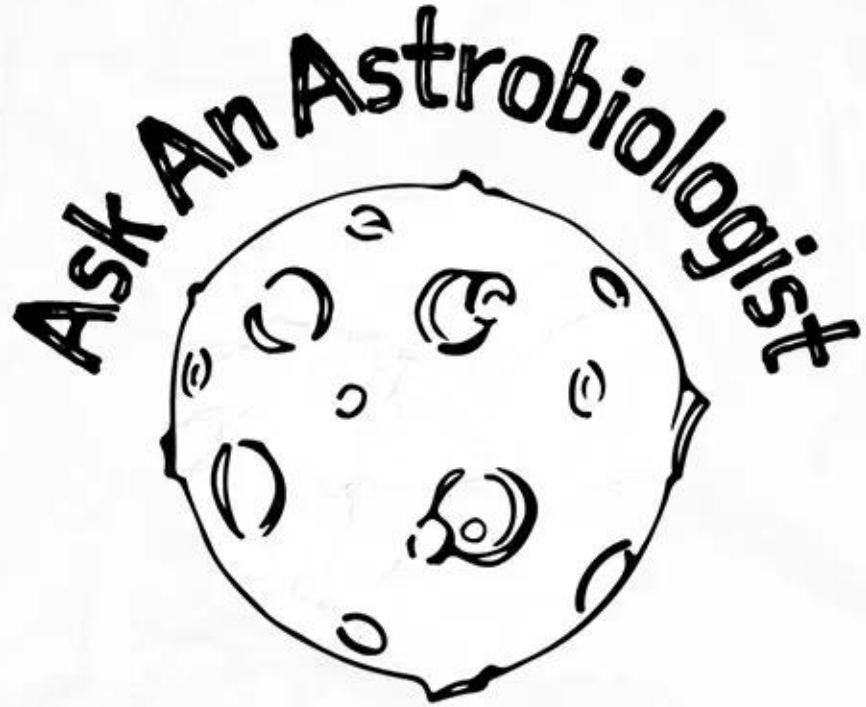

Episode 19: February 19th, 2019

Dr. Sarah Rugheimer

NASA Astrobiology Program

1
00:00:00,500 --> 00:00:29,290
[Music]

2
00:00:33,200 --> 00:00:31,250
greetings friends of astrobiology

3
00:00:34,910 --> 00:00:33,210
welcome to a brand new episode of ask an

4
00:00:37,760 --> 00:00:34,920
astrobiologist a show where we celebrate

5
00:00:39,139 --> 00:00:37,770
science and celebrate scientists my name

6
00:00:40,880 --> 00:00:39,149
is Sanjay some and this program is made

7
00:00:43,069 --> 00:00:40,890
possible by contributions from the NASA

8
00:00:46,670 --> 00:00:43,079
Astrobiology program and the non profit

9
00:00:48,619 --> 00:00:46,680
blue mobile space last month my fiercely

10
00:00:51,139 --> 00:00:48,629
beard energy co-host dr. Graham Lau

11
00:00:53,840 --> 00:00:51,149
known as the Cosmo biologist interviewed

12
00:00:56,420 --> 00:00:53,850
dr. Jill Charter and we talked about the

13
00:00:59,000 --> 00:00:56,430

value and the necessity of exploring for

14
00:01:00,709 --> 00:00:59,010
life beyond our home planets this month

15
00:01:03,470 --> 00:01:00,719
we have a really exciting guest and we

16
00:01:05,539 --> 00:01:03,480
will continue this conversation dr. Sara

17
00:01:08,060 --> 00:01:05,549
Rue Kaymer she is a fellow at the

18
00:01:10,820 --> 00:01:08,070
University of Oxford outstanding

19
00:01:12,740 --> 00:01:10,830
astronomer riveting dancer fearless

20
00:01:14,330 --> 00:01:12,750
Mountaineer and we're gonna be talking

21
00:01:16,640 --> 00:01:14,340
about all these topics in a little bit

22
00:01:19,850 --> 00:01:16,650
but first it's time for your monthly

23
00:01:22,550 --> 00:01:19,860
background quiz so last month Mike if

24
00:01:24,679 --> 00:01:22,560
you could put the picture up we had this

25
00:01:26,450 --> 00:01:24,689
beautiful picture behind dr. Graham

26
00:01:30,319 --> 00:01:26,460
laughs and simply you got it right it is

27
00:01:33,050 --> 00:01:30,329
of course badwater basin in the state of

28
00:01:36,319 --> 00:01:33,060
California in the United States it is a

29
00:01:37,910 --> 00:01:36,329
basin at minus 86 meters below sea level

30
00:01:40,910 --> 00:01:37,920
so it is the lowest point in North

31
00:01:43,429 --> 00:01:40,920
America and just about 100 miles from

32
00:01:47,590 --> 00:01:43,439
there you can see Mount Whitney which is

33
00:01:50,749 --> 00:01:47,600
the tallest mountain in the lower 48 at

34
00:01:54,109 --> 00:01:50,759
4420 meters so quite a big distinction

35
00:01:56,840 --> 00:01:54,119
in elevation there so those of you got

36
00:02:00,679 --> 00:01:56,850
it right congratulations the third-place

37
00:02:03,649 --> 00:02:00,689
winner will get the NASA stickers

38
00:02:08,330 --> 00:02:03,659

congratulations the second-place winner

39
00:02:10,999 --> 00:02:08,340
will get the stickers and the graphic

40
00:02:12,640 --> 00:02:11,009
novels and the first place winner wind

41
00:02:14,619 --> 00:02:12,650
it all with the stick

42
00:02:17,649 --> 00:02:14,629
of graphic novels and the Signet fine

43
00:02:19,360 --> 00:02:17,659
class congratulations all right it's my

44
00:02:20,380 --> 00:02:19,370
great privilege to introduce to you dr.

45
00:02:22,960 --> 00:02:20,390
Sarah Ruby Hamer

46
00:02:25,089 --> 00:02:22,970
so you're an astronomer and I was

47
00:02:27,069 --> 00:02:25,099
wondering if this interest in science

48
00:02:29,140 --> 00:02:27,079
that later blossom into a career in

49
00:02:31,030 --> 00:02:29,150
astronomy and astrology is that

50
00:02:37,750 --> 00:02:31,040
something you had in mind early on as a

51
00:02:41,349 --> 00:02:37,760
kid short answer no the long answer is I

52
00:02:43,720 --> 00:02:41,359
did there was a moment in my childhood

53
00:02:47,319 --> 00:02:43,730
where I liked astronomy but quite

54
00:02:48,729 --> 00:02:47,329
frankly I swore to my dad when I was in

55
00:02:51,640 --> 00:02:48,739
high school I said I'm never gonna take

56
00:02:52,930 --> 00:02:51,650
a physics class as long as I live and

57
00:02:55,059 --> 00:02:52,940
that's because he's a physics professor

58
00:02:58,690 --> 00:02:55,069
and my brother is also a physics

59
00:03:00,910 --> 00:02:58,700
professor and basically all of my

60
00:03:04,330 --> 00:03:00,920
brothers and sisters have a degree in

61
00:03:05,710 --> 00:03:04,340
physics of some sort and so I said I'm

62
00:03:09,129 --> 00:03:05,720
gonna do something different you know

63
00:03:11,830 --> 00:03:09,139

and so I decided to take accounting

64
00:03:15,399 --> 00:03:11,840
instead and it was really boring and the

65
00:03:17,680 --> 00:03:15,409
only class so let me switch into that

66
00:03:19,599 --> 00:03:17,690
late in the physics latley and the term

67
00:03:21,400 --> 00:03:19,609
was physics so I ended up taking physics

68
00:03:23,979 --> 00:03:21,410
in high school despite my declaration

69
00:03:26,409 --> 00:03:23,989
that I wouldn't and I enjoyed it but I

70
00:03:28,180 --> 00:03:26,419
was never gonna major in it never at all

71
00:03:29,830 --> 00:03:28,190
and so when I got to college I was

72
00:03:32,080 --> 00:03:29,840
thinking about doing other things you

73
00:03:34,180 --> 00:03:32,090
know and I got through my first year and

74
00:03:38,259 --> 00:03:34,190
I was thinking what did I enjoy and I'm

75
00:03:42,009 --> 00:03:38,269
like I really I liked physics and so

76
00:03:43,330 --> 00:03:42,019
then I did a major in physics realizing

77
00:03:45,610 --> 00:03:43,340
that it was stupid not to major in it

78
00:03:47,830 --> 00:03:45,620
just because my family has a lot of

79
00:03:49,780 --> 00:03:47,840
physicists in it but I swore I would

80
00:03:51,729 --> 00:03:49,790
never do astronomy so then like all

81
00:03:54,430 --> 00:03:51,739
through undergrad I said I'm never gonna

82
00:03:55,599 --> 00:03:54,440
do astronomy because it's squiggly lines

83
00:03:58,089 --> 00:03:55,609
all day long I mean that was the

84
00:04:00,009 --> 00:03:58,099
impression I had of astronomy I went on

85
00:04:04,089 --> 00:04:00,019
a summer undergrad research project and

86
00:04:06,699 --> 00:04:04,099
I watched my fellow summer undergrad

87
00:04:07,809 --> 00:04:06,709
students doing astronomy projects and

88
00:04:11,830 --> 00:04:07,819

they were literally just going through

89
00:04:13,599 --> 00:04:11,840
like 700 quasar spectra a day going

90
00:04:16,000 --> 00:04:13,609
yes-no yes-no kind of double-checking

91
00:04:18,370 --> 00:04:16,010
the pipeline it looked to me to be the

92
00:04:21,699 --> 00:04:18,380
most single boring job on the planet and

93
00:04:23,290 --> 00:04:21,709
so I said I will never go into astronomy

94
00:04:23,930 --> 00:04:23,300
I never took a single astronomy class

95
00:04:27,200 --> 00:04:23,940
and then

96
00:04:30,050 --> 00:04:27,210
like not at all I didn't go to any

97
00:04:32,660 --> 00:04:30,060
extremity talks or anything and and I

98
00:04:34,040 --> 00:04:32,670
even had a professor and undergrad try

99
00:04:38,630 --> 00:04:34,050
to get me to do an astronomy project

100
00:04:40,370 --> 00:04:38,640
with him and I refused many times and he

101
00:04:41,780 --> 00:04:40,380
pushed me so hard I was I just don't

102
00:04:43,550 --> 00:04:41,790
want to look at squiggly lines all day

103
00:04:45,500 --> 00:04:43,560
is what I said to him and now what do i

104
00:04:47,780 --> 00:04:45,510
do is i generate spectra and look at

105
00:04:49,670 --> 00:04:47,790
squiggly lines all today and you know

106
00:04:52,370 --> 00:04:49,680
it's what the lines mean but when I was

107
00:04:55,370 --> 00:04:52,380
in my you know youth I was not so smart

108
00:04:57,200 --> 00:04:55,380
and did not realize that so it took a

109
00:04:59,930 --> 00:04:57,210
while of me saying never many times

110
00:05:02,480 --> 00:04:59,940
before I got here so tell us a little

111
00:05:03,980 --> 00:05:02,490
bit what a spectroscopy does what is the

112
00:05:07,970 --> 00:05:03,990
spectra why is that important in

113
00:05:10,010 --> 00:05:07,980

astronomy I mean so again it's like

114
00:05:12,260 --> 00:05:10,020
these squiggly lines it's what they mean

115
00:05:14,930 --> 00:05:12,270
so lines absorb at very specific

116
00:05:16,670 --> 00:05:14,940
wavelengths of light molecules absorb a

117
00:05:18,260 --> 00:05:16,680
very specific wavelengths of light and

118
00:05:21,050 --> 00:05:18,270
so by looking at that we can actually

119
00:05:23,630 --> 00:05:21,060
see what's out in the universe whether

120
00:05:27,110 --> 00:05:23,640
it's a star and interstellar dust or on

121
00:05:29,390 --> 00:05:27,120
an exoplanet and so it's it's amazing to

122
00:05:31,010 --> 00:05:29,400
me now sitting from this position of

123
00:05:33,830 --> 00:05:31,020
being an astronomer it's quite amazing

124
00:05:36,800 --> 00:05:33,840
how much we can do by just passively

125
00:05:38,420 --> 00:05:36,810
collecting light on earth how much we

126
00:05:40,820 --> 00:05:38,430
can tell about the universe and its

127
00:05:43,130 --> 00:05:40,830
origin all the way to you know planets

128
00:05:46,490 --> 00:05:43,140
and stars and and other planets that are

129
00:05:48,710 --> 00:05:46,500
orbiting other stars and so my interest

130
00:05:50,990 --> 00:05:48,720
in astronomy is particularly could we

131
00:05:53,710 --> 00:05:51,000
tell if there's life in an exoplanet

132
00:05:56,090 --> 00:05:53,720
from Earth could we how could we tell

133
00:05:58,040 --> 00:05:56,100
it's gonna be difficult because we can't

134
00:06:00,080 --> 00:05:58,050
send you know a microscope to the

135
00:06:02,570 --> 00:06:00,090
surface and look for little things you

136
00:06:05,120 --> 00:06:02,580
know ask wiggling around and in the

137
00:06:07,159 --> 00:06:05,130
ocean so we have to do this all by just

138
00:06:08,780 --> 00:06:07,169

looking at what's imprinted on in the

139
00:06:10,130 --> 00:06:08,790
atmosphere and how you do that is

140
00:06:11,900 --> 00:06:10,140
through spectroscopy and what

141
00:06:14,720 --> 00:06:11,910
wavelengths get absorbed by a bit

142
00:06:16,940 --> 00:06:14,730
different molecules so that's because

143
00:06:18,470 --> 00:06:16,950
biology on a planetary surface would

144
00:06:21,500 --> 00:06:18,480
operate in such a way to completely

145
00:06:23,540 --> 00:06:21,510
change the air or what the air is made

146
00:06:25,820 --> 00:06:23,550
of I mean if we think about the earth

147
00:06:29,330 --> 00:06:25,830
today the the air that we breathe would

148
00:06:30,710 --> 00:06:29,340
be nothing like it is if biology had not

149
00:06:33,050 --> 00:06:30,720
evolved on the planet in the first place

150
00:06:36,150 --> 00:06:33,060
so what about the what about the air on

151
00:06:39,030 --> 00:06:36,160
a planet that's alive is the

152
00:06:40,770 --> 00:06:39,040
Prinze and how can you detect that right

153
00:06:42,930 --> 00:06:40,780
well so as you said I mean in some ways

154
00:06:44,940 --> 00:06:42,940
Earth has been many planets you know

155
00:06:46,410 --> 00:06:44,950
through its history we often think of

156
00:06:48,300 --> 00:06:46,420
Earth as just being a single planet but

157
00:06:50,700 --> 00:06:48,310
it's gone through such a dramatic change

158
00:06:52,500 --> 00:06:50,710
from its formation to today that if you

159
00:06:54,420 --> 00:06:52,510
were to take a snapshot at any given

160
00:06:57,390 --> 00:06:54,430
point it would look very different and

161
00:06:59,340 --> 00:06:57,400
so sure we breathe air and and it has a

162
00:07:00,690 --> 00:06:59,350
heavy imprint of life on the atmosphere

163
00:07:04,920 --> 00:07:00,700

and that's the only hope we really have

164
00:07:06,990 --> 00:07:04,930
of seen life around another star if the

165
00:07:08,580 --> 00:07:07,000
life is really subsurface and not really

166
00:07:09,930 --> 00:07:08,590
interacting a lot with the atmosphere

167
00:07:12,330 --> 00:07:09,940
we're just not going to be able to see

168
00:07:14,400 --> 00:07:12,340
it you know I'm case on point Mars might

169
00:07:15,870 --> 00:07:14,410
have life living in the subsurface and

170
00:07:17,820 --> 00:07:15,880
we can't tell and we're right next door

171
00:07:19,650 --> 00:07:17,830
so we're an exoplanet we're trying to

172
00:07:21,960 --> 00:07:19,660
see like is this planet have a whole

173
00:07:23,940 --> 00:07:21,970
global biosphere an atmosphere where

174
00:07:26,340 --> 00:07:23,950
that life is interacting with the

175
00:07:28,650 --> 00:07:26,350
atmosphere and then it's leaving

176
00:07:30,920 --> 00:07:28,660
fingerprints of different molecules in

177
00:07:35,360 --> 00:07:30,930
that was feared things like oxygen

178
00:07:38,070 --> 00:07:35,370
methane nitrous oxide methyl chloride

179
00:07:40,710 --> 00:07:38,080
all sorts of different molecules that we

180
00:07:44,040 --> 00:07:40,720
might try to look for to try to tease

181
00:07:46,710 --> 00:07:44,050
out could that happen from just geology

182
00:07:48,810 --> 00:07:46,720
and physics and chemistry or does it

183
00:07:50,700 --> 00:07:48,820
really means something like life that's

184
00:07:53,370 --> 00:07:50,710
driving it and so that's the ultimate

185
00:07:55,050 --> 00:07:53,380
goal are you looking for specific

186
00:07:58,770 --> 00:07:55,060
compounds and more like mixtures of

187
00:08:01,260 --> 00:07:58,780
compounds I would say ultimately we need

188
00:08:03,210 --> 00:08:01,270

to see more than one molecule so one

189
00:08:05,520 --> 00:08:03,220
single bio signature gas will not be

190
00:08:07,470 --> 00:08:05,530
enough and this is because even if you

191
00:08:09,870 --> 00:08:07,480
were to detect oxygen we know now of

192
00:08:12,330 --> 00:08:09,880
many ways to get oxygen without life and

193
00:08:13,950 --> 00:08:12,340
so you have to look for other ways to

194
00:08:15,480 --> 00:08:13,960
distinguish between those false

195
00:08:21,290 --> 00:08:15,490
positives other molecules in the

196
00:08:23,460 --> 00:08:21,300
atmosphere and and look for other

197
00:08:24,990 --> 00:08:23,470
combinations of gases so the strut one

198
00:08:26,310 --> 00:08:25,000
of the most commonly excited and

199
00:08:27,960 --> 00:08:26,320
strongest combinations would be

200
00:08:29,820 --> 00:08:27,970
something like oxygen or ozone with

201
00:08:31,440 --> 00:08:29,830
methane because both of those gases

202
00:08:34,650 --> 00:08:31,450
together would be difficult to maintain

203
00:08:36,600 --> 00:08:34,660
at concentrations in less produced by

204
00:08:39,450 --> 00:08:36,610
life and so that's so that's a target

205
00:08:41,430 --> 00:08:39,460
that is often talked about well that's a

206
00:08:43,440 --> 00:08:41,440
big step from going to college and not

207
00:08:45,960 --> 00:08:43,450
wanting to take an astronomy class to

208
00:08:47,700 --> 00:08:45,970
being able to detect compounds in

209
00:08:49,890 --> 00:08:47,710
planetary atmospheres that are not the

210
00:08:52,470 --> 00:08:49,900
earth tell us about that journey

211
00:08:56,670 --> 00:08:52,480
to end up and at this time stage of your

212
00:09:00,360 --> 00:08:56,680
career yes so maybe I'm being too honest

213
00:09:02,910 --> 00:09:00,370

but I'll say I went to a undergrad ru

214
00:09:04,769 --> 00:09:02,920
program in Hawaii for astronomy mainly

215
00:09:09,360 --> 00:09:04,779
because it was Hawaii not because of the

216
00:09:11,519 --> 00:09:09,370
astronomy and and I and I really like

217
00:09:14,700 --> 00:09:11,529
that also didn't convince me after that

218
00:09:16,110 --> 00:09:14,710
summer I remember my my adviser asking

219
00:09:17,460 --> 00:09:16,120
me if I thought it might want you grad

220
00:09:19,500 --> 00:09:17,470
school and a strong and I was like well

221
00:09:21,420 --> 00:09:19,510
not really you know and I still was just

222
00:09:24,030 --> 00:09:21,430
really dead-set against astronomy at

223
00:09:25,860 --> 00:09:24,040
that point and I was gonna do an MD PhD

224
00:09:27,450 --> 00:09:25,870
that was what I was leaning towards and

225
00:09:29,810 --> 00:09:27,460
more of the work that I had done in

226
00:09:32,250 --> 00:09:29,820
undergrad was more Medical Physics and

227
00:09:34,710 --> 00:09:32,260
then what basically what happened is

228
00:09:37,650 --> 00:09:34,720
because of that are you in Hawaii I went

229
00:09:39,840 --> 00:09:37,660
to a conference a double-a s conference

230
00:09:43,160 --> 00:09:39,850
the next summer so this is after I

231
00:09:46,440 --> 00:09:43,170
graduated and I took a year off between

232
00:09:47,880 --> 00:09:46,450
undergrad and grad school and so in that

233
00:09:50,340 --> 00:09:47,890
summer that first summer after I

234
00:09:52,050 --> 00:09:50,350
graduated I presented my summer research

235
00:09:54,150 --> 00:09:52,060
findings at this conference and I sat in

236
00:09:55,769 --> 00:09:54,160
on a session on astrobiology and

237
00:09:58,800 --> 00:09:55,779
detecting life on another planet and I

238
00:10:00,360 --> 00:09:58,810

just was like what you know we can do

239
00:10:01,860 --> 00:10:00,370
this like this is a question that could

240
00:10:04,140 --> 00:10:01,870
be answered in my scientific lifetime

241
00:10:06,210 --> 00:10:04,150
like no one told me you know and I was

242
00:10:07,620 --> 00:10:06,220
so excited like that and honestly like I

243
00:10:08,910 --> 00:10:07,630
never looked back from that point and I

244
00:10:11,900 --> 00:10:08,920
still think it's just by far the most

245
00:10:15,720 --> 00:10:11,910
interesting area of science and then I

246
00:10:19,680 --> 00:10:15,730
came across a book and a teaching

247
00:10:21,480 --> 00:10:19,690
company series by Bob Hazen called well

248
00:10:23,610 --> 00:10:21,490
the book is called Genesis the

249
00:10:25,620 --> 00:10:23,620
scientific quest for life's origins it's

250
00:10:28,500 --> 00:10:25,630
this book I highly recommend it it goes

251
00:10:30,750 --> 00:10:28,510
through a lot of prebiotic chemistry and

252
00:10:32,970 --> 00:10:30,760
I just got really excited about not only

253
00:10:35,130 --> 00:10:32,980
how to detect life on an exoplanet but

254
00:10:38,670 --> 00:10:35,140
you know trying to tease out the origins

255
00:10:41,250 --> 00:10:38,680
of life on Earth and when I realized

256
00:10:42,840 --> 00:10:41,260
that for the first time in the history

257
00:10:44,460 --> 00:10:42,850
of humanity and we've had this question

258
00:10:46,769 --> 00:10:44,470
of are we alone what's our place in the

259
00:10:49,019 --> 00:10:46,779
universe we can begin to answer this

260
00:10:50,760 --> 00:10:49,029
from a scientific standpoint I just was

261
00:10:53,040 --> 00:10:50,770
hooked and so then I only applied to

262
00:10:54,420 --> 00:10:53,050
grad school in astronomy and when I

263
00:10:56,130 --> 00:10:54,430

showed up I felt really out of place

264
00:10:58,500 --> 00:10:56,140
because I hadn't taken any astronomy

265
00:11:00,270 --> 00:10:58,510
undergraduate classes and astronomers

266
00:11:03,150 --> 00:11:00,280
use all sorts of weird units that are

267
00:11:04,110 --> 00:11:03,160
not si like herbs and and you know a you

268
00:11:06,030 --> 00:11:04,120
and I

269
00:11:08,640 --> 00:11:06,040
completely lost by the jargon for the

270
00:11:12,000 --> 00:11:08,650
first six months and and almost dropped

271
00:11:13,650 --> 00:11:12,010
out frankly from that feeling of just

272
00:11:17,280 --> 00:11:13,660
being like oh my god what's happening

273
00:11:19,710 --> 00:11:17,290
but I I'm here today so I empathize I

274
00:11:21,269 --> 00:11:19,720
saw her grad school in in geology heaven

275
00:11:24,240 --> 00:11:21,279
they could never taken a geology class

276
00:11:26,640 --> 00:11:24,250
so the first first year was tough but we

277
00:11:29,160 --> 00:11:26,650
survived actually we asked your

278
00:11:32,430 --> 00:11:29,170
biological aspect of astronomy that got

279
00:11:35,190 --> 00:11:32,440
you excited into the field 100% yeah no

280
00:11:36,690 --> 00:11:35,200
I mean yeah I I like the rest of

281
00:11:39,870 --> 00:11:36,700
astronomy now but really it's

282
00:11:41,370 --> 00:11:39,880
astrobiology I'm here for so you went to

283
00:11:43,380 --> 00:11:41,380
graduate school at Harvard if I'm not

284
00:11:45,210 --> 00:11:43,390
mistaken tell us how that experience was

285
00:11:47,280 --> 00:11:45,220
like particularly because you're you

286
00:11:49,140 --> 00:11:47,290
didn't feel exactly where they're not

287
00:11:51,269 --> 00:11:49,150
belong there so I'm sure you relied on

288
00:11:53,010 --> 00:11:51,279

some mentors and friends like how did

289
00:11:54,329 --> 00:11:53,020
you in grad school is not easy how did

290
00:11:57,320 --> 00:11:54,339
you how did you do it

291
00:11:59,460 --> 00:11:57,330
yeah absolutely it it was really hard

292
00:12:01,530 --> 00:11:59,470
mainly I fell a place for a couple

293
00:12:02,880 --> 00:12:01,540
reasons one is I hadn't had the

294
00:12:05,040 --> 00:12:02,890
astronomy background every other person

295
00:12:07,380 --> 00:12:05,050
in my class knew that they wanted to be

296
00:12:10,829 --> 00:12:07,390
an astronomer for a lot longer and kind

297
00:12:12,930 --> 00:12:10,839
of already had the background as well as

298
00:12:15,810 --> 00:12:12,940
they had all gone to fancy undergrads by

299
00:12:17,910 --> 00:12:15,820
and large and so I had gone to a

300
00:12:21,660 --> 00:12:17,920
community college first in Montana and

301
00:12:25,800 --> 00:12:21,670
then to a school in Calgary in Canada

302
00:12:28,949 --> 00:12:25,810
for my undergrad and so I just really

303
00:12:31,680 --> 00:12:28,959
felt quite out of place you know and I

304
00:12:33,570 --> 00:12:31,690
remember about six times that first six

305
00:12:35,460 --> 00:12:33,580
months calling my dad and just saying I

306
00:12:37,560 --> 00:12:35,470
just want to drop out I just I don't you

307
00:12:40,650 --> 00:12:37,570
know I don't feel like I'm smart enough

308
00:12:42,060 --> 00:12:40,660
to be here I don't feel like long and my

309
00:12:45,960 --> 00:12:42,070
dad was like just give us some time

310
00:12:48,480 --> 00:12:45,970
you'll be okay you know and and it those

311
00:12:50,880 --> 00:12:48,490
feelings faded but that feeling of the

312
00:12:53,070 --> 00:12:50,890
imposter syndrome which really hit me

313
00:12:55,350 --> 00:12:53,080

strongest in grad school and most people

314
00:12:57,180 --> 00:12:55,360
it impacts them the first time really in

315
00:12:58,740 --> 00:12:57,190
a big way in grad school was very

316
00:13:01,740 --> 00:12:58,750
present and and part of that narrative

317
00:13:03,210 --> 00:13:01,750
was having not come from you know MIT

318
00:13:06,060 --> 00:13:03,220
Princeton you know all these other

319
00:13:07,440 --> 00:13:06,070
places and then it combined with the

320
00:13:10,230 --> 00:13:07,450
fact that I didn't know anything about

321
00:13:11,970 --> 00:13:10,240
astronomy so I was you know lost I

322
00:13:16,560 --> 00:13:11,980
remember in my first day in my first

323
00:13:17,970 --> 00:13:16,570
class my my supervisor Dimitar Salah was

324
00:13:19,200 --> 00:13:17,980
teaching said Oh

325
00:13:20,520 --> 00:13:19,210
guys already know hydrostatic

326
00:13:22,140 --> 00:13:20,530
equilibrium so we're just gonna skip

327
00:13:23,670 --> 00:13:22,150
that and that was never covered in any

328
00:13:26,550 --> 00:13:23,680
of my physics classes and I'm just like

329
00:13:27,870 --> 00:13:26,560
oh my god I hope quick we're just

330
00:13:30,420 --> 00:13:27,880
skipping all of this stuff and I don't

331
00:13:32,220 --> 00:13:30,430
even know where we are so and then he

332
00:13:35,070 --> 00:13:32,230
said units and things that I'd never

333
00:13:37,680 --> 00:13:35,080
heard and all these acronyms I remember

334
00:13:39,630 --> 00:13:37,690
not knowing that Hubble was HST and so

335
00:13:40,590 --> 00:13:39,640
people were talking HST HST and I'm like

336
00:13:42,480 --> 00:13:40,600
what I'm like

337
00:13:45,360 --> 00:13:42,490
Oh Hubble oh okay okay okay okay I got

338
00:13:47,340 --> 00:13:45,370

it you know but it was just really like

339
00:13:48,900 --> 00:13:47,350
all this lingo that I didn't know and I

340
00:13:53,490 --> 00:13:48,910
felt really quite out of place for the

341
00:13:56,190 --> 00:13:53,500
first the first year or so so I'm sure

342
00:13:57,630 --> 00:13:56,200
you you you had some good friends there

343
00:13:59,340 --> 00:13:57,640
I notice that Sarah Ballard somebody

344
00:14:01,020 --> 00:13:59,350
you're close to and you guys did a blog

345
00:14:06,270 --> 00:14:01,030
together but we still have that blog

346
00:14:07,590 --> 00:14:06,280
going so tell us about that to answer

347
00:14:11,280 --> 00:14:07,600
the second part of the question how did

348
00:14:15,420 --> 00:14:11,290
I survive so it was really the cohort of

349
00:14:18,660 --> 00:14:15,430
people I came in with I I just really

350
00:14:20,490 --> 00:14:18,670
had a great experience of the other

351
00:14:23,130 --> 00:14:20,500
students in my program and we were all

352
00:14:25,890 --> 00:14:23,140
very supportive of each other and Sarah

353
00:14:27,390 --> 00:14:25,900
Ballard in particular when I would open

354
00:14:28,590 --> 00:14:27,400
up about how I just felt out of place I

355
00:14:30,870 --> 00:14:28,600
don't feel I'm smart enough I'm not

356
00:14:32,010 --> 00:14:30,880
gonna do well she would just say you

357
00:14:35,940 --> 00:14:32,020
have the impostor syndrome

358
00:14:38,460 --> 00:14:35,950
the impostor syndrome and I literally

359
00:14:41,070 --> 00:14:38,470
thought she was just making up an entire

360
00:14:43,050 --> 00:14:41,080
psychological syndrome herself that she

361
00:14:46,200 --> 00:14:43,060
called the imposter syndrome I didn't

362
00:14:47,730 --> 00:14:46,210
think it was a real deal and so she said

363
00:14:49,080 --> 00:14:47,740

this to me I don't know 14 times or

364
00:14:50,820 --> 00:14:49,090
something and then I was texting a

365
00:14:52,140 --> 00:14:50,830
friend from undergrad I was like yeah my

366
00:14:54,000 --> 00:14:52,150
friend called with the imposter syndrome

367
00:14:55,470 --> 00:14:54,010
and he said oh you know that's a real

368
00:14:58,380 --> 00:14:55,480
deal with a Wikipedia page and

369
00:15:00,810 --> 00:14:58,390
everything right and I said what and I

370
00:15:03,750 --> 00:15:00,820
went to the Wikipedia page and I found

371
00:15:05,520 --> 00:15:03,760
the woman who termed impostor syndrome

372
00:15:07,950 --> 00:15:05,530
and I started writing her an email and

373
00:15:10,200 --> 00:15:07,960
I'm like I get how you observe this in

374
00:15:11,730 --> 00:15:10,210
people however I think that I am

375
00:15:13,560 --> 00:15:11,740
actually and then I just realized she

376
00:15:15,900 --> 00:15:13,570
wouldn't believe me look about at that

377
00:15:17,700 --> 00:15:15,910
point in my email of me trying to tell

378
00:15:19,290 --> 00:15:17,710
her why I was the one true imposter and

379
00:15:21,630 --> 00:15:19,300
everyone else's fake imposters I

380
00:15:24,030 --> 00:15:21,640
realized that she would laugh at that so

381
00:15:26,870 --> 00:15:24,040
then I never sent that email to if to

382
00:15:28,910 --> 00:15:26,880
valerie young but that was kind of how i

383
00:15:31,200 --> 00:15:28,920
first heard about the imposter syndrome

384
00:15:31,920 --> 00:15:31,210
it was through really the strength that

385
00:15:34,200 --> 00:15:31,930
the other graduate

386
00:15:35,790 --> 00:15:34,210
students and support that that kept me

387
00:15:38,370 --> 00:15:35,800
going and then Sarah Ballard and I

388
00:15:41,310 --> 00:15:38,380

lashed a podcast that we run called self

389
00:15:44,070 --> 00:15:41,320
care with doctors clurel Sarah because

390
00:15:45,540 --> 00:15:44,080
we're both named Sarah and so we talked

391
00:15:48,420 --> 00:15:45,550
about all sorts of things to do with

392
00:15:51,660 --> 00:15:48,430
maintaining mental health physical

393
00:15:53,639 --> 00:15:51,670
health in grad school in postdoc years

394
00:15:56,340 --> 00:15:53,649
for junior faculty applications we

395
00:15:58,650 --> 00:15:56,350
talked about conferences we talked about

396
00:16:00,990 --> 00:15:58,660
surviving grad school we talked about a

397
00:16:05,000 --> 00:16:01,000
lot about the imposter syndrome we

398
00:16:07,139 --> 00:16:05,010
talked about cognitive distortions

399
00:16:09,750 --> 00:16:07,149
exercising all sorts of things you know

400
00:16:11,760 --> 00:16:09,760
in in our podcast and yes we are indeed

401
00:16:13,790 --> 00:16:11,770
still still going through years strung

402
00:16:17,010 --> 00:16:13,800
so check it out on iTunes or SoundCloud

403
00:16:21,630 --> 00:16:17,020
pretty but is the name again at self

404
00:16:24,090 --> 00:16:21,640
care with doctors Sarah and like I said

405
00:16:28,769 --> 00:16:24,100
you can find it on iTunes or SoundCloud

406
00:16:31,170 --> 00:16:28,779
and have a listen send us send us any we

407
00:16:32,730 --> 00:16:31,180
love getting questions that people have

408
00:16:34,019 --> 00:16:32,740
or feedback or things that they wanted

409
00:16:36,930 --> 00:16:34,029
to talk about as well so we give a

410
00:16:38,519 --> 00:16:36,940
there's a email that we always give at

411
00:16:41,699 --> 00:16:38,529
the end then you can tweet at us and all

412
00:16:44,670 --> 00:16:41,709
that stuff so beyond science you're

413
00:16:47,730 --> 00:16:44,680

pursuing a fair breadth of interests I

414
00:16:49,620 --> 00:16:47,740
you tango dancer your Mountaineer how do

415
00:16:54,570 --> 00:16:49,630
you have time to do all this and and

416
00:16:55,019 --> 00:16:54,580
science I do the other things not all at

417
00:16:58,590 --> 00:16:55,029
once

418
00:16:59,910 --> 00:16:58,600
so they come in phases so for example

419
00:17:02,100 --> 00:16:59,920
like I'm not climbing mountains every

420
00:17:03,750 --> 00:17:02,110
day I climb mountains like once every

421
00:17:06,720 --> 00:17:03,760
year and a half I'll take you know maybe

422
00:17:08,220 --> 00:17:06,730
two weeks to go and do that and then

423
00:17:10,710 --> 00:17:08,230
I've climbed some really tall ones you

424
00:17:12,600 --> 00:17:10,720
know that are like aconcagua in South

425
00:17:16,679 --> 00:17:12,610
America but that's like a whole trip

426
00:17:18,900 --> 00:17:16,689
that I just reserved and trained for at

427
00:17:20,549 --> 00:17:18,910
home but it's it's not really a lot of

428
00:17:24,929 --> 00:17:20,559
time because if they happen so

429
00:17:26,610 --> 00:17:24,939
infrequently dancing again I do a lot of

430
00:17:28,260 --> 00:17:26,620
ballroom dance Argentine tango I

431
00:17:29,820 --> 00:17:28,270
competed in Irish dance for a long time

432
00:17:33,150 --> 00:17:29,830
but those have come at different phases

433
00:17:37,020 --> 00:17:33,160
and so I I do them in my evenings or

434
00:17:38,970 --> 00:17:37,030
weekends to relax and and whatnot but I

435
00:17:41,100 --> 00:17:38,980
don't do everything all the time that's

436
00:17:43,440 --> 00:17:41,110
what it boils down to you seem like it's

437
00:17:45,480 --> 00:17:43,450
an important aspect of keeping a solid

438
00:17:49,260 --> 00:17:45,490

mental health facility this

439
00:17:51,840 --> 00:17:49,270
oneself from inside right or have other

440
00:17:53,910 --> 00:17:51,850
interests I mean I do find when someone

441
00:17:56,760 --> 00:17:53,920
says oh I only do science I'm like

442
00:17:59,340 --> 00:17:56,770
really all right we're gonna have a

443
00:18:00,900 --> 00:17:59,350
short conversation and you know because

444
00:18:03,180 --> 00:18:00,910
there's so many other things that are

445
00:18:05,250 --> 00:18:03,190
interesting I do think you need to take

446
00:18:06,630 --> 00:18:05,260
that mental break and then you it helps

447
00:18:08,310 --> 00:18:06,640
your science because you come back and

448
00:18:10,380 --> 00:18:08,320
you are more refreshing you can think

449
00:18:13,080 --> 00:18:10,390
about things again then and what not so

450
00:18:14,940 --> 00:18:13,090
I try to maintain those but again they

451
00:18:17,460 --> 00:18:14,950
come and go depending on how busy things

452
00:18:18,560 --> 00:18:17,470
are and I certainly haven't done all of

453
00:18:21,360 --> 00:18:18,570
them all the time

454
00:18:23,700 --> 00:18:21,370
cool so in addition to listening to your

455
00:18:25,919 --> 00:18:23,710
podcast will be like the your one piece

456
00:18:27,840 --> 00:18:25,929
of advice for some of our listeners and

457
00:18:30,150 --> 00:18:27,850
viewers who might be feeling impostor

458
00:18:31,890 --> 00:18:30,160
syndrome and in class not even maybe at

459
00:18:33,750 --> 00:18:31,900
university maybe even you know earlier

460
00:18:36,480 --> 00:18:33,760
than that yeah

461
00:18:39,030 --> 00:18:36,490
so I actually two pieces of advice and

462
00:18:41,280 --> 00:18:39,040
and I gave both of those pieces of

463
00:18:42,780 --> 00:18:41,290

advice and a commencement address at the

464
00:18:45,299 --> 00:18:42,790
community college I went to so you guys

465
00:18:47,190 --> 00:18:45,309
can also see that YouTube video if you

466
00:18:50,100 --> 00:18:47,200
searched my name and commencement

467
00:18:52,470 --> 00:18:50,110
address it comes right up and it's about

468
00:18:53,760 --> 00:18:52,480
halfway through the video that my

469
00:18:56,160 --> 00:18:53,770
commencement address starts but

470
00:18:58,290 --> 00:18:56,170
basically in that I always give roughly

471
00:18:59,400 --> 00:18:58,300
two pieces of advice one is don't say no

472
00:19:00,990 --> 00:18:59,410
to yourself

473
00:19:03,600 --> 00:19:01,000
so don't self select out of

474
00:19:05,970 --> 00:19:03,610
opportunities I almost didn't apply to

475
00:19:08,669 --> 00:19:05,980
Harvard because I didn't think there was

476
00:19:11,700 --> 00:19:08,679
a chance I could get in to Harvard and I

477
00:19:14,549 --> 00:19:11,710
remember sitting at the screen on the

478
00:19:16,080 --> 00:19:14,559
application submit button for like five

479
00:19:18,000 --> 00:19:16,090
minutes because it was a 90 dollar

480
00:19:20,430 --> 00:19:18,010
application fee and I remember thinking

481
00:19:23,370 --> 00:19:20,440
I could go to dinner three times for $90

482
00:19:25,770 --> 00:19:23,380
like nice thanks dinner you know and and

483
00:19:27,720 --> 00:19:25,780
that was I just was like why should I

484
00:19:29,460 --> 00:19:27,730
spend this on a school I have zero

485
00:19:32,040 --> 00:19:29,470
chance of being in two and I almost

486
00:19:33,540 --> 00:19:32,050
didn't click Submit and and that

487
00:19:36,390 --> 00:19:33,550
happened so many times like I almost

488
00:19:37,500 --> 00:19:36,400

don't apply you know for a fellowship or

489
00:19:39,840 --> 00:19:37,510
whatever cuz I'm like well I'm not gonna

490
00:19:42,180 --> 00:19:39,850
get it anyway so why bother applying you

491
00:19:44,400 --> 00:19:42,190
know and and in the end I have to apply

492
00:19:46,169 --> 00:19:44,410
to maybe ten times as many things as as

493
00:19:48,330 --> 00:19:46,179
you get in academia that's very common

494
00:19:49,620 --> 00:19:48,340
you know with fellowships and faculty

495
00:19:52,560 --> 00:19:49,630
you just have to apply a lot

496
00:19:54,030 --> 00:19:52,570
so my advice there is just don't say no

497
00:19:55,770 --> 00:19:54,040
to yourself let someone else say no to

498
00:19:58,560 --> 00:19:55,780
you someone else can tell you know but

499
00:19:59,299 --> 00:19:58,570
you don't be the filter that stops you

500
00:20:01,380 --> 00:19:59,309
from applying

501
00:20:04,409 --> 00:20:01,390
because the imposter syndrome can really

502
00:20:06,990 --> 00:20:04,419
do that and my second piece of advice is

503
00:20:08,880 --> 00:20:07,000
that you really like self-care comes

504
00:20:11,669 --> 00:20:08,890
first you can't be a good scientist if

505
00:20:15,120 --> 00:20:11,679
you are not taking care of your mental

506
00:20:16,200 --> 00:20:15,130
and physical health and so and this is

507
00:20:18,000 --> 00:20:16,210
something I learned strongly in

508
00:20:20,850 --> 00:20:18,010
mountaineering as well like you have to

509
00:20:23,070 --> 00:20:20,860
take care of your body first so that

510
00:20:26,280 --> 00:20:23,080
means you know sleep comes first

511
00:20:28,650 --> 00:20:26,290
exercise comes first eating well comes

512
00:20:30,180 --> 00:20:28,660
first and often you know social

513
00:20:31,260 --> 00:20:30,190

connection maintaining good social

514
00:20:33,659 --> 00:20:31,270
connection comes first

515
00:20:35,220 --> 00:20:33,669
and these things are often the things

516
00:20:36,780 --> 00:20:35,230
that go by the wayside when we're most

517
00:20:39,090 --> 00:20:36,790
stressed but those are the things that

518
00:20:41,850 --> 00:20:39,100
are also the best buffers against stress

519
00:20:43,710 --> 00:20:41,860
and and can help you function at your

520
00:20:46,110 --> 00:20:43,720
peak level there's a lot of research on

521
00:20:47,580 --> 00:20:46,120
this and so I go into a bit more detail

522
00:20:49,470 --> 00:20:47,590
about it but in the commencement address

523
00:20:51,419 --> 00:20:49,480
but those are my two pieces of advice is

524
00:20:53,640 --> 00:20:51,429
you know you gotta take care taking care

525
00:20:56,430 --> 00:20:53,650
of yourself is a prerequisite to success

526
00:20:59,580 --> 00:20:56,440
and don't say no to yourself let someone

527
00:21:00,870 --> 00:20:59,590
else say no yeah wise words thank you I

528
00:21:03,180 --> 00:21:00,880
was actually going to ask you about the

529
00:21:05,610 --> 00:21:03,190
overlap between starting and finishing a

530
00:21:07,650 --> 00:21:05,620
scientific project and starting and

531
00:21:10,320 --> 00:21:07,660
ending a climb of a mountain but you

532
00:21:13,530 --> 00:21:10,330
addressed that already a little bit yeah

533
00:21:15,650 --> 00:21:13,540
so yeah I like to dive it a little bit

534
00:21:18,780 --> 00:21:15,660
on the science a few more minutes before

535
00:21:22,710 --> 00:21:18,790
before I to share you with our audience

536
00:21:24,570 --> 00:21:22,720
in terms of the QA it's regarding again

537
00:21:27,150 --> 00:21:24,580
those these atmospheres of exoplanets

538
00:21:29,220 --> 00:21:27,160

are we at a stage now that we can

539
00:21:34,049 --> 00:21:29,230
actually measure the composition of air

540
00:21:36,480 --> 00:21:34,059
on other worlds not for planets like

541
00:21:39,480 --> 00:21:36,490
Earth we can do it for planets that are

542
00:21:42,480 --> 00:21:39,490
a bit bigger a little bit closer so a

543
00:21:46,350 --> 00:21:42,490
bit warmer so we have some measurements

544
00:21:48,600 --> 00:21:46,360
of GJ 1214b as atmosphere but these

545
00:21:50,880 --> 00:21:48,610
planets are you know maybe 500 Kelvin

546
00:21:54,090 --> 00:21:50,890
you know so that's a couple hundred

547
00:21:56,039 --> 00:21:54,100
degrees warmer than our planet so

548
00:21:58,740 --> 00:21:56,049
they're not they're not like earth yet

549
00:22:01,940 --> 00:21:58,750
so we're starting to be able to do this

550
00:22:04,380 --> 00:22:01,950
for bigger closer and warmer planets

551
00:22:06,930 --> 00:22:04,390
really with James Webb Space Telescope

552
00:22:09,360 --> 00:22:06,940
launched in 2021 that'll be the first

553
00:22:12,000 --> 00:22:09,370
pass of being able to do this for

554
00:22:12,539 --> 00:22:12,010
earth-like planets and even with James

555
00:22:13,529 --> 00:22:12,549
Webb

556
00:22:15,299 --> 00:22:13,539
we're only going to be able to

557
00:22:17,789 --> 00:22:15,309
characterize the atmospheres of a

558
00:22:19,019 --> 00:22:17,799
handful of planets not that many and so

559
00:22:21,419 --> 00:22:19,029
we're still not going to be able to have

560
00:22:24,209 --> 00:22:21,429
the statistical sample of planets that

561
00:22:27,389 --> 00:22:24,219
we ultimately would like which is why

562
00:22:31,199 --> 00:22:27,399
I'm also interested in these future

563
00:22:32,579 --> 00:22:31,209

missions like levar and and have exome

564
00:22:35,699 --> 00:22:32,589
and some of the other ones that are

565
00:22:38,339 --> 00:22:35,709
being proposed as at next stage where we

566
00:22:41,190 --> 00:22:38,349
can then start to detect hundreds

567
00:22:43,079 --> 00:22:41,200
planets atmospheres that are like earth

568
00:22:45,810 --> 00:22:43,089
so we're just getting there we're close

569
00:22:48,799 --> 00:22:45,820
but we're not there right yet there's

570
00:22:52,259 --> 00:22:48,809
the sequence James Webb Space Telescope

571
00:22:56,749 --> 00:22:52,269
move our fingers crossed and then have X

572
00:23:02,249 --> 00:23:00,119
new born have X are both proposals for

573
00:23:05,009 --> 00:23:02,259
that next telescope after all I said

574
00:23:08,369 --> 00:23:05,019
so James Webb is is gonna launch let's

575
00:23:11,940 --> 00:23:08,379
hope you know fingers crossed it's it's

576
00:23:15,209 --> 00:23:11,950
had a rocky rocky year but I think the

577
00:23:19,589 --> 00:23:15,219
launch date some marched 2021 if I

578
00:23:21,659 --> 00:23:19,599
remember and that will be really very

579
00:23:23,039 --> 00:23:21,669
exciting and I think we'll get a lot of

580
00:23:24,839 --> 00:23:23,049
exoplanet science out of it we'll be

581
00:23:26,129 --> 00:23:24,849
able to detect a lot of atmospheres but

582
00:23:29,489 --> 00:23:26,139
they might not be earth-like planet

583
00:23:31,499 --> 00:23:29,499
atmospheres and then so so really but we

584
00:23:33,329 --> 00:23:31,509
will be able to do a handful of

585
00:23:35,310 --> 00:23:33,339
earth-like planet atmospheres and we'll

586
00:23:38,339 --> 00:23:35,320
certainly prioritize some targets maybe

587
00:23:40,829 --> 00:23:38,349
like the traffice system planets which

588
00:23:43,499 --> 00:23:40,839

have been in the news a lot and we'll

589
00:23:46,289 --> 00:23:43,509
hopefully get some information about

590
00:23:48,060 --> 00:23:46,299
those those atmospheres but it'll be

591
00:23:50,819 --> 00:23:48,070
really follow-up missions that we'll be

592
00:23:52,499 --> 00:23:50,829
able to detect lots of planets and in

593
00:23:57,329 --> 00:23:52,509
any number that's more statistically

594
00:23:59,489 --> 00:23:57,339
relevant I'm gonna ask you one last

595
00:24:01,889 --> 00:23:59,499
question before I open it up to the

596
00:24:04,169 --> 00:24:01,899
audience and to my colleagues are

597
00:24:07,489 --> 00:24:04,179
working in the ether please channel the

598
00:24:09,839 --> 00:24:07,499
questions to my screen so I can see them

599
00:24:14,249 --> 00:24:09,849
do you think you'll have a chance in

600
00:24:18,089 --> 00:24:14,259
your career to contribute and actually

601
00:24:22,619 --> 00:24:18,099
detect life on other worlds I hope so I

602
00:24:24,209 --> 00:24:22,629
mean that's why I'm here I think at the

603
00:24:26,070 --> 00:24:24,219
you know it's kind of like anything they

604
00:24:28,290 --> 00:24:26,080
show you that graph of how

605
00:24:29,940 --> 00:24:28,300
you are you know and it buries in time

606
00:24:31,320 --> 00:24:29,950
and it's like you go from you know yeah

607
00:24:32,850 --> 00:24:31,330
I can totally do this to own it it's

608
00:24:34,860 --> 00:24:32,860
never gonna happen till I go maybe you

609
00:24:36,960 --> 00:24:34,870
know and I feel like I'm in the oh maybe

610
00:24:38,490 --> 00:24:36,970
part you know it's it's it's gonna be

611
00:24:41,310 --> 00:24:38,500
hard I think it's gonna be really hard

612
00:24:43,110 --> 00:24:41,320
to know you know and we're probably

613
00:24:45,720 --> 00:24:43,120

never gonna know with a hundred percent

614
00:24:48,570 --> 00:24:45,730
certainty we're gonna just try to get a

615
00:24:50,670 --> 00:24:48,580
statistical idea and and try to tick off

616
00:24:53,100 --> 00:24:50,680
all the boxes that we can think of that

617
00:24:55,380 --> 00:24:53,110
we know that could have produced those

618
00:24:57,180 --> 00:24:55,390
signatures without life but without

619
00:24:58,590 --> 00:24:57,190
absence of going to the planet or

620
00:25:00,480 --> 00:24:58,600
without getting some sort of steady

621
00:25:03,360 --> 00:25:00,490
intelligent like hello here we are

622
00:25:07,320 --> 00:25:03,370
signal it's gonna be really difficult to

623
00:25:09,150 --> 00:25:07,330
tell and and so I'm really excited about

624
00:25:10,830 --> 00:25:09,160
it I think it's absolutely a hundred

625
00:25:14,790 --> 00:25:10,840
percent worth dedicating all of my

626
00:25:17,220 --> 00:25:14,800
career to and I really hope that I get

627
00:25:19,830 --> 00:25:17,230
to be part of that in my lifetime I

628
00:25:22,680 --> 00:25:19,840
think it'll be you know a little you

629
00:25:25,380 --> 00:25:22,690
know the most optimistic is ten years

630
00:25:28,110 --> 00:25:25,390
that we find something pretty good I

631
00:25:31,080 --> 00:25:28,120
think I'd put more money on the sort of

632
00:25:32,940 --> 00:25:31,090
twenty five to forty year timeframe and

633
00:25:34,770 --> 00:25:32,950
if it's on the earlier side of that

634
00:25:37,020 --> 00:25:34,780
timeframe then I'll still probably be

635
00:25:39,600 --> 00:25:37,030
kicking around if it's like forty years

636
00:25:41,550 --> 00:25:39,610
from now I don't you know I'll also be

637
00:25:43,050 --> 00:25:41,560
alive but I don't know if I'll still be

638
00:25:46,760 --> 00:25:43,060

doing science we'll see

639
00:25:49,560 --> 00:25:46,770
Oh rubbish I've positive that you will

640
00:25:51,120 --> 00:25:49,570
enthusiasm is like oozing out of the

641
00:25:54,090 --> 00:25:51,130
screen right now you'll be doing science

642
00:25:56,040 --> 00:25:54,100
in 40 years all right it's time for the

643
00:25:59,850 --> 00:25:56,050
questions where my favorite part of the

644
00:26:02,790 --> 00:25:59,860
show the first questions are is from our

645
00:26:05,820 --> 00:26:02,800
user sleeping in react which comes from

646
00:26:08,030 --> 00:26:05,830
reddit and the person asks what do you

647
00:26:10,770 --> 00:26:08,040
think is a chance we could find

648
00:26:14,600 --> 00:26:10,780
multicellular life on another planet in

649
00:26:16,700 --> 00:26:14,610
our solar system in our solar system

650
00:26:20,850 --> 00:26:16,710
interesting what are the chance while I

651
00:26:25,440 --> 00:26:20,860
dia as far as like a number I do think

652
00:26:27,840 --> 00:26:25,450
going to Europa is very interesting

653
00:26:30,120 --> 00:26:27,850
because Europa has liquid water that's

654
00:26:31,950 --> 00:26:30,130
been stable on the surface or I mean

655
00:26:33,720 --> 00:26:31,960
under the subsurface of ice but

656
00:26:36,150 --> 00:26:33,730
interacting with rock and mineral

657
00:26:38,660 --> 00:26:36,160
gradients and hydrothermal vent type

658
00:26:42,170 --> 00:26:38,670
environments and so it's been how

659
00:26:43,520 --> 00:26:42,180
for you know four billion years it's

660
00:26:45,890 --> 00:26:43,530
very difficult to get to because it's

661
00:26:48,170 --> 00:26:45,900
under this huge you know 10 to 100

662
00:26:50,900 --> 00:26:48,180
kilometer thick ice layer how do we

663
00:26:52,580 --> 00:26:50,910

figure out if anything's under that ice

664
00:26:55,100 --> 00:26:52,590
and get that data back but I think you

665
00:26:59,090 --> 00:26:55,110
rope is a absolutely amazing place to

666
00:27:00,560 --> 00:26:59,100
look and on Mars I would assume probably

667
00:27:03,020 --> 00:27:00,570
the life is going to be more unicellular

668
00:27:05,600 --> 00:27:03,030
and subsurface we've been you know

669
00:27:08,840 --> 00:27:05,610
roaming around on the Martian surface

670
00:27:11,180 --> 00:27:08,850
and and even you know recently with with

671
00:27:13,130 --> 00:27:11,190
the death of our dear Rover friend on

672
00:27:14,960 --> 00:27:13,140
Mars but we you know there's no

673
00:27:17,000 --> 00:27:14,970
kangaroos bouncing around on Mars so

674
00:27:19,250 --> 00:27:17,010
it's a life is probably microbial and

675
00:27:21,440 --> 00:27:19,260
subsurface if it still exists today

676
00:27:24,680 --> 00:27:21,450
so for multicellular life I probably

677
00:27:28,310 --> 00:27:24,690
would go for Europa as as the most

678
00:27:32,930 --> 00:27:28,320
habitable place to look I think that

679
00:27:36,590 --> 00:27:32,940
would be Mike that as well next question

680
00:27:39,560 --> 00:27:36,600
is by Marian Denton on Twitter and she

681
00:27:41,390 --> 00:27:39,570
asks he as you know earth atmosphere has

682
00:27:43,610 --> 00:27:41,400
changed a lot by biology as a result of

683
00:27:45,040 --> 00:27:43,620
the great oxidation of it so she asks

684
00:27:47,810 --> 00:27:45,050
thinking about how cyanobacteria

685
00:27:50,390 --> 00:27:47,820
facilitate facilitated the goe by

686
00:27:55,040 --> 00:27:50,400
producing o2 and causing the extinction

687
00:27:57,830 --> 00:27:55,050
of many anaerobic microbes why would the

688
00:28:03,590 --> 00:27:57,840

atmosphere of a planet be if a goe

689
00:28:05,930 --> 00:28:03,600
situation never happens right so perhaps

690
00:28:08,200 --> 00:28:05,940
you just have a lot of nothing and then

691
00:28:11,660 --> 00:28:08,210
the the question is can you tease out

692
00:28:15,320 --> 00:28:11,670
say methane versus just methane produced

693
00:28:17,990 --> 00:28:15,330
from volcanism so methanogenesis is a

694
00:28:21,040 --> 00:28:18,000
pretty easy relatively easy metabolism

695
00:28:23,300 --> 00:28:21,050
it seems to arisen very quickly

696
00:28:25,880 --> 00:28:23,310
ultimately life tends to use the same

697
00:28:28,730 --> 00:28:25,890
redox energy gradients that also geology

698
00:28:32,420 --> 00:28:28,740
tends to use and and because life uses

699
00:28:34,130 --> 00:28:32,430
those same redox gradients those are

700
00:28:35,810 --> 00:28:34,140
also false positives because geology can

701
00:28:40,340 --> 00:28:35,820
use them so methane is a good example of

702
00:28:43,670 --> 00:28:40,350
this so on the other hand earth life

703
00:28:46,490 --> 00:28:43,680
produces you know 30 times the the

704
00:28:48,380 --> 00:28:46,500
amount of methane that that the planet

705
00:28:50,240 --> 00:28:48,390
just would otherwise produce so there's

706
00:28:52,279 --> 00:28:50,250
some thought to maybe if we were to

707
00:28:55,279 --> 00:28:52,289
detect

708
00:28:56,659 --> 00:28:55,289
enough methane and know more about the

709
00:28:58,909 --> 00:28:56,669
UV environment of the star and other

710
00:29:00,940 --> 00:28:58,919
indicators on the planet that we might

711
00:29:03,859 --> 00:29:00,950
be able to say maybe that planet has

712
00:29:06,799 --> 00:29:03,869
methanogenesis going on it but it is

713
00:29:13,129 --> 00:29:06,809

more difficult because that's a pathway

714
00:29:15,590 --> 00:29:13,139
that's also used by geology cool yeah

715
00:29:17,479 --> 00:29:15,600
among super exciting signs of the

716
00:29:21,220 --> 00:29:17,489
question the next is from Julia the

717
00:29:24,950 --> 00:29:21,230
marina's who's asking from Signet and

718
00:29:27,169 --> 00:29:24,960
she asks what are the best gas

719
00:29:30,440 --> 00:29:27,179
combinations to look for other than

720
00:29:31,210 --> 00:29:30,450
methane and oxygen right well that's

721
00:29:34,220 --> 00:29:31,220
difficult

722
00:29:36,470 --> 00:29:34,230
so best gas combinations there are some

723
00:29:38,989 --> 00:29:36,480
that are that have been proposed in it

724
00:29:41,590 --> 00:29:38,999
and I'm blanking on them now I'd have to

725
00:29:44,389 --> 00:29:41,600
send you an email Julia but I think

726
00:29:48,919 --> 00:29:44,399
there are some interesting single

727
00:29:50,749 --> 00:29:48,929
molecules that might be might be good

728
00:29:54,109 --> 00:29:50,759
strong guy signatures like methyl

729
00:29:56,029 --> 00:29:54,119
chloride and 2o has been put forward as

730
00:29:59,419 --> 00:29:56,039
a good bio signature however we're also

731
00:30:02,509 --> 00:29:59,429
finding ways of producing n2o from a

732
00:30:04,129 --> 00:30:02,519
biotic Lea methyl chloride at some of

733
00:30:06,590 --> 00:30:04,139
these other more niche molecules

734
00:30:09,680 --> 00:30:06,600
dimethyl sulfide they're produced in

735
00:30:12,139 --> 00:30:09,690
really small quantities so and often

736
00:30:14,779 --> 00:30:12,149
only by a single or a few microbes that

737
00:30:17,810 --> 00:30:14,789
produce them and so they that what is

738
00:30:19,070 --> 00:30:17,820

the chance that another you know planet

739
00:30:20,419 --> 00:30:19,080
with life would produce those same

740
00:30:24,859 --> 00:30:20,429
molecules because they're often very

741
00:30:27,320 --> 00:30:24,869
niche molecules is difficult to say and

742
00:30:29,239 --> 00:30:27,330
would they imprint the atmosphere would

743
00:30:30,590 --> 00:30:29,249
they be a big enough constituent of the

744
00:30:32,149 --> 00:30:30,600
atmosphere for us to look for them

745
00:30:34,369 --> 00:30:32,159
but I think that's absolutely worth

746
00:30:36,889 --> 00:30:34,379
checking out because those molecules are

747
00:30:38,810 --> 00:30:36,899
more uniquely identified with life so

748
00:30:40,970 --> 00:30:38,820
they'd be really strong by a signature

749
00:30:42,919 --> 00:30:40,980
but they might be harder to detect Sara

750
00:30:44,419 --> 00:30:42,929
Seager has some papers on this where

751
00:30:45,859 --> 00:30:44,429
she's looking at like all of the

752
00:30:47,960 --> 00:30:45,869
possible molecules that life could

753
00:30:49,489 --> 00:30:47,970
produce trying to disentangle which of

754
00:30:51,590 --> 00:30:49,499
them have jitta geological false

755
00:30:53,629 --> 00:30:51,600
positives or photochemical false

756
00:30:56,629 --> 00:30:53,639
positives which of them are produced by

757
00:30:57,470 --> 00:30:56,639
life which of them have spectra and all

758
00:30:59,960 --> 00:30:57,480
that stuff and it's something like

759
00:31:02,029 --> 00:30:59,970
sixteen thousand possible molecules that

760
00:31:04,909 --> 00:31:02,039
life might produce on an exoplanet and

761
00:31:05,930 --> 00:31:04,919
we have spectra 4.0 four percent of

762
00:31:08,240 --> 00:31:05,940
those molecule

763
00:31:11,570 --> 00:31:08,250

so there's a lot of work to do to even

764
00:31:13,820 --> 00:31:11,580
be able to detect molecules that are on

765
00:31:16,040 --> 00:31:13,830
exoplanets because we really only have a

766
00:31:17,720 --> 00:31:16,050
detailed spectra for not that many

767
00:31:21,040 --> 00:31:17,730
molecules kind of big ones that we think

768
00:31:25,370 --> 00:31:21,050
of co2 water you know we have a lot of

769
00:31:27,260 --> 00:31:25,380
you know ozone oxygen methane we have a

770
00:31:33,140 --> 00:31:27,270
lot of lines but to get lines for some

771
00:31:35,540 --> 00:31:33,150
of these more niche gases we need to do

772
00:31:37,250 --> 00:31:35,550
a lot of theoretical or laboratory work

773
00:31:40,070 --> 00:31:37,260
to get even though spectra to be able to

774
00:31:42,590 --> 00:31:40,080
detect them at an exoplanet it's worth

775
00:31:45,580 --> 00:31:42,600
mentioning that it is an extremely

776
00:31:48,440 --> 00:31:45,590
active area of research yessuh yeah yes

777
00:31:50,120 --> 00:31:48,450
are really important you know so and we

778
00:31:51,860 --> 00:31:50,130
need to fund that and this is something

779
00:31:53,090 --> 00:31:51,870
that I think we don't appreciate because

780
00:31:57,590 --> 00:31:53,100
we all use lineless

781
00:31:58,940 --> 00:31:57,600
and but it's not a sexy to fund line

782
00:32:00,890 --> 00:31:58,950
list you know because it's it's like

783
00:32:02,420 --> 00:32:00,900
this basic science and this is something

784
00:32:04,460 --> 00:32:02,430
I think we need to change it's just kind

785
00:32:06,380 --> 00:32:04,470
of a society where we fund more of this

786
00:32:09,170 --> 00:32:06,390
basic research which will have a lot of

787
00:32:12,110 --> 00:32:09,180
implications for the future but it's not

788
00:32:14,000 --> 00:32:12,120

like the it's not it's you know you see

789
00:32:15,860 --> 00:32:14,010
these proposals and it's like do you did

790
00:32:18,080 --> 00:32:15,870
choose the one that's like I'm gonna

791
00:32:20,150 --> 00:32:18,090
detect you know X number of planets or I

792
00:32:22,880 --> 00:32:20,160
need to make some line list and often

793
00:32:25,040 --> 00:32:22,890
that science gets not funded as much as

794
00:32:28,580 --> 00:32:25,050
it should and we all rely on that data

795
00:32:31,100 --> 00:32:28,590
so that that is becoming more echoed in

796
00:32:35,090 --> 00:32:31,110
our community and we're recognizing how

797
00:32:36,830 --> 00:32:35,100
even for you know Jupiter type planets

798
00:32:39,560 --> 00:32:36,840
like just having better methane lines

799
00:32:41,450 --> 00:32:39,570
really changes the observations and so

800
00:32:43,910 --> 00:32:41,460
we're starting to get that message and

801
00:32:49,160 --> 00:32:43,920
have more resources but we do need a lot

802
00:32:51,620 --> 00:32:49,170
more of that indeed I grew that next

803
00:32:55,010 --> 00:32:51,630
question is by Tom Caruso from Facebook

804
00:32:56,780 --> 00:32:55,020
and he firsts thanks you Sarah for the

805
00:33:00,200 --> 00:32:56,790
time and all the efforts you have done

806
00:33:02,690 --> 00:33:00,210
for women in stem in particular and his

807
00:33:06,340 --> 00:33:02,700
question is about remote ice-covered

808
00:33:10,630 --> 00:33:06,350
ocean worlds orbiting hot gas giants

809
00:33:13,150 --> 00:33:10,640
brown dwarf temperatures yeah and he is

810
00:33:16,970 --> 00:33:13,160
asking about is it possible to establish

811
00:33:18,990 --> 00:33:16,980
rough atmospheric parameters connected

812
00:33:21,250 --> 00:33:19,000
perhaps or the internal geology

813
00:33:22,990 --> 00:33:21,260

in an attempt to work with like

814
00:33:25,899 --> 00:33:23,000
instrument design or how can you tune

815
00:33:27,880 --> 00:33:25,909
instruments to detect us stuff that's

816
00:33:30,970 --> 00:33:27,890
interesting and those ice-covered ocean

817
00:33:34,450 --> 00:33:30,980
codes right so ice-covered ocean worlds

818
00:33:36,009 --> 00:33:34,460
have one of two main problems so ocean

819
00:33:38,200 --> 00:33:36,019
worlds in general even if they're not

820
00:33:40,389 --> 00:33:38,210
covered with ice have one problem which

821
00:33:43,029 --> 00:33:40,399
is often ignored by astronomers which is

822
00:33:44,080 --> 00:33:43,039
concentration mechanisms how do the

823
00:33:46,210 --> 00:33:44,090
molecules come together in

824
00:33:48,039 --> 00:33:46,220
concentrations that can create life

825
00:33:50,470 --> 00:33:48,049
that's something that is probably

826
00:33:52,389 --> 00:33:50,480
difficult but when you add also ice on

827
00:33:55,029 --> 00:33:52,399
top of it you're you're protected you

828
00:33:58,240 --> 00:33:55,039
press shielding a lot of that from the

829
00:33:59,560 --> 00:33:58,250
atmosphere so the only way we're going

830
00:34:02,649 --> 00:33:59,570
to be able to detect something as an

831
00:34:04,779 --> 00:34:02,659
exoplanet is if there's enough gas

832
00:34:07,480 --> 00:34:04,789
exchange between the atmosphere and the

833
00:34:10,629 --> 00:34:07,490
planet and life on the planet producing

834
00:34:13,240 --> 00:34:10,639
a lot of molecule and gas composition in

835
00:34:15,849 --> 00:34:13,250
the atmosphere so for something again I

836
00:34:17,859 --> 00:34:15,859
would go to our own solar system Europa

837
00:34:20,200 --> 00:34:17,869
is practically our next-door neighbor

838
00:34:22,899 --> 00:34:20,210

compared to anything else you know and

839
00:34:24,669 --> 00:34:22,909
we can't tell from here if your oppa has

840
00:34:27,430 --> 00:34:24,679
life on it we're gonna have to drill

841
00:34:29,020 --> 00:34:27,440
through you know this ice layer to

842
00:34:30,579 --> 00:34:29,030
detect it and we have orbiters flying

843
00:34:33,399 --> 00:34:30,589
around you're open we still can't tell

844
00:34:36,070 --> 00:34:33,409
so if there's life on on Europa so I

845
00:34:38,560 --> 00:34:36,080
really do think that these ice-covered

846
00:34:40,599 --> 00:34:38,570
ocean worlds as an exoplanet are

847
00:34:46,119 --> 00:34:40,609
probably not going to be targets that

848
00:34:48,399 --> 00:34:46,129
we're going to be able to to go for next

849
00:34:50,079 --> 00:34:48,409
to that the next question and we have a

850
00:34:51,849 --> 00:34:50,089
lot of them this is awesome

851
00:34:53,560 --> 00:34:51,859
thank you all for all these incredible

852
00:34:56,320 --> 00:34:53,570
questions the next question is from

853
00:34:58,630 --> 00:34:56,330
Alperin kaya who's our third-place

854
00:35:01,510 --> 00:34:58,640
winner for this month photo contest she

855
00:35:04,890 --> 00:35:01,520
asks how do we decide that a molecule is

856
00:35:07,510 --> 00:35:04,900
actually a bio signature yes so there's

857
00:35:09,760 --> 00:35:07,520
so one is it has to be produced by life

858
00:35:11,470 --> 00:35:09,770
I think that's that's that's clear but

859
00:35:12,970 --> 00:35:11,480
then we also want something that doesn't

860
00:35:16,780 --> 00:35:12,980
have a lot of geochemical false

861
00:35:19,420 --> 00:35:16,790
positives and or if they are geochemical

862
00:35:21,490 --> 00:35:19,430
false positives we want to know what

863
00:35:23,740 --> 00:35:21,500

other ways can meet what other gases can

864
00:35:26,650 --> 00:35:23,750
be used to discriminate whether this is

865
00:35:28,630 --> 00:35:26,660
a from life or not from life and and so

866
00:35:32,020 --> 00:35:28,640
as I mentioned from Sarah Spears work

867
00:35:35,550 --> 00:35:32,030
life produces literally tens

868
00:35:37,810 --> 00:35:35,560
thousands of molecules you know and so

869
00:35:39,670 --> 00:35:37,820
there's a couple of questions and when

870
00:35:41,920 --> 00:35:39,680
you see all of the molecules that life

871
00:35:43,690 --> 00:35:41,930
can produce well could it produce them

872
00:35:45,700 --> 00:35:43,700
in quantities that would leave a

873
00:35:47,170 --> 00:35:45,710
spectral imprint on the atmosphere for

874
00:35:49,090 --> 00:35:47,180
most of them the answer's no you know

875
00:35:50,890 --> 00:35:49,100
there's just not even if you had the

876
00:35:53,320 --> 00:35:50,900
entire planet covered with this microbe

877
00:35:54,760 --> 00:35:53,330
there wouldn't be enough of that gas in

878
00:35:57,460 --> 00:35:54,770
the atmosphere to leave a spectral

879
00:35:58,960 --> 00:35:57,470
fingerprint so you want to see is it

880
00:36:01,800 --> 00:35:58,970
stable in the atmosphere is the molecule

881
00:36:05,890 --> 00:36:01,810
stable is it gonna be in the atmosphere

882
00:36:09,280 --> 00:36:05,900
for a long time is it doesn't have other

883
00:36:11,650 --> 00:36:09,290
false positives and could we disentangle

884
00:36:14,770 --> 00:36:11,660
those false positives of false positives

885
00:36:17,140 --> 00:36:14,780
if it does so biosignatures are not

886
00:36:19,840 --> 00:36:17,150
necessarily 100% proofs of life

887
00:36:23,340 --> 00:36:19,850
but they have to be signs of life that

888
00:36:25,690 --> 00:36:23,350

were hopefully then through other gas

889
00:36:27,850 --> 00:36:25,700
combinations in the atmosphere have a

890
00:36:30,820 --> 00:36:27,860
more clear indication that yes that that

891
00:36:32,320 --> 00:36:30,830
is probably on earth the classic example

892
00:36:34,300 --> 00:36:32,330
would be like oxygen and methane as I

893
00:36:36,970 --> 00:36:34,310
already mentioned and 2o dimethyl

894
00:36:39,930 --> 00:36:36,980
chloride our methyl chloride and

895
00:36:43,420 --> 00:36:39,940
dimethyl sulfide these gases all are

896
00:36:47,710 --> 00:36:43,430
produced they have spectral fingerprints

897
00:36:51,940 --> 00:36:47,720
and we can tell that it's not geology so

898
00:36:54,610 --> 00:36:51,950
that's kind of the idea go the next one

899
00:36:57,310 --> 00:36:54,620
is from Elizabeth Hutton on Twitter and

900
00:36:59,320 --> 00:36:57,320
she's wondering what are the so what are

901
00:37:00,940 --> 00:36:59,330
some of the most pressing problems in

902
00:37:02,590 --> 00:37:00,950
bio signature detection I can give

903
00:37:04,570 --> 00:37:02,600
address a little bit of them and or

904
00:37:08,440 --> 00:37:04,580
early Earth modelling this early Earth

905
00:37:12,670 --> 00:37:08,450
is an exoplanet essentially right yeah I

906
00:37:14,380 --> 00:37:12,680
mean there's a number of I think

907
00:37:15,820 --> 00:37:14,390
exciting avenues of research I would say

908
00:37:18,820 --> 00:37:15,830
probably the most pressing problem is

909
00:37:20,730 --> 00:37:18,830
lineless right now to be honest that's I

910
00:37:25,300 --> 00:37:20,740
think it's a really important one I

911
00:37:27,160 --> 00:37:25,310
think also getting a better

912
00:37:29,650 --> 00:37:27,170
understanding of time dependence and

913
00:37:32,110 --> 00:37:29,660

flaring and activity of stars which is

914
00:37:34,150 --> 00:37:32,120
more my area I think is important so

915
00:37:36,100 --> 00:37:34,160
that might seem self-serving but I do

916
00:37:42,460 --> 00:37:36,110
think it's a it's an avenue of research

917
00:37:45,170 --> 00:37:42,470
that's important I I think yeah I would

918
00:37:47,960 --> 00:37:45,180
say probably those as well as just

919
00:37:52,099 --> 00:37:47,970
better understanding of false-positives

920
00:37:53,780 --> 00:37:52,109
mechanisms and our you know so how bad

921
00:37:55,490 --> 00:37:53,790
can you get like right now most of the

922
00:37:56,720 --> 00:37:55,500
false positive mechanisms have been for

923
00:37:58,609 --> 00:37:56,730
single gases that could you have a

924
00:38:02,780 --> 00:37:58,619
combination of gases produced in a

925
00:38:04,490 --> 00:38:02,790
positive way you know just can't what

926
00:38:06,589 --> 00:38:04,500
what's the worst case scenario you can

927
00:38:07,880 --> 00:38:06,599
envision that a planet it's producing

928
00:38:09,650 --> 00:38:07,890
something that looks like life but it's

929
00:38:11,480 --> 00:38:09,660
actually a vadik's so kind of teasing

930
00:38:13,640 --> 00:38:11,490
out more of that parameter space to see

931
00:38:15,020 --> 00:38:13,650
just to have a better handle on when we

932
00:38:16,730 --> 00:38:15,030
start launching these telescopes that

933
00:38:19,309 --> 00:38:16,740
can do this we're not going to be

934
00:38:21,829 --> 00:38:19,319
confused or fool ourselves by what we're

935
00:38:24,079 --> 00:38:21,839
seeing and then of course I think yeah

936
00:38:26,180 --> 00:38:24,089
just getting more of a handle on what

937
00:38:28,490 --> 00:38:26,190
other types of gases life could produce

938
00:38:30,500 --> 00:38:28,500

I think there's kind of two main

939
00:38:32,630 --> 00:38:30,510
questions in bio signatures there's the

940
00:38:34,760 --> 00:38:32,640
technological hurdle of just detecting

941
00:38:36,890 --> 00:38:34,770
these that's like one major hurdle can

942
00:38:39,680 --> 00:38:36,900
you detect oxygen whether it's from life

943
00:38:41,450 --> 00:38:39,690
or not in an exoplanet atmosphere that's

944
00:38:44,000 --> 00:38:41,460
one huge hurdle and then the second

945
00:38:45,829 --> 00:38:44,010
hurdle is can you tell if that is from

946
00:38:48,349 --> 00:38:45,839
life or not and those are kind of

947
00:38:50,569 --> 00:38:48,359
separate questions and some in some way

948
00:38:52,039 --> 00:38:50,579
and so I think we're a lot of the

949
00:38:53,780 --> 00:38:52,049
development right now is on the

950
00:38:55,700 --> 00:38:53,790
technological hurdle and a lot of the

951
00:38:57,109 --> 00:38:55,710
theoretical modeling from early earth

952
00:38:59,599 --> 00:38:57,119
atmosphere as well is trying to get a

953
00:39:01,520 --> 00:38:59,609
handle on the interpretation model

954
00:39:03,589 --> 00:39:01,530
simultaneously so that when we get to

955
00:39:07,750 --> 00:39:03,599
the ability of detecting these will will

956
00:39:10,370 --> 00:39:07,760
understand it better don't make sense

957
00:39:13,510 --> 00:39:10,380
yeah next question are quite like from

958
00:39:17,150 --> 00:39:13,520
Stanley Sario Donati on Facebook and

959
00:39:19,760 --> 00:39:17,160
they asked if there is any research you

960
00:39:24,559 --> 00:39:19,770
would like to do if you had unlimited

961
00:39:26,569 --> 00:39:24,569
funding unlimited time I mean if I had

962
00:39:29,240 --> 00:39:26,579
unlimited funding I would just go and

963
00:39:32,690 --> 00:39:29,250

fly something like TPS now you know or

964
00:39:34,339 --> 00:39:32,700
like Lubar or in a have X or Darwin or

965
00:39:36,470 --> 00:39:34,349
any of these missions I would just like

966
00:39:38,780 --> 00:39:36,480
take that you know twelve billion

967
00:39:42,859 --> 00:39:38,790
dollars yes thank you here let's go

968
00:39:45,410 --> 00:39:42,869
build this telescope if I could make 12

969
00:39:48,620 --> 00:39:45,420
billion dollars quickly and in a moral

970
00:39:50,480 --> 00:39:48,630
way that's responsible that's what I

971
00:39:51,559 --> 00:39:50,490
would do I'd like try to try to get this

972
00:39:57,020 --> 00:39:51,569
so we can actually have this answer

973
00:39:59,170 --> 00:39:57,030
sooner yeah I think so for the unlimited

974
00:40:01,059 --> 00:39:59,180
money that's what I would do I would

975
00:40:02,950 --> 00:40:01,069
I did build the best telescope possible

976
00:40:04,569 --> 00:40:02,960
because sometimes it's depressing when

977
00:40:06,280 --> 00:40:04,579
you look at national budgets and I think

978
00:40:08,380 --> 00:40:06,290
in Jim cassings book once there's this

979
00:40:10,960 --> 00:40:08,390
footnote and he says the entire budget

980
00:40:12,460 --> 00:40:10,970
for a TPF like this this telescope that

981
00:40:15,460 --> 00:40:12,470
could do like hundreds of these planets

982
00:40:18,400 --> 00:40:15,470
is two weeks of air conditioning during

983
00:40:22,839 --> 00:40:18,410
the Iraq war is what we spent you know

984
00:40:24,549 --> 00:40:22,849
so it's yeah it's sad you know so I mean

985
00:40:26,079 --> 00:40:24,559
these like they're expensive but they're

986
00:40:31,089 --> 00:40:26,089
not expensive if you know what I mean

987
00:40:33,490 --> 00:40:31,099
so I think that it would be great to get

988
00:40:36,520 --> 00:40:33,500

these telescopes actually funded and

989
00:40:37,720 --> 00:40:36,530
launched through through government

990
00:40:40,630 --> 00:40:37,730
through private sector however it works

991
00:40:42,549 --> 00:40:40,640
and and that would be if I had unlimited

992
00:40:45,579 --> 00:40:42,559
time if I had our unlimited money if I

993
00:40:47,200 --> 00:40:45,589
had unlimited time I guess I you know if

994
00:40:48,640 --> 00:40:47,210
I'd unlimited time I would probably also

995
00:40:50,410 --> 00:40:48,650
do more of my hobbies I would do more

996
00:40:52,359 --> 00:40:50,420
mountaineering some more dancing do some

997
00:40:54,180 --> 00:40:52,369
more writing and I'd probably do the

998
00:40:56,470 --> 00:40:54,190
same science you know because I think

999
00:40:59,620 --> 00:40:56,480
that's what makes me happy is having

1000
00:41:03,010 --> 00:40:59,630
kind of a full and life with lots of

1001
00:41:05,650 --> 00:41:03,020
different things going on in it and it

1002
00:41:07,990 --> 00:41:05,660
shows so assuming you have your 12

1003
00:41:10,390 --> 00:41:08,000
billion dollar mission it's flying the

1004
00:41:12,549 --> 00:41:10,400
next question from Jacob back misra on

1005
00:41:14,920 --> 00:41:12,559
twitter asks and you think of any

1006
00:41:16,630 --> 00:41:14,930
spectral biosignatures that would

1007
00:41:22,329 --> 00:41:16,640
uniquely indicate the presence of

1008
00:41:22,900 --> 00:41:22,339
complex life or the next planet hmm yeah

1009
00:41:26,109 --> 00:41:22,910
interesting

1010
00:41:28,900 --> 00:41:26,119
so there is this is not really a good

1011
00:41:30,309 --> 00:41:28,910
area of my area of expertise there are

1012
00:41:32,049 --> 00:41:30,319
some technical bio signatures that's

1013
00:41:34,450 --> 00:41:32,059

been a little more further afield like

1014
00:41:36,990 --> 00:41:34,460
signs of intelligent our civilization

1015
00:41:41,589 --> 00:41:37,000
life some people put forward like

1016
00:41:42,809 --> 00:41:41,599
chlorofluorocarbons you know and signs

1017
00:41:45,640 --> 00:41:42,819
like that

1018
00:41:49,480 --> 00:41:45,650
Dyson's but even like plants or fungi or

1019
00:41:51,670 --> 00:41:49,490
animals right yes for those I don't

1020
00:41:53,650 --> 00:41:51,680
really see I mean on earth it's like

1021
00:41:54,819 --> 00:41:53,660
mostly microbes you can't distinguish

1022
00:41:56,349 --> 00:41:54,829
like if you were to just look at Earth

1023
00:41:58,059 --> 00:41:56,359
you won't necessarily be able to tell

1024
00:42:00,069 --> 00:41:58,069
that there's human life here versus

1025
00:42:03,099 --> 00:42:00,079
there's microbial life can't think of

1026
00:42:06,069 --> 00:42:03,109
anything that's definitively you know

1027
00:42:07,630 --> 00:42:06,079
but between technological signatures and

1028
00:42:11,200 --> 00:42:07,640
just microbial life that would be a

1029
00:42:12,760 --> 00:42:11,210
unique bio signature other than I do

1030
00:42:14,320 --> 00:42:12,770
think there's some energy

1031
00:42:17,400 --> 00:42:14,330
arguments to be made that you have to

1032
00:42:20,740 --> 00:42:17,410
have oxygen so you just get so much more

1033
00:42:24,580 --> 00:42:20,750
energy from oxygen respiration than any

1034
00:42:26,640 --> 00:42:24,590
other redox gradient that that seems to

1035
00:42:30,280 --> 00:42:26,650
be a necessary precondition for

1036
00:42:31,240 --> 00:42:30,290
multicellular life and so that doesn't

1037
00:42:32,980 --> 00:42:31,250
answer the question because you would

1038
00:42:34,240 --> 00:42:32,990

have oxygen without multicellular life

1039
00:42:38,109 --> 00:42:34,250
as well because that comes from oxygen

1040
00:42:40,510 --> 00:42:38,119
exposure synthesis and from microbes so

1041
00:42:42,250 --> 00:42:40,520
I but I can't think of anything between

1042
00:42:43,590 --> 00:42:42,260
kind of going straight to like techno

1043
00:42:45,010 --> 00:42:43,600
bio signatures that would indicate

1044
00:42:48,310 --> 00:42:45,020
multicellular life

1045
00:42:50,830 --> 00:42:48,320
that's an interesting conclusion um

1046
00:42:53,740 --> 00:42:50,840
the next question is from Bruno pilotage

1047
00:42:55,960 --> 00:42:53,750
on cygnets and he asks is there an

1048
00:43:02,260 --> 00:42:55,970
online database with exoplanets and

1049
00:43:05,230 --> 00:43:02,270
their atmospheres spectra so for example

1050
00:43:07,240 --> 00:43:05,240
on my website I have all the structure

1051
00:43:09,040 --> 00:43:07,250
that I produced for my model so I have

1052
00:43:10,359 --> 00:43:09,050
grids of different types of earth-like

1053
00:43:12,150 --> 00:43:10,369
planets around different stars and

1054
00:43:14,560 --> 00:43:12,160
different time points in Earth's history

1055
00:43:17,070 --> 00:43:14,570
you can go download them play around

1056
00:43:20,099 --> 00:43:17,080
with them plot them on your computer

1057
00:43:24,910 --> 00:43:20,109
there's links to it on my professional

1058
00:43:30,790 --> 00:43:24,920
website so so that's easy to find and

1059
00:43:33,160 --> 00:43:30,800
and as far as other planets there's you

1060
00:43:34,570 --> 00:43:33,170
know a lot of the exoplanets dot-eu and

1061
00:43:36,760 --> 00:43:34,580
exoplanets like some of those main

1062
00:43:38,440 --> 00:43:36,770
exoplanet websites have a lot of the

1063
00:43:40,180 --> 00:43:38,450

parameters just for various known

1064
00:43:42,010 --> 00:43:40,190
exoplanet it's not necessarily their

1065
00:43:44,349 --> 00:43:42,020
atmospheres but you know mass radius

1066
00:43:49,330 --> 00:43:44,359
density kind of other things that you

1067
00:43:54,910 --> 00:43:52,330
next question is from Jim pass on

1068
00:43:56,980 --> 00:43:54,920
Twitter and I think it follows well

1069
00:43:59,710 --> 00:43:56,990
we've been discussing in what ways can

1070
00:44:04,810 --> 00:43:59,720
discovery the bio signatures lead to

1071
00:44:06,340 --> 00:44:04,820
those of TechKnow significance right so

1072
00:44:08,140 --> 00:44:06,350
yeah I'm not really an expert in techno

1073
00:44:10,599 --> 00:44:08,150
signatures I though I did download the

1074
00:44:11,590 --> 00:44:10,609
PDF on my computer to read that just

1075
00:44:17,859 --> 00:44:11,600
came out about Tessa

1076
00:44:19,840 --> 00:44:17,869
techno signatures I I think just being

1077
00:44:21,870 --> 00:44:19,850
able to discriminate so some you they're

1078
00:44:24,070 --> 00:44:21,880
gonna be the same sorts of fundamental

1079
00:44:26,690 --> 00:44:24,080
technological hurdles to do either and

1080
00:44:29,569 --> 00:44:26,700
we're gonna need high quality

1081
00:44:30,980 --> 00:44:29,579
line spectra to do either so one aspect

1082
00:44:33,740 --> 00:44:30,990
that we have talked about that I think

1083
00:44:36,740 --> 00:44:33,750
is really important is some of the high

1084
00:44:38,809 --> 00:44:36,750
resolution spectroscopy techniques and

1085
00:44:41,120 --> 00:44:38,819
being able to detect bio signatures from

1086
00:44:42,620 --> 00:44:41,130
the ground so earlier and up to this

1087
00:44:44,960 --> 00:44:42,630
point in the conversation we've only

1088
00:44:47,390 --> 00:44:44,970

focused on face space missions but you

1089
00:44:49,849 --> 00:44:47,400
can actually detect atmospheres from the

1090
00:44:51,799 --> 00:44:49,859
surface of earth with big ground-based

1091
00:44:54,130 --> 00:44:51,809
telescopes that are maybe 40 meters kind

1092
00:44:57,529 --> 00:44:54,140
of like the e-elt the extremely large

1093
00:44:59,660 --> 00:44:57,539
telescope that's by the Europeans so

1094
00:45:01,579 --> 00:44:59,670
that that telescope with a

1095
00:45:04,970 --> 00:45:01,589
high-resolution spectrometer can

1096
00:45:07,039 --> 00:45:04,980
actually see the Doppler shift of the

1097
00:45:09,980 --> 00:45:07,049
planet as it's going around its star so

1098
00:45:11,450 --> 00:45:09,990
the lines and it can tease out Earth's

1099
00:45:13,309 --> 00:45:11,460
atmosphere so Earth's atmosphere

1100
00:45:15,109 --> 00:45:13,319
effectively we're just looking through

1101
00:45:16,519 --> 00:45:15,119
our column of atmosphere and then it's

1102
00:45:19,609 --> 00:45:16,529
looking at that exoplanet and that

1103
00:45:21,470 --> 00:45:19,619
exoplanets moving compared to us and so

1104
00:45:22,819 --> 00:45:21,480
you can see even if you are looking

1105
00:45:25,099 --> 00:45:22,829
through all of our atmosphere you can

1106
00:45:26,539 --> 00:45:25,109
see it still see oxygen and that

1107
00:45:29,599 --> 00:45:26,549
exoplanet atmosphere because you see

1108
00:45:32,390 --> 00:45:29,609
those oxygen lines going back and forth

1109
00:45:34,609 --> 00:45:32,400
like a Doppler shift you know like a

1110
00:45:36,079 --> 00:45:34,619
siren engine you know and it's pitch

1111
00:45:38,210 --> 00:45:36,089
changing you see the same thing with

1112
00:45:39,920 --> 00:45:38,220
these lines and I think that's really

1113
00:45:42,140 --> 00:45:39,930

exciting so by taking high resolution

1114
00:45:45,920 --> 00:45:42,150
from the ground we can get through our

1115
00:45:48,740 --> 00:45:45,930
own atmosphere and see the Doppler shift

1116
00:45:51,170 --> 00:45:48,750
of atmospheric lines around exoplanets

1117
00:45:54,920 --> 00:45:51,180
for even earth sized temperate

1118
00:45:57,319 --> 00:45:54,930
exoplanets and and not only that the

1119
00:45:59,509 --> 00:45:57,329
thing that like blew my mind the most in

1120
00:46:03,109 --> 00:45:59,519
the last year was you can detect

1121
00:46:06,680 --> 00:46:03,119
isotopes isotopes in the atmosphere of

1122
00:46:08,390 --> 00:46:06,690
an exoplanet and and that just never did

1123
00:46:10,789 --> 00:46:08,400
I think that that would be possible so

1124
00:46:16,430 --> 00:46:10,799
you can detect things like H do instead

1125
00:46:18,259 --> 00:46:16,440
of h2o or c-13 know instead of Co in an

1126
00:46:21,740 --> 00:46:18,269
exoplanet and there's some great papers

1127
00:46:22,819 --> 00:46:21,750
by Paul Moliere and Ignace Snellen which

1128
00:46:26,420 --> 00:46:22,829
I'd recommend if people are interested

1129
00:46:28,450 --> 00:46:26,430
in that and so for techno signatures

1130
00:46:30,859 --> 00:46:28,460
often these molecules they're probably

1131
00:46:32,059 --> 00:46:30,869
not going to be huge imprints in the

1132
00:46:34,309 --> 00:46:32,069
atmosphere if you look at Earth's own

1133
00:46:35,900 --> 00:46:34,319
atmospheres us as humans

1134
00:46:38,900 --> 00:46:35,910
we're influenced and of course the

1135
00:46:40,520 --> 00:46:38,910
atmosphere with co2 however co2 is also

1136
00:46:42,200 --> 00:46:40,530
produced naturally so that wouldn't be

1137
00:46:43,400 --> 00:46:42,210
unique sign of Technology right so

1138
00:46:45,410 --> 00:46:43,410

you're looking for these more niche

1139
00:46:47,630 --> 00:46:45,420
molecules you'll need a lot of good

1140
00:46:50,210 --> 00:46:47,640
resolution spectra and I think maybe

1141
00:46:51,770 --> 00:46:50,220
high resolution spectroscopy from the

1142
00:46:54,260 --> 00:46:51,780
ground is going to be the way to detect

1143
00:46:55,520 --> 00:46:54,270
those that would be my guess so it's

1144
00:46:58,370 --> 00:46:55,530
essentially an engineering problem at

1145
00:47:01,250 --> 00:46:58,380
this point yeah yeah and also kind of

1146
00:47:03,650 --> 00:47:01,260
imagining like we you know we thought

1147
00:47:05,750 --> 00:47:03,660
with study that radio waves are the the

1148
00:47:07,610 --> 00:47:05,760
big deal right because you know we've

1149
00:47:09,860 --> 00:47:07,620
produced radio waves and abundance they

1150
00:47:11,870 --> 00:47:09,870
travel very far but now most of our

1151
00:47:13,760 --> 00:47:11,880
communications are going in five rocky

1152
00:47:15,170 --> 00:47:13,770
cables under the ocean you know we're

1153
00:47:16,850 --> 00:47:15,180
not even producing a lot of those

1154
00:47:19,910 --> 00:47:16,860
anymore so I think it's hard to predict

1155
00:47:22,640 --> 00:47:19,920
what a technological civilization will

1156
00:47:24,140 --> 00:47:22,650
be producing would be the other thing

1157
00:47:25,580 --> 00:47:24,150
but if you if we have enough

1158
00:47:27,140 --> 00:47:25,590
high-resolution spectra of these

1159
00:47:29,060 --> 00:47:27,150
different molecules and we see something

1160
00:47:31,760 --> 00:47:29,070
really bizarre you know that's just like

1161
00:47:33,470 --> 00:47:31,770
oh that's not yeah that's not a molecule

1162
00:47:35,840 --> 00:47:33,480
you get in anything you know from

1163
00:47:38,120 --> 00:47:35,850

chemistry then then that could be an

1164
00:47:40,640 --> 00:47:38,130
interesting follow up right maybe a

1165
00:47:45,140 --> 00:47:40,650
civilization is only know emitting for a

1166
00:47:46,850 --> 00:47:45,150
short period of their life stem or

1167
00:47:49,010 --> 00:47:46,860
they're then doing entirely different

1168
00:47:51,020 --> 00:47:49,020
things that were we're really it's it's

1169
00:47:53,930 --> 00:47:51,030
we're kind of necessarily hamstrung by

1170
00:47:55,340 --> 00:47:53,940
our own experience you know and and so

1171
00:47:58,610 --> 00:47:55,350
we first have to look for things that we

1172
00:48:00,620 --> 00:47:58,620
can recognize before we get like warp

1173
00:48:02,660 --> 00:48:00,630
drive and a Starship Enterprise and we

1174
00:48:04,760 --> 00:48:02,670
can just like jump around and see the

1175
00:48:07,010 --> 00:48:04,770
whole you know galaxies and start really

1176
00:48:10,730 --> 00:48:07,020
exploring in that way we're kind of

1177
00:48:13,070 --> 00:48:10,740
limited to trying to tease out what we

1178
00:48:14,990 --> 00:48:13,080
could detect which is inherently going

1179
00:48:16,940 --> 00:48:15,000
to be more similar to earth in that a

1180
00:48:18,890 --> 00:48:16,950
more carbon-based biochemistry so to

1181
00:48:22,130 --> 00:48:18,900
speak stuff like that I'm glad you

1182
00:48:25,280 --> 00:48:22,140
brought up enterprise because this month

1183
00:48:28,970 --> 00:48:25,290
we had a faithful little spaceship from

1184
00:48:32,660 --> 00:48:28,980
our dear little opportunity that after

1185
00:48:35,150 --> 00:48:32,670
14 years of hard work did not call home

1186
00:48:37,780 --> 00:48:35,160
after being covered by dust it was very

1187
00:48:39,980 --> 00:48:37,790
sad perhaps you can talk about the

1188
00:48:42,260 --> 00:48:39,990

importance of such missions to like

1189
00:48:45,140 --> 00:48:42,270
inspire the scientific community to like

1190
00:48:47,390 --> 00:48:45,150
trigger new questions as we take 30

1191
00:48:50,900 --> 00:48:47,400
seconds to or remember a little obvious

1192
00:48:53,220 --> 00:48:50,910
I know I'm I'm really sad

1193
00:48:53,970 --> 00:48:53,230
had a good run better run

1194
00:48:56,120 --> 00:48:53,980
one could have thought I think

1195
00:48:59,940 --> 00:48:56,130
commission lifetime was what 90 days

1196
00:49:02,840 --> 00:48:59,950
later I loved the cartoons that people

1197
00:49:07,440 --> 00:49:02,850
made about it but yeah no I mean I think

1198
00:49:08,550 --> 00:49:07,450
especially for astrobiology there's so

1199
00:49:09,900 --> 00:49:08,560
many different avenues that are

1200
00:49:11,190 --> 00:49:09,910
interesting which is why you should all

1201
00:49:13,290 --> 00:49:11,200
go into astrobiology because you can go

1202
00:49:15,240 --> 00:49:13,300
from any direction from provided

1203
00:49:18,210 --> 00:49:15,250
chemistry biology whatnot and it's all

1204
00:49:19,560 --> 00:49:18,220
fascinating and when I think about it

1205
00:49:21,180 --> 00:49:19,570
from a planetary perspective there's

1206
00:49:22,740 --> 00:49:21,190
exoplanets which is cool but then

1207
00:49:24,270 --> 00:49:22,750
there's solar system planets which are

1208
00:49:26,849 --> 00:49:24,280
also awesome and those are the ones that

1209
00:49:29,550 --> 00:49:26,859
we can actually go and visit and you

1210
00:49:31,620 --> 00:49:29,560
know actually find out does Mars have

1211
00:49:32,849 --> 00:49:31,630
life on it today or did it have it in

1212
00:49:34,470 --> 00:49:32,859
the past the only way we're going to

1213
00:49:37,470 --> 00:49:34,480

know is by going there because it's not

1214
00:49:39,599 --> 00:49:37,480
Mars is not a global atmospheric bio

1215
00:49:43,080 --> 00:49:39,609
signature case right we would have known

1216
00:49:45,870 --> 00:49:43,090
that by now already so so the only way

1217
00:49:49,200 --> 00:49:45,880
to find that out is to go there to drill

1218
00:49:50,790 --> 00:49:49,210
you know to figure out what's happening

1219
00:49:51,240 --> 00:49:50,800
on the planet and I really hope we do

1220
00:49:55,440 --> 00:49:51,250
that

1221
00:49:57,660 --> 00:49:55,450
my personal you know pitch to Elon Musk

1222
00:49:59,550 --> 00:49:57,670
should he be listening is please don't

1223
00:50:02,000 --> 00:49:59,560
send humans before we've answered this

1224
00:50:05,250 --> 00:50:02,010
question and before we've ever coldly

1225
00:50:07,170 --> 00:50:05,260
contaminated the planet I know that we

1226
00:50:08,910 --> 00:50:07,180
need to be multiplanetary at some point

1227
00:50:12,590 --> 00:50:08,920
but we have one chance not to screw up

1228
00:50:15,840 --> 00:50:12,600
Mars let's not screw it up please please

1229
00:50:17,849 --> 00:50:15,850
okay yeah I think we are we're further

1230
00:50:19,980 --> 00:50:17,859
ahead in the engineering of space

1231
00:50:21,270 --> 00:50:19,990
exploration than we are in sociology and

1232
00:50:23,340 --> 00:50:21,280
ethics and space exploration

1233
00:50:25,740 --> 00:50:23,350
I know and I like if I have ten minutes

1234
00:50:28,560 --> 00:50:25,750
with Elon that is gonna be that it's

1235
00:50:30,330 --> 00:50:28,570
gonna be my pitch you know should I ever

1236
00:50:32,970 --> 00:50:30,340
get that opportunity but yes so I do

1237
00:50:35,130 --> 00:50:32,980
think going to these solar system like

1238
00:50:37,800 --> 00:50:35,140

solar system science is amazing not for

1239
00:50:39,300 --> 00:50:37,810
just detecting is there life then you

1240
00:50:41,070 --> 00:50:39,310
can maybe answer is it a secondary

1241
00:50:42,720 --> 00:50:41,080
origin or it was it transported from

1242
00:50:44,490 --> 00:50:42,730
Earth that's also interesting I think

1243
00:50:46,590 --> 00:50:44,500
secondary origin to me is the most

1244
00:50:49,530 --> 00:50:46,600
exciting but also planetary transfer is

1245
00:50:51,420 --> 00:50:49,540
super exciting too and then say you find

1246
00:50:54,090 --> 00:50:51,430
life and Titan you know unlike the

1247
00:50:56,450 --> 00:50:54,100
liquid methane lakes of Titan that's

1248
00:50:59,130 --> 00:50:56,460
like an entirely different

1249
00:51:00,390 --> 00:50:59,140
biochemistry than Earth so the only way

1250
00:51:03,270 --> 00:51:00,400
that we're going to be able to

1251
00:51:05,970 --> 00:51:03,280
understand different biochemistry from

1252
00:51:06,520 --> 00:51:05,980
Earth for an exoplanet is to kind of get

1253
00:51:08,080 --> 00:51:06,530
a handle

1254
00:51:09,520 --> 00:51:08,090
of them on a place that we can

1255
00:51:11,350 --> 00:51:09,530
understand more either in the lab

1256
00:51:13,780 --> 00:51:11,360
through synthetic biology or like in

1257
00:51:15,790 --> 00:51:13,790
Titan to see them in real life if they

1258
00:51:17,800 --> 00:51:15,800
exist so I think solar system

1259
00:51:20,320 --> 00:51:17,810
exploration is immensely important for

1260
00:51:22,360 --> 00:51:20,330
figuring out kind of more of the unknown

1261
00:51:25,260 --> 00:51:22,370
unknowns that we don't even know you

1262
00:51:28,590 --> 00:51:25,270
know from our limited viewpoint on earth

1263
00:51:32,320 --> 00:51:28,600

the only way to start addressing those

1264
00:51:33,820 --> 00:51:32,330
is in part by going to the solar system

1265
00:51:38,110 --> 00:51:33,830
and looking at places like Enceladus

1266
00:51:41,380 --> 00:51:38,120
Europa Titan Mars and and I think all of

1267
00:51:44,800 --> 00:51:41,390
that is equally also exciting you know

1268
00:51:48,010 --> 00:51:44,810
so yeah I don't know sigh solar system

1269
00:51:50,620 --> 00:51:48,020
is full of opportunities yeah pardon

1270
00:51:53,950 --> 00:51:50,630
pardon the pun um the next question is

1271
00:51:57,580 --> 00:51:53,960
from mr. David time tunnel

1272
00:51:59,560 --> 00:51:57,590
on Twitter and he asks do you think we

1273
00:52:01,540 --> 00:51:59,570
might be able to capture an asteroid to

1274
00:52:04,090 --> 00:52:01,550
put into orbit around Earth as a new

1275
00:52:05,550 --> 00:52:04,100
moon is that possible is that likely is

1276
00:52:09,310 --> 00:52:05,560
that just plain silly

1277
00:52:13,060 --> 00:52:09,320
what do you think well so asteroid

1278
00:52:14,470 --> 00:52:13,070
capture I mean I think at some point

1279
00:52:18,250 --> 00:52:14,480
we're gonna be able to move asteroids

1280
00:52:20,500 --> 00:52:18,260
and go to visit asteroids as humans and

1281
00:52:22,690 --> 00:52:20,510
maybe even do asteroid mining you know

1282
00:52:24,580 --> 00:52:22,700
and and one of the main reasons for that

1283
00:52:26,740 --> 00:52:24,590
is because they're undifferentiated so

1284
00:52:29,830 --> 00:52:26,750
more of the rare earth metals that have

1285
00:52:31,720 --> 00:52:29,840
sunk to our core are still in much

1286
00:52:33,760 --> 00:52:31,730
higher abundances on asteroids so that's

1287
00:52:37,120 --> 00:52:33,770
like the economic reason I think we'll

1288
00:52:38,650 --> 00:52:37,130

have the technology to do that I don't

1289
00:52:39,820 --> 00:52:38,660
think you know we want to create like

1290
00:52:41,410 --> 00:52:39,830
well we're not going to like move

1291
00:52:44,380 --> 00:52:41,420
another moon sized object I mean the

1292
00:52:46,210 --> 00:52:44,390
moon is huge for our earth for stuff but

1293
00:52:47,650 --> 00:52:46,220
I do think we can probably nudge some

1294
00:52:49,660 --> 00:52:47,660
asteroids and also I think it's kind of

1295
00:52:50,890 --> 00:52:49,670
important going back to the at some

1296
00:52:53,080 --> 00:52:50,900
point it would be good to be

1297
00:52:55,090 --> 00:52:53,090
multiplanetary just hopefully not before

1298
00:52:59,470 --> 00:52:55,100
we've adequately scientifically probed

1299
00:53:02,500 --> 00:52:59,480
Mars a huge asteroid impact is still an

1300
00:53:04,990 --> 00:53:02,510
existential threat that we don't we

1301
00:53:07,870 --> 00:53:05,000
don't really have the technology yet to

1302
00:53:09,100 --> 00:53:07,880
avert that crisis should it happen we

1303
00:53:11,070 --> 00:53:09,110
would have to know about that asteroid

1304
00:53:13,690 --> 00:53:11,080
really really far in advance and and

1305
00:53:15,970 --> 00:53:13,700
build a nudge it from a very far orbit

1306
00:53:18,490 --> 00:53:15,980
in order to prevent it from from hitting

1307
00:53:20,180 --> 00:53:18,500
Earth you know kind of the Armageddon

1308
00:53:24,170 --> 00:53:20,190
sort of movie scenario

1309
00:53:25,460 --> 00:53:24,180
is unlikely so so I think that this is

1310
00:53:28,460 --> 00:53:25,470
something that we should devote some

1311
00:53:32,569 --> 00:53:28,470
resources and to doing just to help our

1312
00:53:35,089 --> 00:53:32,579
own you know avoid catastrophe and

1313
00:53:36,349 --> 00:53:35,099

extinction the chance of that is low but

1314
00:53:38,329 --> 00:53:36,359
I think we should spend some time on

1315
00:53:41,900 --> 00:53:38,339
that and in doing so I'm sure we'll be

1316
00:53:43,640 --> 00:53:41,910
manipulating these asteroids thanks yeah

1317
00:53:46,220 --> 00:53:43,650
I think it's a promising future for

1318
00:53:48,079 --> 00:53:46,230
Humanity to take advantage of the the

1319
00:53:52,220 --> 00:53:48,089
resources that are and are in our solar

1320
00:53:54,440 --> 00:53:52,230
system absolutely big plug can I just

1321
00:53:55,760 --> 00:53:54,450
say big plug to the expanse series if

1322
00:53:58,490 --> 00:53:55,770
you have not watched the expanse series

1323
00:54:00,890 --> 00:53:58,500
and anyone watching that's like wow so

1324
00:54:02,120 --> 00:54:00,900
good just gets better and better give it

1325
00:54:03,289 --> 00:54:02,130
the first 4 or 5 episodes because

1326
00:54:07,779 --> 00:54:03,299
they're kind of slow and then it just

1327
00:54:10,010 --> 00:54:07,789
takes off all right good play good plug

1328
00:54:12,140 --> 00:54:10,020
next question is by richard gordon on

1329
00:54:14,420 --> 00:54:12,150
sega nets and you asked more about the

1330
00:54:16,490 --> 00:54:14,430
scientific process of getting data back

1331
00:54:19,490 --> 00:54:16,500
from telescopes how is it decided who

1332
00:54:20,930 --> 00:54:19,500
gets to analyze the data the spectra

1333
00:54:25,490 --> 00:54:20,940
that comes back from those space

1334
00:54:27,740 --> 00:54:25,500
telescopes so typically what happens is

1335
00:54:30,370 --> 00:54:27,750
we put in telescope observing proposals

1336
00:54:34,339 --> 00:54:30,380
for these space telescopes time

1337
00:54:37,210 --> 00:54:34,349
something like well if you look at the

1338
00:54:40,819 --> 00:54:37,220

cost of the mission right and and then

1339
00:54:42,799 --> 00:54:40,829
average average that over its time in

1340
00:54:46,130 --> 00:54:42,809
the mission lifetime it's about a dollar

1341
00:54:48,859 --> 00:54:46,140
a second so it's very very pricey so you

1342
00:54:51,380 --> 00:54:48,869
have to competitively petition for that

1343
00:54:52,910 --> 00:54:51,390
time you know so you're not paying that

1344
00:54:54,079 --> 00:54:52,920
that was already funded in the launch

1345
00:54:55,970 --> 00:54:54,089
out of it and whatnot

1346
00:54:59,299 --> 00:54:55,980
but the the point is that they're very

1347
00:55:01,190 --> 00:54:59,309
competitive the these missions so you

1348
00:55:02,930 --> 00:55:01,200
probably only roughly ten percent of

1349
00:55:04,640 --> 00:55:02,940
telescope proposals are accepted you

1350
00:55:05,809 --> 00:55:04,650
propose to look at a certain target you

1351
00:55:08,390 --> 00:55:05,819
give a good science case you tell

1352
00:55:09,920 --> 00:55:08,400
exactly how long we need to observe it

1353
00:55:13,370 --> 00:55:09,930
to get the science out that we want and

1354
00:55:16,069 --> 00:55:13,380
then if your proposal is accepted you

1355
00:55:17,660 --> 00:55:16,079
get proprietary access to that data for

1356
00:55:20,510 --> 00:55:17,670
a period of time before it becomes

1357
00:55:22,490 --> 00:55:20,520
public data and so you can then write

1358
00:55:25,130 --> 00:55:22,500
your paper on it or or use that and

1359
00:55:27,170 --> 00:55:25,140
study it so I am a theorist so I don't

1360
00:55:31,010 --> 00:55:27,180
do this myself but I am a kowai on

1361
00:55:32,870 --> 00:55:31,020
several successful Hubble proposals and

1362
00:55:33,890 --> 00:55:32,880
and that's essentially what happens is

1363
00:55:38,210 --> 00:55:33,900

you have

1364
00:55:40,280 --> 00:55:38,220
data and you can analyze it and then you

1365
00:55:42,230 --> 00:55:40,290
publish it and then it gets released at

1366
00:55:44,660 --> 00:55:42,240
some point it's all archived so you can

1367
00:55:45,350 --> 00:55:44,670
go on NASA's website and look at you

1368
00:55:47,180 --> 00:55:45,360
know the iue

1369
00:55:49,880 --> 00:55:47,190
which is a satellite that I use a lot

1370
00:55:51,650 --> 00:55:49,890
that's that's all archive data you can

1371
00:55:55,010 --> 00:55:51,660
go you can download it you can plot it

1372
00:55:58,340 --> 00:55:55,020
you can have fun with it cool thank you

1373
00:56:00,340 --> 00:55:58,350
for that so we're really close at our

1374
00:56:03,200 --> 00:56:00,350
mark Sarah it's been an absolute joy

1375
00:56:04,760 --> 00:56:03,210
perhaps like I'd like to close this this

1376
00:56:06,650 --> 00:56:04,770
this beautiful interview with perhaps

1377
00:56:09,320 --> 00:56:06,660
you have some some final thoughts on

1378
00:56:11,030 --> 00:56:09,330
perhaps to our youngest audience and how

1379
00:56:13,910 --> 00:56:11,040
to get involved in astrobiology in the

1380
00:56:16,190 --> 00:56:13,920
first place right so don't do what I did

1381
00:56:18,680 --> 00:56:16,200
which is not take a breath of science

1382
00:56:20,060 --> 00:56:18,690
courses I didn't take a single astronomy

1383
00:56:22,640 --> 00:56:20,070
course for example and I didn't take a

1384
00:56:24,620 --> 00:56:22,650
lot of chemistry and and I think that if

1385
00:56:26,990 --> 00:56:24,630
I could go back in time I would take

1386
00:56:30,160 --> 00:56:27,000
more of everything you know I would take

1387
00:56:35,360 --> 00:56:30,170
more geology more chemistry more biology

1388
00:56:37,730 --> 00:56:35,370

and just realize that science is it

1389
00:56:39,440 --> 00:56:37,740
doesn't have these barriers that we put

1390
00:56:40,850 --> 00:56:39,450
in it between these disciplines like

1391
00:56:42,680 --> 00:56:40,860
most of the interesting science is

1392
00:56:44,060 --> 00:56:42,690
happening at the intersections of these

1393
00:56:47,270 --> 00:56:44,070
borders and biochemistry and

1394
00:56:48,680 --> 00:56:47,280
astrobiology as being the you know the

1395
00:56:50,330 --> 00:56:48,690
quintessential I think example of

1396
00:56:53,570 --> 00:56:50,340
combining all of the sciences together

1397
00:56:55,570 --> 00:56:53,580
so I think as a as a young scientist

1398
00:56:58,010 --> 00:56:55,580
starting out wanting to do astrobiology

1399
00:57:00,970 --> 00:56:58,020
while I'm sure there's a certain area

1400
00:57:03,320 --> 00:57:00,980
that interests you and pursue that area

1401
00:57:05,810 --> 00:57:03,330
try not to do what I did which is say oh

1402
00:57:07,730 --> 00:57:05,820
but squiggly lines are boring and ignore

1403
00:57:09,740 --> 00:57:07,740
everything to do with astronomy as a

1404
00:57:11,210 --> 00:57:09,750
result and then feel completely out of

1405
00:57:14,000 --> 00:57:11,220
place when you decide that's what you

1406
00:57:17,420 --> 00:57:14,010
want to do so take just a breadth of

1407
00:57:20,270 --> 00:57:17,430
science courses I recommend I really do

1408
00:57:22,100 --> 00:57:20,280
like Genesis the scientific quest for

1409
00:57:23,750 --> 00:57:22,110
life's origins by Bob Hazen he also has

1410
00:57:26,960 --> 00:57:23,760
some other books like story of Earth and

1411
00:57:29,200 --> 00:57:26,970
and just read about all the yeah a lot

1412
00:57:32,120 --> 00:57:29,210
of the cool astrobiology

1413
00:57:35,930 --> 00:57:32,130

sort of broad survey books that have

1414
00:57:38,330 --> 00:57:35,940
come out and yeah go into it it's so

1415
00:57:42,170 --> 00:57:38,340
exciting I will I just have never looked

1416
00:57:45,020 --> 00:57:42,180
back it's been an amazing time a destiny

1417
00:57:47,390 --> 00:57:45,030
but I think it's a wonderful foot place

1418
00:57:48,829 --> 00:57:47,400
to to close his interview Sarah for

1419
00:57:50,510 --> 00:57:48,839
personal perspective it was just an

1420
00:57:52,130 --> 00:57:50,520
incredible adventure having this

1421
00:57:53,870 --> 00:57:52,140
conversation with you we went through so

1422
00:57:55,549 --> 00:57:53,880
many topics everything was fascinating I

1423
00:57:57,890 --> 00:57:55,559
hope those of you who are watching had a

1424
00:57:59,900 --> 00:57:57,900
similar good experience don't forget to

1425
00:58:02,750 --> 00:57:59,910
tune in next month for ask an

1426
00:58:04,789 --> 00:58:02,760
astrobiologists don't forget yes what is

1427
00:58:06,589 --> 00:58:04,799
the picture behind me until then

1428
00:58:07,210 --> 00:58:06,599
everybody stay curious