27,530

would become interspersed anywhere that

1015

00:41:32,320 --> 00:41:30,200

any kind of fracturing would occur I

1016

00:41:33,940 --> 00:41:32,330

think I think your question is getting

1017

00:41:35,710 --> 00:41:33,950

us something kind of profound but I

1018

00:41:36,640 --> 00:41:35,720

don't really have an answer to it

1019

00:41:40,480 --> 00:41:36,650

someone to think a little more about

1020

00:41:42,820 --> 00:41:40,490

fracturing and high-pressure - thank you

1021

00:41:45,450 --> 00:41:42,830

Richard next question is by Nitin who

1022

00:41:48,099 --> 00:41:45,460

asked via Twitter how reliable is it

1023

00:41:51,690 --> 00:41:48,109

working on microbes in certain hazing

1024

00:41:56,859 --> 00:41:51,700

systems on earth - that on exoplanets

1025

00:42:00,040 --> 00:41:56,869

okay so the other bummer about Ganymede

1026
00:42:03,160 --> 00:42:00,050
and Titan at least from my simple

1027
00:42:05,560 --> 00:42:03,170
modeling of the rocket interaction is

1028
00:42:08,380 --> 00:42:05,570
that if you expect fracturing to occur

1029
00:42:10,359 --> 00:42:08,390
from cooling of the rock and if pressure

1030
00:42:14,170 --> 00:42:10,369
has a role in closing down any fractures

1031
00:42:16,510 --> 00:42:14,180
that occur Ganymede and Titan and

1032
00:42:18,820 --> 00:42:16,520
Callisto have such high pressure that

1033
00:42:20,109 --> 00:42:18,830
closed really efficiently and from that

1034
00:42:22,690 --> 00:42:20,119
standpoint you wouldn't have a lot of

1035
00:42:27,400 --> 00:42:22,700
water outer lock water rock interaction

1036
00:42:29,620 --> 00:42:27,410
I because I have a concern about this

1037
00:42:31,780 --> 00:42:29,630
and I want to I want to believe that

1038
00:42:33,880 --> 00:42:31,790

that water I contractions can occur in

1039

00:42:36,370 --> 00:42:33,890

these objects I think about other ways

1040

00:42:37,600 --> 00:42:36,380

that Tektronix might occur and that's

1041

00:42:39,460 --> 00:42:37,610

something I've been discussing with a

1042

00:42:42,609 --> 00:42:39,470

colleague Paul Byrne who studies

1043

00:42:45,609 --> 00:42:42,619

Tektronix and so he comes ahead of a

1044

00:42:48,430 --> 00:42:45,619

different way he also has sort of plum

1045

00:42:51,430 --> 00:42:48,440

news about fracturing but maybe there

1046

00:42:53,380 --> 00:42:51,440

are other ways that rocks in Center and

1047

00:42:58,320 --> 00:42:53,390

you can create more surface area for

1048

00:43:01,410 --> 00:42:58,330

water rock interaction but the fact that

1049

00:43:03,580 --> 00:43:01,420

Titan has this methane rich atmosphere

1050

00:43:05,740 --> 00:43:03,590

suggests that water rock interactions

1051
00:43:07,980 --> 00:43:05,750
have occurred at some point and the fact

1052
00:43:10,630 --> 00:43:07,990
that Titan is a load in for the object

1053
00:43:12,250 --> 00:43:10,640
it seems like there's currently not any

1054
00:43:14,590 --> 00:43:12,260
way to explain the low density of Titans

1055
00:43:17,020 --> 00:43:14,600
interior without invoking hydrated rock

1056
00:43:19,510 --> 00:43:17,030
and so that to me suggests water rock

1057
00:43:21,120 --> 00:43:19,520
interactions occurring okay so what that

1058
00:43:25,960 --> 00:43:21,130
says is that my model is simple and

1059
00:43:27,340 --> 00:43:25,970
needs to become less simple it's

1060
00:43:29,080 --> 00:43:27,350
important to start with the model as

1061
00:43:32,680 --> 00:43:29,090
well constraints and by model again we

1062
00:43:36,220 --> 00:43:32,690
mean computer simulations Tom Caruso

1063
00:43:38,020 --> 00:43:36,230

asks via Facebook the so far channel so

1064

00:43:40,240 --> 00:43:38,030

the sound fixing and ranging channel

1065

00:43:42,310 --> 00:43:40,250

here on earth acts like a horizontal

1066

00:43:44,650 --> 00:43:42,320

pipe organ in our oceans allowing sound

1067

00:43:46,420 --> 00:43:44,660

waves to travel great distances do you

1068

00:43:54,540 --> 00:43:46,430

think a so far channel would exist in a

1069

00:44:01,090 --> 00:43:58,450

yeah this is intriguing yeah it's this

1070

00:44:04,030 --> 00:44:01,100

inversion channel you know whales use it

1071

00:44:06,520 --> 00:44:04,040

to communicate around the world it's a

1072

00:44:08,140 --> 00:44:06,530

really romantic idea but my

1073

00:44:10,240 --> 00:44:08,150

understanding is that so far channel

1074

00:44:14,500 --> 00:44:10,250

occurs because Earth's ocean is heated

1075

00:44:17,410 --> 00:44:14,510

from above and so my assumption is that

1076

00:44:19,030 --> 00:44:17,420

the sound speed profile so it's mp4 file

1077

00:44:22,270 --> 00:44:19,040

for Earth is this thing where it it

1078

00:44:23,859 --> 00:44:22,280

decreases and then and so the so far

1079

00:44:25,900 --> 00:44:23,869

channel is that is that inversion point

1080

00:44:28,780 --> 00:44:25,910

and so sound waves that starts in that

1081

00:44:30,430 --> 00:44:28,790

in that inflection zone it's gets

1082

00:44:32,680 --> 00:44:30,440

diffracted back into the

1083

00:44:36,010 --> 00:44:32,690

the so far Channel whether it channels

1084

00:44:38,289 --> 00:44:36,020

up or down but if the sound speed is

1085

00:44:39,750 --> 00:44:38,299

increasing uniformly in the ocean which

1086

00:44:42,010 --> 00:44:39,760

you would expect if the ocean is just

1087

00:44:44,650 --> 00:44:42,020

the temperature profile of the ocean is

1088

00:44:48,609 --> 00:44:44,660

uniform then there would not be a so far

1089

00:44:51,750 --> 00:44:48,619

Channel that's great explanations

1090

00:44:56,440 --> 00:44:55,420

Jinna Kochi again asks could you say

1091

00:44:57,849 --> 00:44:56,450

something about international

1092

00:44:59,440 --> 00:44:57,859

collaboration and astrobiology

1093

00:45:05,289 --> 00:44:59,450

particularly perhaps for the Europa

1094

00:45:08,819 --> 00:45:05,299

clipper mission an all in favour of

1095

00:45:14,140 --> 00:45:08,829

international collaboration astrobiology

1096

00:45:18,010 --> 00:45:14,150

so the Clipper in particular we are just

1097

00:45:20,470 --> 00:45:18,020

beginning to formally talk to the juice

1098

00:45:22,329 --> 00:45:20,480

mission it's the Jupiter icy satellite

1099

00:45:24,270 --> 00:45:22,339

Explorer mission that's led by ISA so

1100

00:45:28,299 --> 00:45:24,280

they're going to orbit the enemy

1101

00:45:29,859 --> 00:45:28,309

starting around 2030 it's possible that

1102

00:45:32,620 --> 00:45:29,869

your clipper will be around at that time

1103

00:45:34,660 --> 00:45:32,630

as well their goal is not just to

1104

00:45:37,089 --> 00:45:34,670

explore Ganymede though but to flyby

1105

00:45:38,620 --> 00:45:37,099

Europe a couple times to fly by Callisto

1106

00:45:41,680 --> 00:45:38,630

and also to understand Jupiter in its

1107

00:45:44,920 --> 00:45:41,690

environment and so in that sense there's

1108

00:45:48,910 --> 00:45:44,930

a great chance for ISA and NASA

1109

00:45:50,620 --> 00:45:48,920

scientists to collaborate to join their

1110

00:45:54,099 --> 00:45:50,630

data together to make synergistic

1111

00:45:56,410 --> 00:45:54,109

results so in that sense there's a great

1112

00:45:59,289 --> 00:45:56,420

collaboration happening astrobology is

1113

00:46:01,420 --> 00:45:59,299

inherently collaborative I've enjoyed in

1114

00:46:03,519 --> 00:46:01,430

my time working at JPL specific

1115

00:46:06,490 --> 00:46:03,529

particularly collaborating with the root

1116

00:46:10,000 --> 00:46:06,500

LC in Tokyo and so this is a group

1117

00:46:13,299 --> 00:46:10,010

that's largely interested in Earth's

1118

00:46:14,799 --> 00:46:13,309

interior and planetary interiors and has

1119

00:46:16,450 --> 00:46:14,809

really great expertise in that in

1120

00:46:19,779 --> 00:46:16,460

particular but also in hydrothermal

1121

00:46:21,519 --> 00:46:19,789

systems and so I think it's really

1122

00:46:24,430 --> 00:46:21,529

important for scientists but especially

1123

00:46:27,039 --> 00:46:24,440

for astrobiologists to visit and

1124

00:46:28,779 --> 00:46:27,049

exchange information and perspectives so

1125

00:46:31,990 --> 00:46:28,789

we could challenge each other and come

1126

00:46:35,170 --> 00:46:32,000

up with new ideas that's very romantic

1127

00:46:37,240 --> 00:46:35,180

way of putting it I would agree 100% so

1128

00:46:39,010 --> 00:46:37,250

on Sagan and we often have early career

1129

00:46:40,960 --> 00:46:39,020

individuals who are excited about sure

1130

00:46:42,730 --> 00:46:40,970

biology but not quite sure know how to

1131

00:46:44,140 --> 00:46:42,740

get into the discipline what kind of

1132

00:46:46,540 --> 00:46:44,150

advice would you have for

1133

00:46:50,890 --> 00:46:46,550

upcoming astrobiologists and how to get

1134

00:46:52,930 --> 00:46:50,900

involved with with with science well so

1135

00:46:54,190 --> 00:46:52,940

so if you're a grad student in that

1136

00:46:57,300 --> 00:46:54,200

since you're not putting astrobiology

1137

00:47:01,480 --> 00:46:57,310

you thought rubella just go to apps icon

1138

00:47:03,610 --> 00:47:01,490

if you're a chance grad through the apps

1139

00:47:05,740 --> 00:47:03,620

icon which is the astrobiology science

1140

00:47:07,690 --> 00:47:05,750

conference which happens every two years

1141

00:47:09,120 --> 00:47:07,700

and next year we'll be in Bellevue

1142

00:47:12,190 --> 00:47:09,130

Washington

1143

00:47:15,760 --> 00:47:12,200

so I look forward to revisiting old time

1144

00:47:20,110 --> 00:47:15,770

with us and right at icon thank you I

1145

00:47:21,670 --> 00:47:20,120

hope that happens anyway but the other I

1146

00:47:23,950 --> 00:47:21,680

guess the other thing so networking is

1147

00:47:25,450 --> 00:47:23,960

important that's what I'm saying you

1148

00:47:28,300 --> 00:47:25,460

know short of going to a conference you

1149

00:47:30,490 --> 00:47:28,310

can seek out mentors professors don't

1150

00:47:32,800 --> 00:47:30,500

get that many emails they'd be happy to

1151
00:47:34,480 --> 00:47:32,810
talk about that research and they're

1152
00:47:35,860 --> 00:47:34,490
actually pretty approachable I would say

1153
00:47:37,150 --> 00:47:35,870
a mistake that I made as an

1154
00:47:39,580 --> 00:47:37,160
undergraduate was to be afraid of

1155
00:47:42,040 --> 00:47:39,590
talking to professor's because I thought

1156
00:47:44,470 --> 00:47:42,050
they were this unobtainable level of

1157
00:47:47,350 --> 00:47:44,480
knowledge you know the first my family

1158
00:47:50,260 --> 00:47:47,360
to get a PhD so I didn't have a role

1159
00:47:52,120 --> 00:47:50,270
model in that sense so that's a big

1160
00:47:53,140 --> 00:47:52,130
thing and the other thing is you know

1161
00:47:56,980 --> 00:47:53,150
taking a lot of different classes

1162
00:47:59,680 --> 00:47:56,990
getting exposed to geology biology

1163
00:48:04,270 --> 00:47:59,690

chemistry you know the fundamentals but

1164

00:48:06,450 --> 00:48:04,280

also then learning about the this book

1165

00:48:10,780 --> 00:48:06,460

throughout of those so oceanography

1166

00:48:13,690 --> 00:48:10,790

marine biology that sort of I'm glad you

1167

00:48:14,730 --> 00:48:13,700

mentioned the mentoring aspect chrysalis

1168

00:48:17,740 --> 00:48:14,740

pups

1169

00:48:23,170 --> 00:48:17,750

who-who are your mentors and how did

1170

00:48:25,000 --> 00:48:23,180

they help you well yeah I mentioned this

1171

00:48:27,930 --> 00:48:25,010

this colleague from the internship so

1172

00:48:31,510 --> 00:48:27,940

you can have informal mentors as well

1173

00:48:35,890 --> 00:48:31,520

people who inspire you and I mentioned

1174

00:48:38,230 --> 00:48:35,900

Carl Sagan also a conformal mentor you

1175

00:48:39,850 --> 00:48:38,240

know I I came to JPL to be honest as I

1176

00:48:42,760 --> 00:48:39,860

was following Bob Pappalardo is the

1177

00:48:44,980 --> 00:48:42,770

project scientist for for the flipper I

1178

00:48:46,660 --> 00:48:44,990

originally thought I would go to Boulder

1179

00:48:49,570 --> 00:48:46,670

where he was at the time and then he got

1180

00:48:50,770 --> 00:48:49,580

a job here you know so now since I

1181

00:48:52,300 --> 00:48:50,780

wasn't even really strategically

1182

00:48:53,260 --> 00:48:52,310

targeting figure of a mission I just

1183

00:48:54,940 --> 00:48:53,270

thought you're someone that I want to

1184

00:48:58,030 --> 00:48:54,950

work with this seems to do good science

1185

00:49:02,770 --> 00:48:58,040

and also seems to be thinking and

1186

00:49:05,080 --> 00:49:02,780

and everyone thinks but but I don't know

1187

00:49:06,550 --> 00:49:05,090

he's careful in a way that I relate to I

1188

00:49:12,100 --> 00:49:06,560

think finding mentors that you relate to

1189

00:49:14,830 --> 00:49:12,110

is it's really important I don't know

1190

00:49:17,020 --> 00:49:14,840

I'm the model where you have a committee

1191

00:49:18,940 --> 00:49:17,030

and I was constantly checking in with my

1192

00:49:21,160 --> 00:49:18,950

committee members I love changing

1193

00:49:25,660 --> 00:49:21,170

committee members as identify people who

1194

00:49:28,200 --> 00:49:25,670

I wanted to learn from you know so so

1195

00:49:31,050 --> 00:49:28,210

that's all that's all really important

1196

00:49:33,640 --> 00:49:31,060

what else can I say about my personal

1197

00:49:35,260 --> 00:49:33,650

mentor experiences

1198

00:49:36,640 --> 00:49:35,270

well I'll mention that as an

1199

00:49:39,010 --> 00:49:36,650

undergraduate I did an undergraduate

1200

00:49:40,690 --> 00:49:39,020

thesis so I built an experiment and I

1201
00:49:44,350 --> 00:49:40,700
measured the stickiness of methanol

1202
00:49:47,170 --> 00:49:44,360
frosts try to address how stuff came

1203
00:49:48,580 --> 00:49:47,180
together in the early solar nebula on a

1204
00:49:51,010 --> 00:49:48,590
length scale of greater than a

1205
00:49:53,260 --> 00:49:51,020
centimeter but less than you know meters

1206
00:49:55,690 --> 00:49:53,270
where gravity starts become important um

1207
00:49:57,880 --> 00:49:55,700
so anyway I mentor there was Frank but

1208
00:50:00,730 --> 00:49:57,890
Bridges who was he was mainly interested

1209
00:50:02,350 --> 00:50:00,740
in magneto resistance and building new

1210
00:50:06,670 --> 00:50:02,360
hard drives but he had this side project

1211
00:50:08,530 --> 00:50:06,680
with Doug Linn on on you know Saturn's

1212
00:50:10,660 --> 00:50:08,540
Saturn's ring would be knew that much

1213
00:50:12,640 --> 00:50:10,670

about at the time and speaking of stuff

1214

00:50:14,620 --> 00:50:12,650

in general so I've learned a lot of

1215

00:50:15,910 --> 00:50:14,630

experimental stuff from him he just said

1216

00:50:18,730 --> 00:50:15,920

usually here's the thing you should

1217

00:50:21,880 --> 00:50:18,740

build and then I went and built it you

1218

00:50:23,980 --> 00:50:21,890

know gave me advice along the way and

1219

00:50:25,660 --> 00:50:23,990

you know he also can read about your

1220

00:50:27,160 --> 00:50:25,670

papers and said read beads and so that

1221

00:50:30,100 --> 00:50:27,170

was more of a kind of a soft mentorship

1222

00:50:31,960 --> 00:50:30,110

of like okay go and learn some stuff but

1223

00:50:34,000 --> 00:50:31,970

he kept me motivated and that was that

1224

00:50:37,540 --> 00:50:34,010

was really important and pivotal in my

1225

00:50:39,100 --> 00:50:37,550

development very cool yeah I will echo

1226

00:50:40,810 --> 00:50:39,110

that advice of knocking on doors to

1227

00:50:43,600 --> 00:50:40,820

people you admire is is a good way to

1228

00:50:45,580 --> 00:50:43,610

learn about how they got to feel and how

1229

00:50:48,430 --> 00:50:45,590

they can help you get into it so great

1230

00:50:50,350 --> 00:50:48,440

advice and we started this interview by

1231

00:50:52,360 --> 00:50:50,360

talking about your participation as a

1232

00:50:55,510 --> 00:50:52,370

science advisor in the movie Europa

1233

00:50:57,640 --> 00:50:55,520

report can you tell us of more about how

1234

00:51:05,230 --> 00:50:57,650

that was and working with with with

1235

00:51:08,560 --> 00:51:05,240

Hollywood that was a unique experience

1236

00:51:11,950 --> 00:51:08,570

I've done I've done various consulting

1237

00:51:13,630 --> 00:51:11,960

things various levels of formality the

1238

00:51:14,770 --> 00:51:13,640

when most of those about in my

1239

00:51:20,820 --> 00:51:14,780

interaction with the science and

1240

00:51:25,150 --> 00:51:20,830

entertainment exchange which is a double

1241

00:51:28,930 --> 00:51:25,160

triple a has funded society that tries

1242

00:51:32,320 --> 00:51:28,940

to connect scientists with filmmakers

1243

00:51:34,599 --> 00:51:32,330

and writers and video game producers to

1244

00:51:38,920 --> 00:51:34,609

help with public understanding of

1245

00:51:42,160 --> 00:51:38,930

science contrast europa report I just

1246

00:51:44,079 --> 00:51:42,170

met a producer of the would-be film when

1247

00:51:46,300 --> 00:51:44,089

I was volunteering at the JPL open house

1248

00:51:48,339 --> 00:51:46,310

they were looking for people to talk to

1249

00:51:50,980 --> 00:51:48,349

because Europa was just coming into the

1250

00:51:51,760 --> 00:51:50,990

consciousness of filmmakers at the time

1251

00:51:53,200 --> 00:51:51,770

there were actually a couple of

1252

00:51:55,839 --> 00:51:53,210

apparently a couple of Europa movie

1253

00:51:58,810 --> 00:51:55,849

concepts but yeah so for that I ended up

1254

00:52:01,089 --> 00:51:58,820

being connected directly with the writer

1255

00:52:03,099 --> 00:52:01,099

for the screenplay at that point they

1256

00:52:05,440 --> 00:52:03,109

just had some money and they had a guy

1257

00:52:07,690 --> 00:52:05,450

who had a concept and I got to see a

1258

00:52:09,339 --> 00:52:07,700

very early version of the script and I

1259

00:52:11,829 --> 00:52:09,349

got to talk to him mostly in the

1260

00:52:14,440 --> 00:52:11,839

evenings after work you know from my

1261

00:52:19,050 --> 00:52:14,450

apartment by the phone this guy in New

1262

00:52:23,020 --> 00:52:19,060

York there I guess work late and I

1263

00:52:25,359 --> 00:52:23,030

suspect that my going through what's

1264

00:52:26,620 --> 00:52:25,369

cool about Europa and the fact that we

1265

00:52:29,140 --> 00:52:26,630

were talking about the science

1266

00:52:30,849 --> 00:52:29,150

definition team report for the Europa

1267

00:52:32,650 --> 00:52:30,859

clipper that we were going through many

1268

00:52:34,420 --> 00:52:32,660

states many iterations of studying

1269

00:52:37,780 --> 00:52:34,430

possible missions to Europe at that time

1270

00:52:39,940 --> 00:52:37,790

I suspect that led to the naming of the

1271

00:52:41,470 --> 00:52:39,950

movie as Europa report and in the theme

1272

00:52:44,740 --> 00:52:41,480

of the movie is very you know talking

1273

00:52:47,079 --> 00:52:44,750

about Europa and why it's cool that was

1274

00:52:49,960 --> 00:52:47,089

a cool it does need experience you know

1275

00:52:52,030 --> 00:52:49,970

he was we we had the chance later on

1276

00:52:54,640 --> 00:52:52,040

Kevin Hamels brought in also as a

1277

00:52:56,260 --> 00:52:54,650

science adviser and so the three of us

1278

00:53:00,010 --> 00:52:56,270

got to go back and forth and talk about

1279

00:53:02,349 --> 00:53:00,020

fun science things like to be put in

1280

00:53:05,890 --> 00:53:02,359

that would fit would make the movie feel

1281

00:53:07,450 --> 00:53:05,900

more realistic you know so artificial

1282

00:53:14,560 --> 00:53:07,460

gravity I think I'm having a rotating

1283

00:53:15,070 --> 00:53:14,570

spacecraft the dangers of hydrazine very

1284

00:53:17,260 --> 00:53:15,080

cool

1285

00:53:19,150 --> 00:53:17,270

Steve you leave a very exciting life

1286

00:53:21,130 --> 00:53:19,160

it's been a real privilege to talk to

1287

00:53:22,450 --> 00:53:21,140

you today we're right up time so if you

1288

00:53:23,950 --> 00:53:22,460

have more questions please don't

1289

00:53:25,359 --> 00:53:23,960

hesitate to reach out to Steve you can

1290

00:53:28,719 --> 00:53:25,369

find him on Twitter at

1291

00:53:30,249 --> 00:53:28,729

at Steve underscore vents thanks again

1292

00:53:32,019 --> 00:53:30,259

this I know you're an extremely busy

1293

00:53:33,039 --> 00:53:32,029

scientist I've been clear from what

1294

00:53:34,329 --> 00:53:33,049

you've been talking about that you have

1295

00:53:37,239 --> 00:53:34,339

your fingers and a lot of different

1296

00:53:39,130 --> 00:53:37,249

things so thank you again for speaking

1297

00:53:41,319 --> 00:53:39,140

with us please stay in touch with us out

1298

00:53:42,549 --> 00:53:41,329

here at asking astrobiologists for those

1299

00:53:44,559 --> 00:53:42,559

of you are watching don't forget the

1300

00:53:47,069 --> 00:53:44,569

background quiz will give you the answer

1301

00:53:48,780 --> 00:53:47,079

next week and until then stay curious