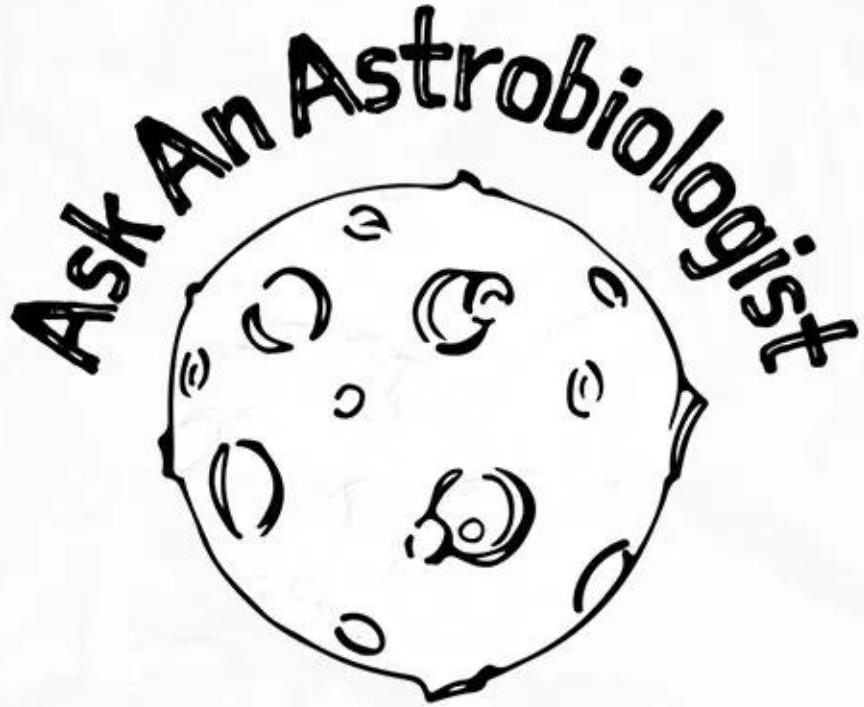

Episode 12: March 20th, 2018

Dr. Shawn Domagal-Goldman

NASA Astrobiology Program

1
00:00:00,500 --> 00:00:29,320
[Music]

2
00:00:33,950 --> 00:00:31,609
greetings friends of astrobiology and

3
00:00:35,959 --> 00:00:33,960
welcome to a brand new episode of ask an

4
00:00:38,479 --> 00:00:35,969
astrobiologist a show where we celebrate

5
00:00:39,950 --> 00:00:38,489
science and celebrate scientists my name

6
00:00:42,020 --> 00:00:39,960
is Sandra um and this program is made

7
00:00:44,810 --> 00:00:42,030
possible by contributions from the NASA

8
00:00:46,580 --> 00:00:44,820
Astrobiology program Elsi the earth Life

9
00:00:49,010 --> 00:00:46,590
Science Institute at Tokyo Tech and the

10
00:00:50,500 --> 00:00:49,020
nonprofit blue bubble space today we're

11
00:00:53,090 --> 00:00:50,510
absolutely delighted to welcome

12
00:00:56,000 --> 00:00:53,100
astrobiologist extraordinaire dr. Sean

13
00:00:58,549 --> 00:00:56,010

dongle Goldman who is a research space

14
00:01:00,349 --> 00:00:58,559
scientists at the NASA Goddard Space

15
00:01:01,279 --> 00:01:00,359
Flight Center in the state of Maryland

16
00:01:03,560 --> 00:01:01,289
in the United States

17
00:01:05,780 --> 00:01:03,570
he's an expert in the chemistry of the

18
00:01:08,330 --> 00:01:05,790
environment back in the early Earth he's

19
00:01:09,980 --> 00:01:08,340
also he also simulates the atmospheres

20
00:01:11,480 --> 00:01:09,990
of planets that are far far away

21
00:01:14,030 --> 00:01:11,490
orbiting other stars and called

22
00:01:16,219 --> 00:01:14,040
exoplanets and he's also an enabler of

23
00:01:18,170 --> 00:01:16,229
future telescopes that will help us

24
00:01:20,359 --> 00:01:18,180
discover life hopefully and we know that

25
00:01:23,179 --> 00:01:20,369
it's there on other worlds Sean it's

26
00:01:25,120 --> 00:01:23,189
great to have you today thanks I'm joy

27
00:01:27,950 --> 00:01:25,130
happy to be here big fan of the show

28
00:01:30,140 --> 00:01:27,960
thank you before we start though it's

29
00:01:32,300 --> 00:01:30,150
time for your monthly background quiz I

30
00:01:33,890 --> 00:01:32,310
know everybody's excited about Mike if

31
00:01:38,120 --> 00:01:33,900
you could put up the background from

32
00:01:42,020 --> 00:01:38,130
last month this beautiful setting is of

33
00:01:43,219 --> 00:01:42,030
course bumpass hell and have to make you

34
00:01:45,319 --> 00:01:43,229
pronounce this properly this is a

35
00:01:47,450 --> 00:01:45,329
beautiful hot spring in Lassen Volcanic

36
00:01:49,789 --> 00:01:47,460
National Park in the state of California

37
00:01:51,200 --> 00:01:49,799
in America the beautiful colors come

38
00:01:53,240 --> 00:01:51,210

from the different minerals and also

39
00:01:55,249 --> 00:01:53,250
from the microbes the little microbial

40
00:01:57,139 --> 00:01:55,259
organisms that live in the water and

41
00:01:59,060 --> 00:01:57,149
it's a nice analogue to planetary

42
00:02:02,120 --> 00:01:59,070
settings that we know in fact possibly

43
00:02:04,969 --> 00:02:02,130
existed on the planet Mars this month

44
00:02:06,950 --> 00:02:04,979
the background is behind me some clues

45
00:02:10,339 --> 00:02:06,960
for it as you can probably see from

46
00:02:12,050 --> 00:02:10,349
these structures here and we'll let you

47
00:02:14,930 --> 00:02:12,060
know next time the winner

48
00:02:17,870 --> 00:02:14,940
this months as background quiz is at

49
00:02:19,940 --> 00:02:17,880
twisted Marv congratulations at twisted

50
00:02:23,210 --> 00:02:19,950
mark you have won the complete set of

51
00:02:25,699 --> 00:02:23,220
the astrobiology comic books as well as

52
00:02:28,430 --> 00:02:25,709
some stickers with a NASA logo on it

53
00:02:30,170 --> 00:02:28,440
please get in touch with us via social

54
00:02:31,809 --> 00:02:30,180
media or however you find us and we'll

55
00:02:34,160 --> 00:02:31,819
get those to you thanks for playing

56
00:02:38,270 --> 00:02:34,170
what is behind me we'll let you know in

57
00:02:39,800 --> 00:02:38,280
next month Sean before we start talking

58
00:02:41,420 --> 00:02:39,810
about science cuz you do so many things

59
00:02:43,070 --> 00:02:41,430
and it's so exciting to talk about this

60
00:02:46,190 --> 00:02:43,080
I want to get to know you a bit more

61
00:02:47,809 --> 00:02:46,200
first um how did you become a scientist

62
00:02:50,120 --> 00:02:47,819
in the first place you have Earth and

63
00:02:54,470 --> 00:02:50,130

Mars behind you what triggered that

64
00:02:56,600 --> 00:02:54,480
interest the thing yeah for as long as I

65
00:02:57,890 --> 00:02:56,610
remember I knowing what I wanted to do I

66
00:02:59,240 --> 00:02:57,900
wanted to be a scientist the one

67
00:03:00,589 --> 00:02:59,250
exception to that is there's one point

68
00:03:02,600 --> 00:03:00,599
in high school I was also pursuing a

69
00:03:04,550 --> 00:03:02,610
broadcast a sports casting career and I

70
00:03:06,520 --> 00:03:04,560
decided I wanted to make news instead of

71
00:03:08,449 --> 00:03:06,530
reporting on other people making news

72
00:03:10,670 --> 00:03:08,459
although here you know we're kind of out

73
00:03:13,070 --> 00:03:10,680
a news program today so there you go I

74
00:03:14,690 --> 00:03:13,080
do remember being with my brother in

75
00:03:16,039 --> 00:03:14,700
terms of like turning to astrobiology I

76
00:03:18,410 --> 00:03:16,049
was with my brother we lived in Chicago

77
00:03:20,210 --> 00:03:18,420
you couldn't see the stars at night but

78
00:03:21,770 --> 00:03:20,220
we went out one night and there was an

79
00:03:23,900 --> 00:03:21,780
eclipse a lunar eclipse and so you could

80
00:03:25,400 --> 00:03:23,910
see the stars for a change and we were

81
00:03:26,960 --> 00:03:25,410
just like laying on the lawn in the

82
00:03:28,819 --> 00:03:26,970
front yard kind of staring up at the sky

83
00:03:31,610 --> 00:03:28,829
and my brother said you know do you

84
00:03:33,949 --> 00:03:31,620
think there's anyone out there and I

85
00:03:36,080 --> 00:03:33,959
thought I didn't have a good answer to

86
00:03:37,430 --> 00:03:36,090
that question but it sounded like

87
00:03:40,490 --> 00:03:37,440
something that would be fun and

88
00:03:41,960 --> 00:03:40,500

challenging to pursue so I started

89
00:03:43,910 --> 00:03:41,970
looking at astrobiology as a career that

90
00:03:44,240 --> 00:03:43,920
was I was in college then and I never

91
00:03:46,780 --> 00:03:44,250
looked back

92
00:03:49,069 --> 00:03:46,790
it's fun I got any great people like you

93
00:03:50,720 --> 00:03:49,079
it's amazing now looking at the Stars

94
00:03:52,430 --> 00:03:50,730
just opens up the soul a little bit I

95
00:03:54,500 --> 00:03:52,440
remember during their solar eclipse last

96
00:03:56,569 --> 00:03:54,510
summer I had to stand up literally as

97
00:03:58,190 --> 00:03:56,579
this moon was crossing the Sun because

98
00:03:58,940 --> 00:03:58,200
it's just so moving so I totally get

99
00:04:01,340 --> 00:03:58,950
what you're saying

100
00:04:03,949 --> 00:04:01,350
so how did you how did you become an

101
00:04:05,000 --> 00:04:03,959
astrobiologist it's one can approach a

102
00:04:08,660 --> 00:04:05,010
discipline from a bunch of different

103
00:04:11,479 --> 00:04:08,670
trajectories and what was your path so I

104
00:04:14,240 --> 00:04:11,489
I really leaned into astrobiology from

105
00:04:15,470 --> 00:04:14,250
kind of that moment forward and I when I

106
00:04:17,330 --> 00:04:15,480
went to graduate school I looked

107
00:04:19,460 --> 00:04:17,340
specifically for programs that were good

108
00:04:21,080 --> 00:04:19,470
at astrobiology so I was looking at the

109
00:04:22,790 --> 00:04:21,090
University of Washington your alma mater

110
00:04:24,690 --> 00:04:22,800
for grad school as well as Penn State

111
00:04:26,700 --> 00:04:24,700
which is where I ended up going

112
00:04:28,920 --> 00:04:26,710
because they both had specific programs

113
00:04:31,020 --> 00:04:28,930

in astrobiology and we're offering

114
00:04:32,250 --> 00:04:31,030
degrees in at least that time Washington

115
00:04:34,410 --> 00:04:32,260
was offering a certificate but now they

116
00:04:36,960 --> 00:04:34,420
both offer degrees I went into the

117
00:04:39,360 --> 00:04:36,970
geosciences in part because I had some

118
00:04:41,190 --> 00:04:39,370
expertise in geochemistry and I could do

119
00:04:42,750 --> 00:04:41,200
some modeling I didn't like I knew I

120
00:04:44,160 --> 00:04:42,760
didn't want to be in a lab because

121
00:04:45,630 --> 00:04:44,170
there's chemicals in a lab that can kill

122
00:04:48,720 --> 00:04:45,640
you and I'm a klutz and that's a bad

123
00:04:51,300 --> 00:04:48,730
combination so I you know I decided I

124
00:04:53,400 --> 00:04:51,310
wanted to do modeling I decided I wanted

125
00:04:55,200 --> 00:04:53,410
to do astrobiology and I decided I

126
00:04:56,430 --> 00:04:55,210
wanted to do something with geochemistry

127
00:04:58,170 --> 00:04:56,440
because I had some background in that

128
00:05:00,450 --> 00:04:58,180
and so you know those three things put

129
00:05:01,830 --> 00:05:00,460
together the best place I thought and I

130
00:05:02,970 --> 00:05:01,840
think I was right in retrospect but

131
00:05:04,830 --> 00:05:02,980
everyone thinks the right and retrospect

132
00:05:05,520 --> 00:05:04,840
for stuff like this was Penn State so I

133
00:05:08,580 --> 00:05:05,530
went there

134
00:05:10,020 --> 00:05:08,590
studied early Earth and like why oxygen

135
00:05:12,030 --> 00:05:10,030
were breathing like how it first came to

136
00:05:14,280 --> 00:05:12,040
be on our planet and when and why it

137
00:05:15,900 --> 00:05:14,290
happened when it did then started

138
00:05:17,310 --> 00:05:15,910

thinking about like you know that for

139
00:05:19,230 --> 00:05:17,320
exoplanets and stuff like that but

140
00:05:21,150 --> 00:05:19,240
that's how I I really got started by

141
00:05:23,970 --> 00:05:21,160
doing kind of a targeted search for

142
00:05:25,320 --> 00:05:23,980
graduate school programs and modeling of

143
00:05:26,970 --> 00:05:25,330
course you don't mean walking around

144
00:05:28,470 --> 00:05:26,980
university dressed really nicely like

145
00:05:31,110 --> 00:05:28,480
you are today but actually computer

146
00:05:34,590 --> 00:05:31,120
simulations of atmospheres of the

147
00:05:36,900 --> 00:05:34,600
ancient earth right so you can see you

148
00:05:38,100 --> 00:05:36,910
can you can yeah you people can make a

149
00:05:41,190 --> 00:05:38,110
career with the first kind of modeling

150
00:05:42,990 --> 00:05:41,200
but I definitely can so yeah it's doing

151
00:05:45,180 --> 00:05:43,000
you know simulations you know on a

152
00:05:46,590 --> 00:05:45,190
computer like this one or sometimes on a

153
00:05:49,440 --> 00:05:46,600
supercomputer that we're dialing into

154
00:05:51,000 --> 00:05:49,450
and running our simulations there and

155
00:05:53,040 --> 00:05:51,010
and really what that's about is it's

156
00:05:54,990 --> 00:05:53,050
like you try to take some you know

157
00:05:57,690 --> 00:05:55,000
intuition you have as a scientist of

158
00:06:00,000 --> 00:05:57,700
like how a natural system works and you

159
00:06:01,350 --> 00:06:00,010
try to code that up with some math and

160
00:06:02,820 --> 00:06:01,360
and then put that in the computer and

161
00:06:05,460 --> 00:06:02,830
then let the computer decide how things

162
00:06:07,680 --> 00:06:05,470
play out it's fun because the computers

163
00:06:12,090 --> 00:06:07,690

be like math you like science modeling

164
00:06:14,190 --> 00:06:12,100
is a lot of fun yes so your work in the

165
00:06:15,870 --> 00:06:14,200
environmental chemistry of the ancient

166
00:06:17,880 --> 00:06:15,880
earth kind of contributed to our

167
00:06:20,430 --> 00:06:17,890
understanding that more than half of

168
00:06:23,730 --> 00:06:20,440
Earth history was devoid of any oxygen

169
00:06:25,260 --> 00:06:23,740
in the atmosphere is that right yeah and

170
00:06:26,640 --> 00:06:25,270
and this is something I think we've

171
00:06:28,700 --> 00:06:26,650
known as scientists for a long time but

172
00:06:30,960 --> 00:06:28,710
what we started thinking about is like

173
00:06:33,180 --> 00:06:30,970
what how do we actually kind of know

174
00:06:34,710 --> 00:06:33,190
exactly when it happened and why it

175
00:06:35,850 --> 00:06:34,720
happened when it did and how do we get

176
00:06:38,050 --> 00:06:35,860
in you know scientists are always

177
00:06:39,400 --> 00:06:38,060
wanting to dive into the details so

178
00:06:40,629 --> 00:06:39,410
you know there's these plots we have

179
00:06:42,100 --> 00:06:40,639
where like there's these huge changes

180
00:06:44,980 --> 00:06:42,110
that are like from the top of the plot

181
00:06:47,230 --> 00:06:44,990
to the bottom that kind of set this this

182
00:06:49,420 --> 00:06:47,240
paradigm that oxygen rose like around

183
00:06:50,530 --> 00:06:49,430
halfway through its history and then you

184
00:06:52,060 --> 00:06:50,540
know a dissertation work you're not

185
00:06:53,409 --> 00:06:52,070
looking at that huge step function

186
00:06:55,600 --> 00:06:53,419
you're looking at like the little

187
00:06:57,159 --> 00:06:55,610
Wiggles on the side of it that help that

188
00:06:59,230 --> 00:06:57,169

you know kind of led up to that big

189
00:07:00,340 --> 00:06:59,240
change and that's one of the things in

190
00:07:02,260 --> 00:07:00,350
science right like sometimes there's

191
00:07:03,700 --> 00:07:02,270
this big picture question that other

192
00:07:05,320 --> 00:07:03,710
people are have been addressing for

193
00:07:06,970 --> 00:07:05,330
decades and you're trying to fill in

194
00:07:09,040 --> 00:07:06,980
some details that help support that big

195
00:07:10,840 --> 00:07:09,050
picture and I won't go into the details

196
00:07:12,520 --> 00:07:10,850
because then you'd lose some viewers but

197
00:07:14,740 --> 00:07:12,530
that's you know a lot of my dissertation

198
00:07:16,719 --> 00:07:14,750
work was on those sort of little details

199
00:07:17,830 --> 00:07:16,729
off to the side the details are fun

200
00:07:20,140 --> 00:07:17,840
though I mean when you think about the

201
00:07:22,840 --> 00:07:20,150
reality of Earth history I take like

202
00:07:24,670 --> 00:07:22,850
maybe this side as the beginning of

203
00:07:27,159 --> 00:07:24,680
Earth and that side as you know it today

204
00:07:28,659 --> 00:07:27,169
for more than half of it there was no

205
00:07:31,030 --> 00:07:28,669
oxygen in the atmosphere and yet our

206
00:07:34,240 --> 00:07:31,040
planet was very much alive and we've

207
00:07:36,879 --> 00:07:34,250
talked about oxygen in past shows as

208
00:07:39,760 --> 00:07:36,889
being an important bio signature so a

209
00:07:41,980 --> 00:07:39,770
signature of life on other worlds um but

210
00:07:43,900 --> 00:07:41,990
it's far from sure right and you also

211
00:07:46,750 --> 00:07:43,910
made some computer simulations that show

212
00:07:49,900 --> 00:07:46,760
that you can use oxygen as that can be

213
00:07:52,180 --> 00:07:49,910

produced without any life so tell us

214
00:07:55,360 --> 00:07:52,190
more about this this oxygen how valuable

215
00:07:57,340 --> 00:07:55,370
it is to explore for life elsewhere well

216
00:07:59,230 --> 00:07:57,350
so right so oxygen is one of the things

217
00:08:00,880 --> 00:07:59,240
that life makes that we instantly

218
00:08:02,140 --> 00:08:00,890
recognize if it if we were looking at

219
00:08:03,700 --> 00:08:02,150
Earth with the telescope we'd see the

220
00:08:05,800 --> 00:08:03,710
oxygen in Earth's atmosphere and there'd

221
00:08:07,840 --> 00:08:05,810
be a kind of a telltale sign that there

222
00:08:09,129 --> 00:08:07,850
was probably life on on earth because

223
00:08:11,140 --> 00:08:09,139
that's oh that's a guess it's really

224
00:08:13,270 --> 00:08:11,150
hard to keep in the atmosphere unless

225
00:08:14,590 --> 00:08:13,280
life is making it at massive quantities

226
00:08:15,550 --> 00:08:14,600
or something's making a massive

227
00:08:17,770 --> 00:08:15,560
quantities and life's the best

228
00:08:19,120 --> 00:08:17,780
explanation for that but one of the

229
00:08:21,010 --> 00:08:19,130
challenges we have is like whether I'm

230
00:08:23,080 --> 00:08:21,020
talking to another scientist from

231
00:08:25,270 --> 00:08:23,090
another field or you know a family

232
00:08:26,920 --> 00:08:25,280
member one of the questions we get is

233
00:08:29,290 --> 00:08:26,930
like well you're talking about aliens

234
00:08:31,060 --> 00:08:29,300
right like how how are you gonna know if

235
00:08:32,980 --> 00:08:31,070
it's like some alien form of life that's

236
00:08:35,050 --> 00:08:32,990
like weird and different like what we

237
00:08:37,240 --> 00:08:35,060
have on modern-day earth and there's two

238
00:08:39,579 --> 00:08:37,250

things you can do one is you can go to

239
00:08:41,320 --> 00:08:39,589
places like in the background of your of

240
00:08:42,760 --> 00:08:41,330
your image right there and go to places

241
00:08:45,760 --> 00:08:42,770
that are on modern-day earth that are

242
00:08:48,150 --> 00:08:45,770
really weird today but life still exists

243
00:08:49,980 --> 00:08:48,160
the other thing you can do is you

244
00:08:51,810 --> 00:08:49,990
go backwards in time to when the earth

245
00:08:53,880 --> 00:08:51,820
had different environments in its past

246
00:08:56,360 --> 00:08:53,890
and this period of time that half of

247
00:08:58,500 --> 00:08:56,370
Earth's history you were talking about

248
00:09:00,120 --> 00:08:58,510
that half a verse issue you were talking

249
00:09:02,250 --> 00:09:00,130
about before where there was no oxygen

250
00:09:03,870 --> 00:09:02,260
but life think about what I were saying

251
00:09:05,910 --> 00:09:03,880
about set right if we're planning to

252
00:09:07,260 --> 00:09:05,920
look for oxygen as our bio signature we

253
00:09:10,830 --> 00:09:07,270
might have missed it for that first half

254
00:09:12,720 --> 00:09:10,840
of Earth's history and maybe about a

255
00:09:14,190 --> 00:09:12,730
third of the history of life on Earth so

256
00:09:16,200 --> 00:09:14,200
then we started thinking about like what

257
00:09:18,360 --> 00:09:16,210
other signals would tip us off that

258
00:09:21,060 --> 00:09:18,370
there was life on Earth before oxygen

259
00:09:22,290 --> 00:09:21,070
was present on earth and and we started

260
00:09:25,050 --> 00:09:22,300
looking at like you know certain organic

261
00:09:26,970 --> 00:09:25,060
gases that life makes there's actually

262
00:09:28,440 --> 00:09:26,980
kind of like this global smog layer that

263
00:09:30,000 --> 00:09:28,450

we that was kind of the details I was

264
00:09:31,500 --> 00:09:30,010
talking about originally we were like oh

265
00:09:33,450 --> 00:09:31,510
it was kind of interesting and

266
00:09:36,030 --> 00:09:33,460
fascinating there was like this you know

267
00:09:38,160 --> 00:09:36,040
orange haze over the sky of Earth that

268
00:09:40,320 --> 00:09:38,170
at that time or at least the parts of

269
00:09:42,060 --> 00:09:40,330
the time it turns out that actually may

270
00:09:44,070 --> 00:09:42,070
be a bio signature the sign that we

271
00:09:47,220 --> 00:09:44,080
recognize that life was present on a

272
00:09:49,320 --> 00:09:47,230
planet without oxygen that it may be

273
00:09:51,030 --> 00:09:49,330
hard to sustain that on an otherwise

274
00:09:53,490 --> 00:09:51,040
earth-like world unless you had massive

275
00:09:57,030 --> 00:09:53,500
quantities of methane being produced by

276
00:09:58,290 --> 00:09:57,040
a by a biosphere so yeah I mean it's

277
00:10:01,530 --> 00:09:58,300
it's one of these things where I started

278
00:10:03,750 --> 00:10:01,540
off thinking about like oxygen in the

279
00:10:05,580 --> 00:10:03,760
atmosphere of earlier the lack of oxygen

280
00:10:07,410 --> 00:10:05,590
in the atmosphere and it's taken me all

281
00:10:10,290 --> 00:10:07,420
the way to like well how do we know that

282
00:10:11,670 --> 00:10:10,300
that planets alive so the infant opossum

283
00:10:13,440 --> 00:10:11,680
planets they're playing you know they're

284
00:10:15,180 --> 00:10:13,450
they're playing dead right you wouldn't

285
00:10:17,550 --> 00:10:15,190
you have to make sure you know how to to

286
00:10:19,260 --> 00:10:17,560
know they're alive yeah no that's a good

287
00:10:21,390 --> 00:10:19,270
way to put it I mean the ancient earth

288
00:10:23,730 --> 00:10:21,400

was essentially an exoplanet right it

289
00:10:25,770 --> 00:10:23,740
was so different than modern Earth the

290
00:10:27,720 --> 00:10:25,780
Sun was fainter it was spinning faster

291
00:10:29,640 --> 00:10:27,730
no grass no animals no trees the

292
00:10:33,840 --> 00:10:29,650
atmosphere was different moon was closer

293
00:10:35,970 --> 00:10:33,850
in nights were stronger yeah the UV flux

294
00:10:38,040 --> 00:10:35,980
from the Sun was stronger so how has

295
00:10:39,690 --> 00:10:38,050
studying the ancient earth kind of

296
00:10:42,960 --> 00:10:39,700
tipped you off to a career in

297
00:10:44,400 --> 00:10:42,970
understanding other planets you know

298
00:10:46,380 --> 00:10:44,410
what say let me let me actually

299
00:10:48,030 --> 00:10:46,390
generalize for a second like if you if

300
00:10:49,740 --> 00:10:48,040
you look at the people that are been

301
00:10:51,870 --> 00:10:49,750
leading some of the astrobiology

302
00:10:55,410 --> 00:10:51,880
Mississippi missions for NASA like John

303
00:10:57,300 --> 00:10:55,420
grotzinger a diol would myself john arne

304
00:10:59,710 --> 00:10:57,310
on the telescope side the former two

305
00:11:01,600 --> 00:10:59,720
people are people that lead mars well

306
00:11:04,059 --> 00:11:01,610
missions there's actually a rich history

307
00:11:05,800 --> 00:11:04,069
of people doing work on early Earth and

308
00:11:07,269 --> 00:11:05,810
then pivoting and doing work on other

309
00:11:09,280 --> 00:11:07,279
planets and I think it's it's what

310
00:11:11,199 --> 00:11:09,290
you're saying Sanjay right like early

311
00:11:14,740 --> 00:11:11,209
Earth is the most alien planet for which

312
00:11:15,999 --> 00:11:14,750
we have data on its biosphere right we

313
00:11:18,699 --> 00:11:16,009

don't have a biosphere that we've

314
00:11:20,319 --> 00:11:18,709
discovered beyond Earth yet so the most

315
00:11:22,210 --> 00:11:20,329
different you can get from Earth are is

316
00:11:24,790 --> 00:11:22,220
sort of the most different paths that it

317
00:11:26,350 --> 00:11:24,800
presents to us and that's in this era of

318
00:11:27,340 --> 00:11:26,360
the Archaean when when there was no

319
00:11:29,019 --> 00:11:27,350
oxygen in the atmosphere because

320
00:11:30,340 --> 00:11:29,029
everything was different except theirs

321
00:11:32,139 --> 00:11:30,350
except for two things one there was

322
00:11:34,600 --> 00:11:32,149
still water and two there was still life

323
00:11:36,100 --> 00:11:34,610
right and just everything else was was

324
00:11:37,319 --> 00:11:36,110
dramatically different in the kind of

325
00:11:41,829 --> 00:11:37,329
life we had was different

326
00:11:45,340 --> 00:11:41,839
so by looking at that it it does kind of

327
00:11:46,960 --> 00:11:45,350
two things it makes you take all these

328
00:11:48,850 --> 00:11:46,970
principles of what we call Earth System

329
00:11:50,740 --> 00:11:48,860
science right to think about how the

330
00:11:53,410 --> 00:11:50,750
atmosphere and the oceans and the

331
00:11:55,780 --> 00:11:53,420
biology and the and the sun's energy how

332
00:11:57,850 --> 00:11:55,790
all that stuff interacts and you're

333
00:12:00,150 --> 00:11:57,860
taking you're trying to be like kind of

334
00:12:02,199 --> 00:12:00,160
like tease out the most basic principles

335
00:12:04,150 --> 00:12:02,209
so that you could not just describe

336
00:12:05,949 --> 00:12:04,160
modern-day earth but also there's a

337
00:12:07,720 --> 00:12:05,959
vastly different ancient earth and if

338
00:12:09,129 --> 00:12:07,730

you can describe both modern earth and

339
00:12:11,499 --> 00:12:09,139
ancient earth despite their differences

340
00:12:13,509 --> 00:12:11,509
with then you you're onto something

341
00:12:14,499 --> 00:12:13,519
because it then then both your intuition

342
00:12:16,720 --> 00:12:14,509
and the models that come out of your

343
00:12:19,049 --> 00:12:16,730
intuition are generalized enough to

344
00:12:21,549 --> 00:12:19,059
handle these vastly different cases and

345
00:12:23,920 --> 00:12:21,559
we can't be certain that it's going to

346
00:12:25,660 --> 00:12:23,930
be able to handle all the like diversity

347
00:12:27,100 --> 00:12:25,670
of cases and probably you know the

348
00:12:29,410 --> 00:12:27,110
diversity of cases out there in the

349
00:12:30,999 --> 00:12:29,420
universe is probably much broader but at

350
00:12:33,670 --> 00:12:31,009
least you're validating against the

351
00:12:36,790 --> 00:12:33,680
diversity of cases that we have data on

352
00:12:38,230 --> 00:12:36,800
today and and just by doing that your

353
00:12:40,119 --> 00:12:38,240
models are becoming more flexible I

354
00:12:42,249 --> 00:12:40,129
think your brain is becoming more

355
00:12:44,710 --> 00:12:42,259
flexible it's it's good for the

356
00:12:46,900 --> 00:12:44,720
astrobiologists soul I think to to think

357
00:12:48,160 --> 00:12:46,910
about early Earth yeah the rocks after

358
00:12:49,449 --> 00:12:48,170
all are their history books of our

359
00:12:50,889 --> 00:12:49,459
planet and you have the pages are

360
00:12:52,960 --> 00:12:50,899
scattered all over the world so how do

361
00:12:54,549 --> 00:12:52,970
we read them and how do we get in summer

362
00:12:57,549 --> 00:12:54,559
ripped out we're missing some pages from

363
00:12:59,679 --> 00:12:57,559

that book it's so frustrating that's the

364
00:13:01,449 --> 00:12:59,689
fun part of it so in terms of bio

365
00:13:04,119 --> 00:13:01,459
signatures on other worlds like what we

366
00:13:06,610 --> 00:13:04,129
know how a planet our life influence a

367
00:13:08,249 --> 00:13:06,620
planet is very much driven by the only

368
00:13:11,090 --> 00:13:08,259
life that we know of is terrestrial life

369
00:13:13,670 --> 00:13:11,100
what kind of work is going on in your

370
00:13:15,980 --> 00:13:13,680
in your team to identify bio signatures

371
00:13:18,200 --> 00:13:15,990
that can possibly be agnostic like

372
00:13:20,840 --> 00:13:18,210
really not care but what type of life is

373
00:13:22,970 --> 00:13:20,850
there so let me actually let me give a

374
00:13:25,760 --> 00:13:22,980
shout out before I even start your your

375
00:13:28,280 --> 00:13:25,770
guest last week was Sarah Walker right

376
00:13:29,720 --> 00:13:28,290
indeed so she she's actually one of the

377
00:13:30,920 --> 00:13:29,730
people that got us starting to think

378
00:13:33,140 --> 00:13:30,930
about this and this is the other cool

379
00:13:37,540 --> 00:13:33,150
thing about astrobiology the way it's

380
00:13:39,680 --> 00:13:37,550
emerging as almost a field into itself

381
00:13:41,090 --> 00:13:39,690
you know Sarah Walker's been thinking

382
00:13:43,190 --> 00:13:41,100
about that question of agnostic bio

383
00:13:44,570 --> 00:13:43,200
signatures as it applies mostly in

384
00:13:46,430 --> 00:13:44,580
historically she's been thinking about

385
00:13:48,410 --> 00:13:46,440
this for I see worlds like Europa and

386
00:13:50,300 --> 00:13:48,420
Enceladus in our solar system and

387
00:13:52,460 --> 00:13:50,310
thinking about what could we understand

388
00:13:53,510 --> 00:13:52,470

about the chemistry of an ocean that

389
00:13:55,820 --> 00:13:53,520
would tell us that there was life

390
00:13:57,170 --> 00:13:55,830
swimming around in that ocean but

391
00:13:59,150 --> 00:13:57,180
recently she's been talking to the

392
00:14:00,860 --> 00:13:59,160
exoplanet scientists like myself about

393
00:14:03,680 --> 00:14:00,870
how we can take those same principles

394
00:14:06,470 --> 00:14:03,690
and apply them to exoplanets now the

395
00:14:09,980 --> 00:14:06,480
challenge is we're not gonna have a

396
00:14:12,380 --> 00:14:09,990
Rover or submarine crawling around or

397
00:14:15,110 --> 00:14:12,390
swimming around and sampling a soil or

398
00:14:17,480 --> 00:14:15,120
some water that we can then use

399
00:14:19,160 --> 00:14:17,490
analytical chemistry to find out every

400
00:14:21,530 --> 00:14:19,170
single trace species that's in that

401
00:14:23,720 --> 00:14:21,540
sample right so we can't get the level

402
00:14:26,030 --> 00:14:23,730
of detail of understanding as a result

403
00:14:27,680 --> 00:14:26,040
on an exoplanet that we're gonna get for

404
00:14:29,780 --> 00:14:27,690
Mars or your row bar or anything else

405
00:14:33,260 --> 00:14:29,790
that we can send a rover or a robot to

406
00:14:35,180 --> 00:14:33,270
the way we're thinking and this is like

407
00:14:38,120 --> 00:14:35,190
super preliminary and we haven't really

408
00:14:40,010 --> 00:14:38,130
worked out the details yet as what you

409
00:14:42,650 --> 00:14:40,020
may be able to do is maybe I'll able to

410
00:14:44,870 --> 00:14:42,660
like ascertain or model using our

411
00:14:47,930 --> 00:14:44,880
computer models the underlying

412
00:14:49,280 --> 00:14:47,940
complexity in an atmosphere that results

413
00:14:52,310 --> 00:14:49,290

from the top level chemicals that are

414
00:14:53,660 --> 00:14:52,320
present in it and and the basic the most

415
00:14:55,460 --> 00:14:53,670
basic way I could explain it is like

416
00:14:56,930 --> 00:14:55,470
there's some gases like oxygen that sort

417
00:14:58,970 --> 00:14:56,940
of have a family of reactions associated

418
00:15:01,190 --> 00:14:58,980
with them those other gases like methane

419
00:15:03,080 --> 00:15:01,200
that have a family of reactions that are

420
00:15:05,360 --> 00:15:03,090
associated with them now if you have a

421
00:15:07,370 --> 00:15:05,370
methane in the atmosphere without oxygen

422
00:15:09,230 --> 00:15:07,380
that's going to have sort of one set of

423
00:15:10,310 --> 00:15:09,240
reactions if you have oxygen in the

424
00:15:12,230 --> 00:15:10,320
atmosphere without methane that's

425
00:15:14,210 --> 00:15:12,240
another set if you've got both together

426
00:15:16,250 --> 00:15:14,220
two things happen one you've you've now

427
00:15:17,870 --> 00:15:16,260
got both families but there's sort of

428
00:15:19,400 --> 00:15:17,880
additional families of reactions that

429
00:15:21,410 --> 00:15:19,410
come into play and become really

430
00:15:23,130 --> 00:15:21,420
important when that sort of connect

431
00:15:26,910 --> 00:15:23,140
those two families

432
00:15:28,050 --> 00:15:26,920
and and that the implied diversity of

433
00:15:29,660 --> 00:15:28,060
the chemical network when you've got the

434
00:15:32,160 --> 00:15:29,670
oxygen and the methane there together

435
00:15:33,690 --> 00:15:32,170
might be the bio signature that we have

436
00:15:35,340 --> 00:15:33,700
for modern day earth now just take

437
00:15:37,470 --> 00:15:35,350
everything I said and imagine sort of

438
00:15:39,870 --> 00:15:37,480

different pairs of molecules not just

439
00:15:41,040 --> 00:15:39,880
oxygen of nothing but you you start to

440
00:15:42,720 --> 00:15:41,050
get it like what's in the atmosphere

441
00:15:44,490 --> 00:15:42,730
what are the major species and what does

442
00:15:46,670 --> 00:15:44,500
that imply for the underlying network of

443
00:15:50,550 --> 00:15:46,680
reactions connecting those major species

444
00:15:52,319 --> 00:15:50,560
that may be a way to quantify our

445
00:15:53,819 --> 00:15:52,329
assessment of whether or not a planet

446
00:15:55,230 --> 00:15:53,829
has life and it would be agnostic

447
00:15:57,090 --> 00:15:55,240
because at that point you're not

448
00:15:59,490 --> 00:15:57,100
assuming that the life's making oxygen

449
00:16:00,960 --> 00:15:59,500
or methane or any particular gas what

450
00:16:02,910 --> 00:16:00,970
you're trying to do is measure how

451
00:16:04,319 --> 00:16:02,920
complex the atmosphere chemistry is

452
00:16:07,259 --> 00:16:04,329
based on what you're seeing and

453
00:16:09,630 --> 00:16:07,269
comparing that to a case a null case

454
00:16:11,759 --> 00:16:09,640
where a planet did not have life and how

455
00:16:13,860 --> 00:16:11,769
complex the chemistry would be if there

456
00:16:16,199 --> 00:16:13,870
was nothing making of no life making

457
00:16:19,139 --> 00:16:16,209
gases at the surface so you're looking

458
00:16:22,740 --> 00:16:19,149
for the signature of the contribution of

459
00:16:24,150 --> 00:16:22,750
life in the atmosphere so life changes

460
00:16:25,620 --> 00:16:24,160
the atmosphere of our planet I mean this

461
00:16:27,900 --> 00:16:25,630
is the case for modern Earth today and

462
00:16:30,000 --> 00:16:27,910
it is so life processes on the surface

463
00:16:31,769 --> 00:16:30,010

of a planet far away changes the

464
00:16:33,420 --> 00:16:31,779
chemistry of an atmosphere and how

465
00:16:36,689 --> 00:16:33,430
complex that chemistry is what we can

466
00:16:38,250 --> 00:16:36,699
then look for using telescopes yeah that

467
00:16:39,139 --> 00:16:38,260
was a shorter better way of saying it

468
00:16:41,370 --> 00:16:39,149
yes

469
00:16:42,930 --> 00:16:41,380
it makes me I understood this is really

470
00:16:45,090 --> 00:16:42,940
fascinating work so let's speak about

471
00:16:47,550 --> 00:16:45,100
telescopes a little bit I mean the first

472
00:16:50,009 --> 00:16:47,560
was one thing coming

473
00:16:51,600 --> 00:16:50,019
just one thing to that that oxygen and

474
00:16:53,040 --> 00:16:51,610
methane example I had one of the thing

475
00:16:54,180 --> 00:16:53,050
one of the reasons we can do that and

476
00:16:55,769 --> 00:16:54,190
play these games where we're looking at

477
00:16:57,449 --> 00:16:55,779
the different families of reactions is

478
00:16:59,850 --> 00:16:57,459
you essentially have one family that is

479
00:17:01,860 --> 00:16:59,860
dominant now today and another family

480
00:17:04,740 --> 00:17:01,870
that was dominant back in the Archaean

481
00:17:05,850 --> 00:17:04,750
before oxygen rose and and they were you

482
00:17:07,740 --> 00:17:05,860
know as long as life stare they're both

483
00:17:09,480 --> 00:17:07,750
there to some degree but only because

484
00:17:11,400 --> 00:17:09,490
it's in part because we've had sort of

485
00:17:12,929 --> 00:17:11,410
these different phases of Earth that we

486
00:17:15,809 --> 00:17:12,939
understand the full diversity of

487
00:17:17,669 --> 00:17:15,819
chemicals and reactions that has that

488
00:17:19,590 --> 00:17:17,679

happens in a planetary atmosphere sorry

489
00:17:22,020 --> 00:17:19,600
you're about to pop I'll let you pivot

490
00:17:24,600 --> 00:17:22,030
that's right so the our teen is a time

491
00:17:26,370 --> 00:17:24,610
period of Earth from zero so formation

492
00:17:28,350 --> 00:17:26,380
to two and a half billion years ago and

493
00:17:30,150 --> 00:17:28,360
if we still have two billion years since

494
00:17:32,460 --> 00:17:30,160
then until today so it's a very very

495
00:17:34,530 --> 00:17:32,470
very long time ago if we take again this

496
00:17:36,300 --> 00:17:34,540
this this time scale as evolution of

497
00:17:40,080 --> 00:17:36,310
Earth history like dinosaurs are like

498
00:17:42,090 --> 00:17:40,090
yeah so very recent are we talking about

499
00:17:43,290 --> 00:17:42,100
time piers on earth very very long time

500
00:17:45,300 --> 00:17:43,300
ago which is amazing that we can have

501
00:17:47,190 --> 00:17:45,310
science up on earth from that time here

502
00:17:48,870 --> 00:17:47,200
it's just so cool anyways I was pivoting

503
00:17:49,950 --> 00:17:48,880
because we talked about telescopes which

504
00:17:52,110 --> 00:17:49,960
is really something very exciting

505
00:17:54,540 --> 00:17:52,120
particularly because today the European

506
00:17:58,470 --> 00:17:54,550
Union authorized the developments of

507
00:18:00,510 --> 00:17:58,480
this exoplanet atmospheric seeker space

508
00:18:02,430 --> 00:18:00,520
telescope called Arial which will fly I

509
00:18:03,780 --> 00:18:02,440
think into 2020 is something so it's

510
00:18:05,700 --> 00:18:03,790
it's very appropriate that we talked

511
00:18:09,470 --> 00:18:05,710
about telescopes today but you know the

512
00:18:12,000 --> 00:18:09,480
first exoplanet was discovered in 1995

513
00:18:13,980 --> 00:18:12,010

using telescopes and then a lot has

514
00:18:15,510 --> 00:18:13,990
changed in our understanding of

515
00:18:16,620 --> 00:18:15,520
exoplanets particularly on the

516
00:18:18,570 --> 00:18:16,630
scientific side but also on the

517
00:18:20,610 --> 00:18:18,580
technological side and now scientists

518
00:18:22,260 --> 00:18:20,620
work together with engineers to kind of

519
00:18:23,880 --> 00:18:22,270
fine-tune the telescopes based on our

520
00:18:25,200 --> 00:18:23,890
understanding can you tell us a little

521
00:18:28,260 --> 00:18:25,210
bit about the evolution of space

522
00:18:29,700 --> 00:18:28,270
telescopes since the mid 90s and until

523
00:18:30,420 --> 00:18:29,710
up to what you're working on which is

524
00:18:31,620 --> 00:18:30,430
the Louvre Wars

525
00:18:34,470 --> 00:18:31,630
telescope which we'll talk quite a bit

526
00:18:35,670 --> 00:18:34,480
negative so what you the first thing

527
00:18:37,320 --> 00:18:35,680
I'll just point out is that the

528
00:18:38,070 --> 00:18:37,330
timescales for these things is really

529
00:18:39,390 --> 00:18:38,080
long

530
00:18:40,320 --> 00:18:39,400
you know the telescope's were worth

531
00:18:42,600 --> 00:18:40,330
thinking about that we're

532
00:18:44,820 --> 00:18:42,610
conceptualizing today wouldn't launch

533
00:18:46,260 --> 00:18:44,830
for 20 years so for any students they're

534
00:18:47,790 --> 00:18:46,270
just keep that in your mind for if I

535
00:18:49,020 --> 00:18:47,800
talked about Louvre are it's not gonna

536
00:18:51,210 --> 00:18:49,030
launch for 20 years so if you think

537
00:18:52,800 --> 00:18:51,220
that's cool you know do good at school

538
00:18:54,210 --> 00:18:52,810

and then like you could be on the

539
00:18:56,070 --> 00:18:54,220
science or the engineering team with us

540
00:18:57,990 --> 00:18:56,080
when that thing launches you have time

541
00:19:00,390 --> 00:18:58,000
to get from my level of your career

542
00:19:01,830 --> 00:19:00,400
before that happens but that also has

543
00:19:03,300 --> 00:19:01,840
implications for going back in time

544
00:19:05,000 --> 00:19:03,310
because you said you know like the first

545
00:19:07,860 --> 00:19:05,010
exoplanets were discovered in the 90s

546
00:19:09,420 --> 00:19:07,870
the tell us even JWST which were about

547
00:19:11,970 --> 00:19:09,430
to flop or which we're about to launch

548
00:19:13,680 --> 00:19:11,980
you know that that telescope is really

549
00:19:15,150 --> 00:19:13,690
being conceptualized at the time that

550
00:19:17,160 --> 00:19:15,160
our first exoplanets were still being

551
00:19:19,380 --> 00:19:17,170
discovered and before we had found any

552
00:19:21,510 --> 00:19:19,390
earth-like exoplanets and the

553
00:19:23,340 --> 00:19:21,520
implications are that you know what is

554
00:19:24,510 --> 00:19:23,350
an awesome telescope and it's going to

555
00:19:26,430 --> 00:19:24,520
do some amazing things for exoplanets

556
00:19:27,570 --> 00:19:26,440
along with Ario and some other missions

557
00:19:29,370 --> 00:19:27,580
they're gonna start thinking about the

558
00:19:31,860 --> 00:19:29,380
chemical diversity of worlds that are

559
00:19:33,900 --> 00:19:31,870
out there beyond our solar system but we

560
00:19:37,290 --> 00:19:33,910
we've never designed a telescope from

561
00:19:39,300 --> 00:19:37,300
the start especially this flagship scale

562
00:19:41,160 --> 00:19:39,310
with the intention of looking at

563
00:19:43,220 --> 00:19:41,170

exoplanets and particularly around the

564
00:19:45,690 --> 00:19:43,230
idea of looking at potentially habitable

565
00:19:47,130 --> 00:19:45,700
exoplanets looking for signs of life now

566
00:19:48,630 --> 00:19:47,140
everything we would do with the future

567
00:19:49,740 --> 00:19:48,640
telescope is gonna gonna sort of

568
00:19:51,030 --> 00:19:49,750
leverage and

569
00:19:53,040 --> 00:19:51,040
utilize the stuff we've done in the past

570
00:19:54,900 --> 00:19:53,050
right like Hubble's taught us about how

571
00:19:56,280 --> 00:19:54,910
to make telescopes that can see all the

572
00:19:58,020 --> 00:19:56,290
way down into the ultraviolet really

573
00:19:59,940 --> 00:19:58,030
well and how to make them last long and

574
00:20:01,530 --> 00:19:59,950
how to service them so we continue and

575
00:20:04,020 --> 00:20:01,540
upgrade them with new generations of

576
00:20:05,640 --> 00:20:04,030
instruments JWST is teaching us about

577
00:20:07,710 --> 00:20:05,650
how to build bigger telescopes because

578
00:20:09,840 --> 00:20:07,720
if you haven't seen the videos of Webb

579
00:20:11,640 --> 00:20:09,850
it's like this transformer telescope it

580
00:20:12,810 --> 00:20:11,650
this is gonna start off all packaged up

581
00:20:15,720 --> 00:20:12,820
in the rocket and then it's gonna like

582
00:20:17,280 --> 00:20:15,730
unfold to this huge aperture that and

583
00:20:18,990 --> 00:20:17,290
that big aperture the bigger it's almost

584
00:20:20,550 --> 00:20:19,000
like having a bigger camera lens it lets

585
00:20:23,040 --> 00:20:20,560
you see fainter stuff which for

586
00:20:24,840 --> 00:20:23,050
astronomers means further away then

587
00:20:26,220 --> 00:20:24,850
we're at the same time like as soon as

588
00:20:28,050 --> 00:20:26,230

Webb's done we're gonna start seriously

589
00:20:29,880 --> 00:20:28,060
building this this next telescope w

590
00:20:32,010 --> 00:20:29,890
first which is developing a special

591
00:20:34,500 --> 00:20:32,020
technology called a coronagraph which

592
00:20:36,360 --> 00:20:34,510
will block out the Starlight so like so

593
00:20:38,250 --> 00:20:36,370
this is a corona here chronograph for a

594
00:20:41,400 --> 00:20:38,260
Sun here and if you block out the corona

595
00:20:43,590 --> 00:20:41,410
of the Sun you can see the corona around

596
00:20:45,240 --> 00:20:43,600
the Sun right so a coronagraph for an

597
00:20:47,850 --> 00:20:45,250
exoplanet is doing the same thing we do

598
00:20:50,280 --> 00:20:47,860
to study the sun's corona only instead

599
00:20:52,170 --> 00:20:50,290
of studying the corona of the Sun we're

600
00:20:54,270 --> 00:20:52,180
blocking out the Starlight to study an

601
00:20:55,680 --> 00:20:54,280
exoplanet right next to that star so

602
00:20:57,660 --> 00:20:55,690
we're developing that technology further

603
00:21:00,150 --> 00:20:57,670
to be able to block out ten billion

604
00:21:02,580 --> 00:21:00,160
photons from the star for every photon

605
00:21:04,860 --> 00:21:02,590
we get from the planet you put all that

606
00:21:06,570 --> 00:21:04,870
together right you take the ability to

607
00:21:08,550 --> 00:21:06,580
build UV telescopes and make them last a

608
00:21:10,770 --> 00:21:08,560
long time which help will taught us with

609
00:21:12,750 --> 00:21:10,780
building bigger telescopes which is what

610
00:21:14,760 --> 00:21:12,760
Webb is teaching us with the ability to

611
00:21:16,920 --> 00:21:14,770
block out starlight so we can see these

612
00:21:18,750 --> 00:21:16,930
individual earth-like exoplanets which

613
00:21:20,640 --> 00:21:18,760

is the technology W first is helping

614
00:21:22,200 --> 00:21:20,650
develop you put all that together into a

615
00:21:24,090 --> 00:21:22,210
single future telescope which we're

616
00:21:26,850 --> 00:21:24,100
calling levar or hab X is another

617
00:21:29,430 --> 00:21:26,860
version of it and that is what you will

618
00:21:31,080 --> 00:21:29,440
need to be able to look for signs of

619
00:21:33,660 --> 00:21:31,090
life and look at like the chemical

620
00:21:37,470 --> 00:21:33,670
composition these earth-like exoplanets

621
00:21:40,560 --> 00:21:37,480
or potentially earth-like exoplanets and

622
00:21:43,380 --> 00:21:40,570
I am so excited about that like I am I'm

623
00:21:44,790 --> 00:21:43,390
literally all in on it like my my whole

624
00:21:47,520 --> 00:21:44,800
career right now is dedicated to

625
00:21:50,670 --> 00:21:47,530
thinking about how to do this best and

626
00:21:51,990 --> 00:21:50,680
what which missions we could fly it gets

627
00:21:54,420 --> 00:21:52,000
into budgets and stuff like that but

628
00:21:57,180 --> 00:21:54,430
like like I really want to dedicate the

629
00:22:00,270 --> 00:21:57,190
rest of my life to this enterprise of

630
00:22:02,530 --> 00:22:00,280
like finding signs of life on exoplanets

631
00:22:04,890 --> 00:22:02,540
or looking so thoroughly for

632
00:22:06,670 --> 00:22:04,900
signs of life and having not found them

633
00:22:08,020 --> 00:22:06,680
start to put some really good

634
00:22:10,300 --> 00:22:08,030
constraints on just how lonely the

635
00:22:11,860 --> 00:22:10,310
universe is I want to get I want to die

636
00:22:13,330 --> 00:22:11,870
in one of those one of those two

637
00:22:15,010 --> 00:22:13,340
scenarios either knowing that we're

638
00:22:17,380 --> 00:22:15,020

alone or knowing that we're pretty

639
00:22:18,490 --> 00:22:17,390
lonely I'm sorry even knowing that we're

640
00:22:22,000 --> 00:22:18,500
not alone or knowing that we're pretty

641
00:22:23,470 --> 00:22:22,010
lonely right that has a lot of

642
00:22:25,570 --> 00:22:23,480
implications I think right if we're

643
00:22:27,340 --> 00:22:25,580
alone in the universe that means you

644
00:22:28,870 --> 00:22:27,350
know Humanity are the guardians of

645
00:22:30,850 --> 00:22:28,880
intelligence and ending in the galaxy

646
00:22:32,500 --> 00:22:30,860
right and are we are we prepared for

647
00:22:34,720 --> 00:22:32,510
such a responsibility you know I'm not

648
00:22:36,520 --> 00:22:34,730
sure sorry this is where astrobiology

649
00:22:39,100 --> 00:22:36,530
and exoplanet science becomes really

650
00:22:40,750 --> 00:22:39,110
important is it brings back a sense of

651
00:22:42,360 --> 00:22:40,760
humility of where we are in the planet

652
00:22:44,320 --> 00:22:42,370
perhaps even a sense of responsibility

653
00:22:49,060 --> 00:22:44,330
for life in the universe

654
00:22:50,290 --> 00:22:49,070
so philosophy aside yeah but that's why

655
00:22:53,350 --> 00:22:50,300
I mean this is why it's so exciting

656
00:22:55,120 --> 00:22:53,360
right this is someone someone said to me

657
00:22:57,780 --> 00:22:55,130
I think is mat mountain there's there's

658
00:23:01,360 --> 00:22:57,790
only gonna be one time in human history

659
00:23:04,180 --> 00:23:01,370
where we as a scientific community prove

660
00:23:05,470 --> 00:23:04,190
or or convince collect collect enough

661
00:23:07,000 --> 00:23:05,480
data to draw the conclusion that we're

662
00:23:09,190 --> 00:23:07,010
not alone that's gonna happen one time

663
00:23:10,990 --> 00:23:09,200

and there's I think there's a good

664
00:23:11,620 --> 00:23:11,000
chance that that one time happens while

665
00:23:15,360 --> 00:23:11,630
we're alive

666
00:23:17,650 --> 00:23:15,370
that's cool that is very cool Wow

667
00:23:20,140 --> 00:23:17,660
tingling in my spine thinking about that

668
00:23:22,000 --> 00:23:20,150
and by the way your your aura about

669
00:23:23,410 --> 00:23:22,010
levar I can feel it from here it's

670
00:23:26,440 --> 00:23:23,420
really intense and I'm really excited

671
00:23:29,500 --> 00:23:26,450
for you that for you so it so part of

672
00:23:31,600 --> 00:23:29,510
who you are now it's awesome it's just

673
00:23:34,240 --> 00:23:31,610
the last thing on this you know big

674
00:23:36,780 --> 00:23:34,250
stuff like this did you know the

675
00:23:40,600 --> 00:23:36,790
flagship missions supplies and our other

676
00:23:42,400 --> 00:23:40,610
partner space agencies they don't happen

677
00:23:43,870 --> 00:23:42,410
with a small team of like me and a

678
00:23:45,370 --> 00:23:43,880
couple friends here like at NASA Goddard

679
00:23:47,590 --> 00:23:45,380
right like I'm glad you bring that when

680
00:23:48,970 --> 00:23:47,600
we build big projects like this we build

681
00:23:51,010 --> 00:23:48,980
them for the science community and

682
00:23:52,660 --> 00:23:51,020
really for the global community right

683
00:23:55,180 --> 00:23:52,670
for our citizens across the world

684
00:23:57,580 --> 00:23:55,190
because the data we pulled down are

685
00:23:59,350 --> 00:23:57,590
gonna be first of all open to the public

686
00:24:01,330 --> 00:23:59,360
because it's that's what happens with

687
00:24:03,430 --> 00:24:01,340
our flagship missions but B they'd have

688
00:24:05,080 --> 00:24:03,440

to be because this the the the

689
00:24:07,930 --> 00:24:05,090
processing of that information is such a

690
00:24:09,190 --> 00:24:07,940
difficult scientific problem it requires

691
00:24:11,430 --> 00:24:09,200
all hands on deck

692
00:24:12,690 --> 00:24:11,440
we need geologists there

693
00:24:14,100 --> 00:24:12,700
helping us interpret the data we need

694
00:24:16,080 --> 00:24:14,110
biologists it can't just be the

695
00:24:18,419 --> 00:24:16,090
astronomers looking at those at the data

696
00:24:20,820 --> 00:24:18,429
from a mission like leVoir so you know

697
00:24:23,999 --> 00:24:20,830
loofah ours gonna be your mission - for

698
00:24:26,759 --> 00:24:24,009
sure I'm excited to see the data can't

699
00:24:28,220 --> 00:24:26,769
wait yeah so in addition to being a

700
00:24:30,480 --> 00:24:28,230
scientist you're the father of ever

701
00:24:32,909 --> 00:24:30,490
lovely little daughter how are you able

702
00:24:35,850 --> 00:24:32,919
to do both successfully I mean science

703
00:24:37,499 --> 00:24:35,860
is a very intensive career and it's not

704
00:24:41,220 --> 00:24:37,509
saying that it takes a lot of time I'm

705
00:24:45,509 --> 00:24:41,230
how are you able to balance both a lot

706
00:24:47,100 --> 00:24:45,519
of caffeine for one coffee you know if

707
00:24:48,539 --> 00:24:47,110
it weren't for that I don't think I'd

708
00:24:52,200 --> 00:24:48,549
get through a day much less a week or a

709
00:24:56,759 --> 00:24:52,210
month a lot of it is trying to be as

710
00:24:57,840 --> 00:24:56,769
present as I can be wherever I'm at but

711
00:24:59,580 --> 00:24:57,850
that that can be hard too because

712
00:25:01,139 --> 00:24:59,590
sometimes you've got an emergency from

713
00:25:02,490 --> 00:25:01,149

work happening when you're home or vice

714
00:25:05,519 --> 00:25:02,500
versa

715
00:25:08,580 --> 00:25:05,529
but I I try to I try when I'm with my

716
00:25:10,889 --> 00:25:08,590
kid Maya who's four at home to really be

717
00:25:12,240 --> 00:25:10,899
with her and to be focused on her I only

718
00:25:14,460 --> 00:25:12,250
get a few hours a night with her right I

719
00:25:16,320 --> 00:25:14,470
mean I I tend I'm the bomb the bus in

720
00:25:18,990 --> 00:25:16,330
our family right now right I go from

721
00:25:20,879 --> 00:25:19,000
daycare and I go home I generally cook

722
00:25:22,320 --> 00:25:20,889
dinner and we need dinner as a family we

723
00:25:25,049 --> 00:25:22,330
maybe do one or two other activities and

724
00:25:27,769 --> 00:25:25,059
then it's bedtime and in that in that

725
00:25:30,299 --> 00:25:27,779
span of time on not on email I'm not

726
00:25:31,740 --> 00:25:30,309
maybe I'm on slack because sometimes

727
00:25:33,389 --> 00:25:31,750
that my students have an emergency they

728
00:25:36,029 --> 00:25:33,399
need to tend to but I try to be pretty

729
00:25:37,470 --> 00:25:36,039
focused and and you'll see like if you

730
00:25:39,539 --> 00:25:37,480
looked at my email records like you'll

731
00:25:42,210 --> 00:25:39,549
see there's like a hole between like

732
00:25:44,340 --> 00:25:42,220
5:00 p.m. and like 9:00 or my kid goes

733
00:25:46,070 --> 00:25:44,350
to bed late she doesn't like go sleep so

734
00:25:49,019 --> 00:25:46,080
like between like 9:00 or 10:00 p.m.

735
00:25:50,389 --> 00:25:49,029
where I'm not on email but then after

736
00:25:53,039 --> 00:25:50,399
she goes to sleep I'll go downstairs

737
00:25:54,570 --> 00:25:53,049
I'll open up my laptop and I'll start

738
00:25:56,549 --> 00:25:54,580

you know emailing people again or

739
00:25:58,830 --> 00:25:56,559
pulling together whatever thing was due

740
00:26:00,539 --> 00:25:58,840
today or tomorrow or yesterday that I

741
00:26:01,889 --> 00:26:00,549
have to finish up and I'll do that till

742
00:26:03,509 --> 00:26:01,899
I go to sleep and then I wake up with

743
00:26:04,710 --> 00:26:03,519
her and I'm making breakfast with her

744
00:26:07,409 --> 00:26:04,720
and I've got an hour two in the morning

745
00:26:10,789 --> 00:26:07,419
with her so part of it is trying to

746
00:26:13,019 --> 00:26:10,799
build boundaries around my life at home

747
00:26:16,289 --> 00:26:13,029
for those precious few hours a day I

748
00:26:17,100 --> 00:26:16,299
have with my family can't always do it I

749
00:26:19,799 --> 00:26:17,110
do my best

750
00:26:22,230 --> 00:26:19,809
that's words of wisdom thank you for

751
00:26:23,490 --> 00:26:22,240
sharing that um so for those of you who

752
00:26:26,220 --> 00:26:23,500
are watching

753
00:26:27,540 --> 00:26:26,230
please use hashtag asked Astra bio to

754
00:26:30,210 --> 00:26:27,550
submit your questions either on Twitter

755
00:26:33,150 --> 00:26:30,220
or put them directly on the Signet org

756
00:26:35,130 --> 00:26:33,160
chat and we'll open them up to Shawn in

757
00:26:36,510 --> 00:26:35,140
just a few minutes the last question I

758
00:26:38,970 --> 00:26:36,520
want to ask because we could talk about

759
00:26:40,680 --> 00:26:38,980
this stuff forever but you have a lot of

760
00:26:42,390 --> 00:26:40,690
we have a lot of students watching on

761
00:26:44,220 --> 00:26:42,400
asking astrobiologists and as long as

762
00:26:46,590 --> 00:26:44,230
perhaps you have some some guidance some

763
00:26:47,760 --> 00:26:46,600

some advice for them as they start

764
00:26:51,720 --> 00:26:47,770
building their career to become

765
00:26:53,550 --> 00:26:51,730
astrobiologists I the best so the the

766
00:26:55,680 --> 00:26:53,560
cheesy advice is like to find something

767
00:26:58,440 --> 00:26:55,690
you love and do it right I think if you

768
00:27:00,210 --> 00:26:58,450
want to really excel in astrobiology if

769
00:27:02,160 --> 00:27:00,220
there's a more general version of that

770
00:27:03,900 --> 00:27:02,170
which is like find all the things you

771
00:27:06,000 --> 00:27:03,910
love and then find place they intersect

772
00:27:08,960 --> 00:27:06,010
right so if you're really an

773
00:27:12,000 --> 00:27:08,970
astrobiology you also need to find out

774
00:27:13,980 --> 00:27:12,010
what discipline you want to have as a

775
00:27:15,300 --> 00:27:13,990
basis right because I I'm I come in

776
00:27:16,980 --> 00:27:15,310
astrobiology fundamentally as an earth

777
00:27:18,920 --> 00:27:16,990
scientist that's trained to think about

778
00:27:21,210 --> 00:27:18,930
planets as these interacting systems

779
00:27:23,250 --> 00:27:21,220
astronomers come at it with a different

780
00:27:24,960 --> 00:27:23,260
perspective they come at it from an

781
00:27:27,390 --> 00:27:24,970
observers perspective sometimes from a

782
00:27:29,100 --> 00:27:27,400
big data perspective when I'm in the

783
00:27:30,300 --> 00:27:29,110
room with an astronomer and a biologist

784
00:27:31,650 --> 00:27:30,310
comes at it from a different perspective

785
00:27:33,350 --> 00:27:31,660
right they're often looking at it from

786
00:27:36,300 --> 00:27:33,360
the perspective of a cell or some

787
00:27:37,290 --> 00:27:36,310
biochemistry when I think of all those

788
00:27:40,650 --> 00:27:37,300

folks in the same room interacting

789
00:27:42,870 --> 00:27:40,660
together our solutions are much stronger

790
00:27:45,150 --> 00:27:42,880
than it is if I were doing it I really

791
00:27:47,010 --> 00:27:45,160
believe that the smartest person alive

792
00:27:48,900 --> 00:27:47,020
couldn't do this stuff on their own you

793
00:27:51,150 --> 00:27:48,910
need a bunch of really smart people

794
00:27:52,530 --> 00:27:51,160
working together so all that is to say

795
00:27:54,000 --> 00:27:52,540
it's not enough to just love

796
00:27:56,310 --> 00:27:54,010
astrobiology you have to find that other

797
00:27:58,080 --> 00:27:56,320
thing about biology or the chemistry or

798
00:28:00,000 --> 00:27:58,090
the astronomy or the geology that you

799
00:28:01,950 --> 00:28:00,010
also love and want to be an expert in

800
00:28:04,500 --> 00:28:01,960
and then the other aspect of this is

801
00:28:07,020 --> 00:28:04,510
find the from the kind of thing you love

802
00:28:08,610 --> 00:28:07,030
to do I love computers like I'm a nerd I

803
00:28:10,680 --> 00:28:08,620
would be happy sitting at a terminal all

804
00:28:14,010 --> 00:28:10,690
day writing code and trying to get it to

805
00:28:15,420 --> 00:28:14,020
work and debugging it so that that means

806
00:28:17,790 --> 00:28:15,430
I'm also going to be willing to stay up

807
00:28:19,530 --> 00:28:17,800
late at night doing that if you love

808
00:28:22,350 --> 00:28:19,540
outdoors maybe you want to be doing

809
00:28:23,580 --> 00:28:22,360
fieldwork if you love all the pictures

810
00:28:25,290 --> 00:28:23,590
we get from Hubble and all these other

811
00:28:26,820 --> 00:28:25,300
great telescopes on the ground and in

812
00:28:29,880 --> 00:28:26,830
space maybe you want to be an observer

813
00:28:31,650 --> 00:28:29,890

if you love lab work if you love like

814
00:28:32,340 --> 00:28:31,660
tinkering around maybe you want to be in

815
00:28:34,500 --> 00:28:32,350
the lab

816
00:28:36,360 --> 00:28:34,510
you have to find all these things about

817
00:28:38,340 --> 00:28:36,370
what you enjoy and what you're good at

818
00:28:40,560 --> 00:28:38,350
and you looked about all you're good not

819
00:28:43,529 --> 00:28:40,570
good at right like I know I'm a really

820
00:28:46,409 --> 00:28:43,539
bad lab scientist right so if you're an

821
00:28:48,570 --> 00:28:46,419
undergrad a there's always a temptation

822
00:28:50,340 --> 00:28:48,580
to focus too early to get those letters

823
00:28:52,159 --> 00:28:50,350
of recommendation that say this person

824
00:28:54,779 --> 00:28:52,169
is ready to pick up a PhD tomorrow I

825
00:28:56,310 --> 00:28:54,789
think it's important to demonstrate as

826
00:28:58,650 --> 00:28:56,320
an undergraduate day that you can do

827
00:29:00,180 --> 00:28:58,660
research but I also think it's important

828
00:29:02,240 --> 00:29:00,190
for you to experiment a little bit with

829
00:29:04,470 --> 00:29:02,250
different kinds of scientific

830
00:29:06,500 --> 00:29:04,480
internships so that you can find out

831
00:29:10,320 --> 00:29:06,510
what you really like on the day to day

832
00:29:12,210 --> 00:29:10,330
because ultimately you're gonna you're

833
00:29:13,590 --> 00:29:12,220
gonna have to work hard like it's just

834
00:29:15,120 --> 00:29:13,600
that's just reality it's hyper

835
00:29:17,070 --> 00:29:15,130
competitive in our market right now for

836
00:29:19,980 --> 00:29:17,080
you for getting jobs and proposals and

837
00:29:21,360 --> 00:29:19,990
all that and even if I and I tell my

838
00:29:22,680 --> 00:29:21,370

students it's all time even if I as your

839
00:29:24,390 --> 00:29:22,690
boss say you don't have to work hard

840
00:29:26,250 --> 00:29:24,400
which I don't think they do like not for

841
00:29:28,529 --> 00:29:26,260
me but they do have to work hard for

842
00:29:30,210 --> 00:29:28,539
themselves because if they're not some

843
00:29:32,549 --> 00:29:30,220
other student at some other institution

844
00:29:36,180 --> 00:29:32,559
is working hard and their CV is going to

845
00:29:38,850 --> 00:29:36,190
be that much stronger as a result so and

846
00:29:40,740 --> 00:29:38,860
it's easier to work hard if you love all

847
00:29:42,779 --> 00:29:40,750
the parts of what you're doing right not

848
00:29:44,850 --> 00:29:42,789
just the big picture question of are we

849
00:29:46,080 --> 00:29:44,860
alone but like the little detailed

850
00:29:48,390 --> 00:29:46,090
questions that are helping build up to

851
00:29:49,500 --> 00:29:48,400
that question and also you also you also

852
00:29:51,779 --> 00:29:49,510
have to love the techniques you're

853
00:29:53,970 --> 00:29:51,789
applying to the detail and the big

854
00:29:55,470 --> 00:29:53,980
picture questions so don't just find the

855
00:29:57,720 --> 00:29:55,480
thing you love we all have astrobiology

856
00:30:00,120 --> 00:29:57,730
I know the details you love about that

857
00:30:02,070 --> 00:30:00,130
question but it brings me to my next

858
00:30:04,049 --> 00:30:02,080
point and I'll open up to the questions

859
00:30:05,760 --> 00:30:04,059
in a second but I'm sure like me you get

860
00:30:07,289 --> 00:30:05,770
a lot of emails from students all over

861
00:30:09,149 --> 00:30:07,299
the world who are asking how do I become

862
00:30:10,649 --> 00:30:09,159
an astrobiologist astrobiology is a lot

863
00:30:12,299 --> 00:30:10,659

at my university I want to become an

864
00:30:15,720 --> 00:30:12,309
astronaut just how do I do it

865
00:30:17,580 --> 00:30:15,730
what do you respond to that it partially

866
00:30:20,010 --> 00:30:17,590
depends on the student if if they're an

867
00:30:22,200 --> 00:30:20,020
undergrad what if they're if I if I can

868
00:30:23,669 --> 00:30:22,210
sit down with them I'll try to but the

869
00:30:25,289 --> 00:30:23,679
main thing is look at the institutions

870
00:30:27,630 --> 00:30:25,299
that offer astrobiology programs for

871
00:30:29,730 --> 00:30:27,640
graduate school it's I think more

872
00:30:31,740 --> 00:30:29,740
important to be at a good astrobiology

873
00:30:35,039 --> 00:30:31,750
institution for graduate school than it

874
00:30:37,710 --> 00:30:35,049
is for undergrad you can be behind in in

875
00:30:39,779 --> 00:30:37,720
astrobiology and under and catch up in

876
00:30:40,799 --> 00:30:39,789
grad school and you can do it after grad

877
00:30:42,090 --> 00:30:40,809
school too right if you're a grad

878
00:30:44,280 --> 00:30:42,100
student out there you want to pivot

879
00:30:45,070 --> 00:30:44,290
astrobiology you can do that too if

880
00:30:46,330 --> 00:30:45,080
you're an undergrad

881
00:30:48,130 --> 00:30:46,340
the way to pivot is to go to a grad

882
00:30:50,140 --> 00:30:48,140
school that's good at it if you're a

883
00:30:51,700 --> 00:30:50,150
grad student the ways to pivot are a go

884
00:30:53,350 --> 00:30:51,710
to AB grad con where you're gonna meet

885
00:30:56,290 --> 00:30:53,360
other people interested in astrobiology

886
00:30:56,620 --> 00:30:56,300
and you're really not the network what's

887
00:31:00,430 --> 00:30:56,630
that

888
00:31:02,770 --> 00:31:00,440

biology graduate conference it's where

889
00:31:04,090 --> 00:31:02,780
no we met at FSI Khan but it's you and I

890
00:31:08,020 --> 00:31:04,100
hung out there a lot back in the day

891
00:31:10,480 --> 00:31:08,030
it's it is an informal conference for bi

892
00:31:14,200 --> 00:31:10,490
and of graduate students and postdocs

893
00:31:16,060 --> 00:31:14,210
early career people it's awesome and if

894
00:31:18,400 --> 00:31:16,070
you want to be an astrobiologist and and

895
00:31:20,380 --> 00:31:18,410
you're in grad school i cannot recommend

896
00:31:22,660 --> 00:31:20,390
going there strongly enough especially

897
00:31:24,400 --> 00:31:22,670
if you're at an institution where you're

898
00:31:27,130 --> 00:31:24,410
not building up that interdisciplinary

899
00:31:28,810 --> 00:31:27,140
thinking and network at the institution

900
00:31:30,700 --> 00:31:28,820
itself and then the last thing is if

901
00:31:32,560 --> 00:31:30,710
you're a grad student and you want to

902
00:31:34,870 --> 00:31:32,570
get more into astrobiology and it's not

903
00:31:37,330 --> 00:31:34,880
something your advisor does or your your

904
00:31:39,340 --> 00:31:37,340
your home department does look at

905
00:31:41,680 --> 00:31:39,350
postdocs that take the skills that

906
00:31:42,880 --> 00:31:41,690
you're developing as a PhD student the

907
00:31:45,010 --> 00:31:42,890
specific research skills you're

908
00:31:46,990 --> 00:31:45,020
developing on your dissertation and find

909
00:31:48,700 --> 00:31:47,000
a way to turn those tools to

910
00:31:50,410 --> 00:31:48,710
astrobiological questions I have a

911
00:31:52,150 --> 00:31:50,420
postdoc in our group right now that

912
00:31:55,210 --> 00:31:52,160
didn't do any astrobiology research in

913
00:31:57,580 --> 00:31:55,220

her PhD work but she has a great

914
00:31:59,050 --> 00:31:57,590
flexible molecular modeling tool that

915
00:32:02,290 --> 00:31:59,060
she can apply to astrobiological

916
00:32:03,850 --> 00:32:02,300
questions so she's taking her the the

917
00:32:06,280 --> 00:32:03,860
detailed expertise and tools she

918
00:32:08,680 --> 00:32:06,290
developed as a PhD student and now she's

919
00:32:10,840 --> 00:32:08,690
in our in our lab and our group applying

920
00:32:13,210 --> 00:32:10,850
those two specific astrobiology

921
00:32:15,010 --> 00:32:13,220
questions and you know she's a national

922
00:32:17,440 --> 00:32:15,020
biologist now because she's doing that

923
00:32:20,520 --> 00:32:17,450
stuff so you can always use your postdoc

924
00:32:22,090 --> 00:32:20,530
or your next postdoc to pivot as well I

925
00:32:23,770 --> 00:32:22,100
can totally relate

926
00:32:24,970 --> 00:32:23,780
I discovered astrobiology halfway

927
00:32:27,070 --> 00:32:24,980
through a master's degree and it

928
00:32:30,100 --> 00:32:27,080
completely changed my academic path so

929
00:32:31,720 --> 00:32:30,110
it's possible alright enough of us at

930
00:32:33,400 --> 00:32:31,730
least enough of me it's time for me to

931
00:32:34,990 --> 00:32:33,410
open it up for questions

932
00:32:37,570 --> 00:32:35,000
oh yeah and again if you're watching

933
00:32:39,670 --> 00:32:37,580
please use hashtag asked Astro bio and

934
00:32:42,010 --> 00:32:39,680
Twitter or as defraction directly on the

935
00:32:43,750 --> 00:32:42,020
second adore chat and we'll ask John

936
00:32:45,520 --> 00:32:43,760
about them so the first one is a great

937
00:32:47,800 --> 00:32:45,530
question he talks about the planetary

938
00:32:49,270 --> 00:32:47,810

context in addition to the bio signature

939
00:32:50,950 --> 00:32:49,280
I think is important know but you didn't

940
00:32:53,620 --> 00:32:50,960
get a chance to talk about that but

941
00:32:54,670 --> 00:32:53,630
maybe we can hear so this is at Sophie

942
00:32:57,010 --> 00:32:54,680
Grayson

943
00:32:59,620 --> 00:32:57,020
asks what are the criteria to be

944
00:33:00,970 --> 00:32:59,630
considered a habitable planet I read an

945
00:33:02,410 --> 00:33:00,980
article today about how planets aren't

946
00:33:03,370 --> 00:33:02,420
considered habitable because they have

947
00:33:05,530 --> 00:33:03,380
too much water

948
00:33:07,180 --> 00:33:05,540
are there any uncommon things that

949
00:33:13,120 --> 00:33:07,190
detract from the likelihood of a planet

950
00:33:16,960 --> 00:33:13,130
being habitable that's a great question

951
00:33:18,430 --> 00:33:16,970
I let me break this into two into two

952
00:33:19,570 --> 00:33:18,440
pieces right because some one of the

953
00:33:21,400 --> 00:33:19,580
things that's really hard about

954
00:33:24,460 --> 00:33:21,410
astrobiology is because it's so exciting

955
00:33:27,970 --> 00:33:24,470
it's hard to write a paper and not have

956
00:33:31,120 --> 00:33:27,980
a headline about the paper overemphasize

957
00:33:32,800 --> 00:33:31,130
like your conclusions right so I I don't

958
00:33:34,180 --> 00:33:32,810
I don't think I've read the news

959
00:33:35,170 --> 00:33:34,190
articles related it out I've seen some

960
00:33:36,370 --> 00:33:35,180
of the headlines about like you know

961
00:33:38,920 --> 00:33:36,380
some of these worlds might have too much

962
00:33:41,920 --> 00:33:38,930
water there are reasons to think that

963
00:33:43,810 --> 00:33:41,930

that might be the case but I don't think

964
00:33:47,050 --> 00:33:43,820
we can really be conclusive about that

965
00:33:48,640 --> 00:33:47,060
yet right now the reasons that you that

966
00:33:51,820 --> 00:33:48,650
too much water might be a bad thing is

967
00:33:53,860 --> 00:33:51,830
you know if you imagine life needing a

968
00:33:55,690 --> 00:33:53,870
certain amount of nutrients and having

969
00:33:58,600 --> 00:33:55,700
sort of some constant rate of nutrients

970
00:34:00,640 --> 00:33:58,610
coming up into an ocean but then you

971
00:34:02,170 --> 00:34:00,650
make the ocean like a thousand times a

972
00:34:03,910 --> 00:34:02,180
hundred to a thousand times as big

973
00:34:06,790 --> 00:34:03,920
you've now diluted all those nutrients

974
00:34:08,310 --> 00:34:06,800
and a much bigger water pool and also

975
00:34:10,840 --> 00:34:08,320
can have implications for the way that

976
00:34:13,060 --> 00:34:10,850
nutrients get recycled it might be less

977
00:34:15,040 --> 00:34:13,070
efficient and might has implications for

978
00:34:16,450 --> 00:34:15,050
the heat flow from from below if you

979
00:34:18,310 --> 00:34:16,460
start farming like ice layers at the

980
00:34:20,500 --> 00:34:18,320
bottom of an ocean which you can form

981
00:34:22,570 --> 00:34:20,510
these like sort of dense forms of ice if

982
00:34:25,060 --> 00:34:22,580
you if your oceans become too thick that

983
00:34:27,100 --> 00:34:25,070
could prevent convection that that leads

984
00:34:30,010 --> 00:34:27,110
to good heat release but also good

985
00:34:32,050 --> 00:34:30,020
nutrient cycling at the ocean floor you

986
00:34:34,149 --> 00:34:32,060
also lose continents and weathering and

987
00:34:35,980 --> 00:34:34,159
some amount of climate stability from

988
00:34:37,480 --> 00:34:35,990

that there's all kinds of things that I

989
00:34:39,940 --> 00:34:37,490
could imagine going wrong if you've got

990
00:34:43,120 --> 00:34:39,950
oceans that are too deep however we

991
00:34:45,130 --> 00:34:43,130
don't have any planets that have like

992
00:34:47,830 --> 00:34:45,140
literally ocean but kevin costner style

993
00:34:49,450 --> 00:34:47,840
ocean worlds that are totally covered by

994
00:34:51,580 --> 00:34:49,460
ocean and that have these like you know

995
00:34:53,950 --> 00:34:51,590
much more massive water reservoirs and

996
00:34:56,290 --> 00:34:53,960
and i and i think the best way to think

997
00:34:59,790 --> 00:34:56,300
about articles like that both in in in

998
00:35:04,360 --> 00:34:59,800
the scientific literature and in the the

999
00:35:06,040 --> 00:35:04,370
press is that's a hypothesis that having

1000
00:35:08,110 --> 00:35:06,050
too much water is a bad thing

1001
00:35:10,630 --> 00:35:08,120
and it's a hypothesis that we should

1002
00:35:12,310 --> 00:35:10,640
test and the test is going to be to

1003
00:35:14,080 --> 00:35:12,320
build you know a telescope that can see

1004
00:35:15,490 --> 00:35:14,090
a variety of worlds and look for signs

1005
00:35:18,340 --> 00:35:15,500
of life on it what I'd like to do is

1006
00:35:20,380 --> 00:35:18,350
look for bio signatures on one of these

1007
00:35:22,420 --> 00:35:20,390
super water rich world's not give up on

1008
00:35:24,940 --> 00:35:22,430
it actually look and then look for it on

1009
00:35:27,310 --> 00:35:24,950
a planet that has oceans more like what

1010
00:35:28,870 --> 00:35:27,320
we have on modern-day earth and then the

1011
00:35:31,450 --> 00:35:28,880
prediction would be that the the first

1012
00:35:33,040 --> 00:35:31,460
planet wouldn't have bio signatures at

1013
00:35:34,990 --> 00:35:33,050

least or as a class a planet they

1014
00:35:37,050 --> 00:35:35,000
wouldn't be as common or as strong as

1015
00:35:39,160 --> 00:35:37,060
they are on the more earth-like world

1016
00:35:40,870 --> 00:35:39,170
one of the things I love the most about

1017
00:35:42,970 --> 00:35:40,880
astrobiology is is really strong

1018
00:35:45,070 --> 00:35:42,980
creative nature you have to have try and

1019
00:35:46,750 --> 00:35:45,080
imagine those faraway worlds and detach

1020
00:35:48,820 --> 00:35:46,760
yourself from the biases you have about

1021
00:35:50,770 --> 00:35:48,830
life on Earth and extrapolate those

1022
00:35:52,120 --> 00:35:50,780
insights to other worlds and so it won't

1023
00:35:54,520 --> 00:35:52,130
has to be careful about making but

1024
00:35:56,970 --> 00:35:54,530
making such a big conclusive statements

1025
00:35:59,470 --> 00:35:56,980
you know because we just don't know yet

1026
00:36:00,910 --> 00:35:59,480
and let's like and the big things like

1027
00:36:02,920 --> 00:36:00,920
don't give up right like just like

1028
00:36:05,490 --> 00:36:02,930
there's reasons to doubt but let's turn

1029
00:36:10,600 --> 00:36:05,500
that into a hypothesis to test with like

1030
00:36:12,850 --> 00:36:10,610
observations next question is by Michael

1031
00:36:16,320 --> 00:36:12,860
Wong also an excellent question who asks

1032
00:36:21,700 --> 00:36:16,330
what would biggest bio signature be

1033
00:36:24,220 --> 00:36:21,710
before the rise of oxygen I think it's

1034
00:36:26,260 --> 00:36:24,230
okay so Vegas can be taken in a number

1035
00:36:28,420 --> 00:36:26,270
of ways I think the biggest the most

1036
00:36:31,360 --> 00:36:28,430
observable thing would have been the

1037
00:36:32,770 --> 00:36:31,370
presence of of an organic haze that may

1038
00:36:35,040 --> 00:36:32,780

have been that we think was present for

1039
00:36:37,210 --> 00:36:35,050
for periods of Earth history early on

1040
00:36:39,370 --> 00:36:37,220
that would have had a whopping big

1041
00:36:40,930 --> 00:36:39,380
signal in terms of how it affects the

1042
00:36:42,280 --> 00:36:40,940
distribution of colors from the plan on

1043
00:36:44,470 --> 00:36:42,290
the planet instead of being a pale blue

1044
00:36:47,800 --> 00:36:44,480
dot would have been like a pale orange

1045
00:36:48,790 --> 00:36:47,810
or pale lemon a yellow dot and that

1046
00:36:51,610 --> 00:36:48,800
would have been that would have been

1047
00:36:55,780 --> 00:36:51,620
like totally apparent the hard thing

1048
00:36:58,390 --> 00:36:55,790
becomes knowing for sure that that kind

1049
00:37:00,190 --> 00:36:58,400
of haze or aerosol I couldn't have

1050
00:37:01,570 --> 00:37:00,200
formed without life we actually have an

1051
00:37:03,850 --> 00:37:01,580
example of that in our own solar system

1052
00:37:06,370 --> 00:37:03,860
on Titan so you have to make sure that

1053
00:37:08,050 --> 00:37:06,380
you you you assess the chemical compare

1054
00:37:10,510 --> 00:37:08,060
the chemical composition of the

1055
00:37:13,180 --> 00:37:10,520
planetary atmosphere sufficiently to

1056
00:37:14,640 --> 00:37:13,190
rule out non-biological like just purely

1057
00:37:17,770 --> 00:37:14,650
atmospheric photochemistry

1058
00:37:19,720 --> 00:37:17,780
processes and make sure that that's not

1059
00:37:21,849 --> 00:37:19,730
making the haze that you're seeing

1060
00:37:24,190 --> 00:37:21,859
we think that if you if you detect a lot

1061
00:37:27,400 --> 00:37:24,200
of co2 in that planetary atmosphere that

1062
00:37:29,740 --> 00:37:27,410
that would put a brake on haze formation

1063
00:37:31,299 --> 00:37:29,750

to the point where you could only make

1064
00:37:32,470 --> 00:37:31,309
it if you're making tremendous amounts

1065
00:37:36,400 --> 00:37:32,480
of methane at the surface that are

1066
00:37:38,019 --> 00:37:36,410
probably only possible with life but all

1067
00:37:39,339 --> 00:37:38,029
that said like and so that's kind of the

1068
00:37:41,380 --> 00:37:39,349
I think the strongest is probably that

1069
00:37:43,170 --> 00:37:41,390
haze the next strongest is probably

1070
00:37:45,250 --> 00:37:43,180
looking at the ratio of methane to

1071
00:37:48,309 --> 00:37:45,260
carbon dioxide in the atmosphere in

1072
00:37:50,400 --> 00:37:48,319
general but all of those bio signatures

1073
00:37:52,599 --> 00:37:50,410
I would not put as much confidence in as

1074
00:37:54,460 --> 00:37:52,609
oxygen the oxygen we have on modern-day

1075
00:37:56,650 --> 00:37:54,470
earth partially because we don't have

1076
00:37:58,779 --> 00:37:56,660
many good abiotic production mechanisms

1077
00:38:01,599 --> 00:37:58,789
non biological production mechanisms for

1078
00:38:03,400 --> 00:38:01,609
oxygen but we do for methane and also

1079
00:38:05,109 --> 00:38:03,410
partially because we've been thinking

1080
00:38:07,930 --> 00:38:05,119
really hard about them the woes make

1081
00:38:09,400 --> 00:38:07,940
nature could could make that oxygen we

1082
00:38:11,740 --> 00:38:09,410
haven't been thinking as hard because

1083
00:38:13,750 --> 00:38:11,750
it's kind of a newer proposal for a bio

1084
00:38:16,059 --> 00:38:13,760
signature for this hazy stuff it's it's

1085
00:38:18,549 --> 00:38:16,069
new so and newer stuff in science is

1086
00:38:20,829 --> 00:38:18,559
just in general less tested and that

1087
00:38:23,170 --> 00:38:20,839
idea because it's new is less tested so

1088
00:38:26,769 --> 00:38:23,180

I'm not as confident in it even though

1089
00:38:28,059 --> 00:38:26,779
I'm on the papers that proposed it you

1090
00:38:30,400 --> 00:38:28,069
have to be honest about you know your

1091
00:38:35,140 --> 00:38:30,410
own work too so a great question

1092
00:38:37,059 --> 00:38:35,150
Mike I'm so gram Lao asks very good

1093
00:38:38,950 --> 00:38:37,069
questions I know you are also very

1094
00:38:40,870 --> 00:38:38,960
passionate about science communication

1095
00:38:43,180 --> 00:38:40,880
so communicating the value of science to

1096
00:38:45,549 --> 00:38:43,190
the general public and Graham Lao asks

1097
00:38:47,650 --> 00:38:45,559
having met each other through AB grad

1098
00:38:49,779 --> 00:38:47,660
Khan and same lab which is a science

1099
00:38:51,640 --> 00:38:49,789
communication competition I wonder if

1100
00:38:53,319 --> 00:38:51,650
dr. debacle Goldman could speak to the

1101
00:38:54,789 --> 00:38:53,329
importance of creating networking

1102
00:38:56,920 --> 00:38:54,799
environments for young scientists and

1103
00:39:02,309 --> 00:38:56,930
communicators to share their interests

1104
00:39:04,720 --> 00:39:02,319
and collaborate I think it's essential I

1105
00:39:06,279 --> 00:39:04,730
had even though I was sort of like more

1106
00:39:11,289 --> 00:39:06,289
senior kind of helping like fan lab

1107
00:39:12,910 --> 00:39:11,299
happen I was only a postdoc and I got a

1108
00:39:14,579 --> 00:39:12,920
tremendous amount of value in my own

1109
00:39:16,870 --> 00:39:14,589
career from meeting people like Graham

1110
00:39:18,160 --> 00:39:16,880
through through the fame of activity and

1111
00:39:20,950 --> 00:39:18,170
throughout grad Cohn and other and stuff

1112
00:39:23,380 --> 00:39:20,960
like that and it happens in a number of

1113
00:39:27,370 --> 00:39:23,390

ways one of the most important things I

1114
00:39:30,400 --> 00:39:27,380
think is is having a network of people

1115
00:39:32,349 --> 00:39:30,410
that have shared values to what you have

1116
00:39:33,789 --> 00:39:32,359
and and and and I mean that in a

1117
00:39:37,420 --> 00:39:33,799
professional context right

1118
00:39:38,890 --> 00:39:37,430
I value communication a lot Sanjoy you

1119
00:39:40,539 --> 00:39:38,900
clearly do by putting this show on

1120
00:39:41,920 --> 00:39:40,549
Graham Lau clearly does because of all

1121
00:39:46,000 --> 00:39:41,930
the amazing stuff that he's been doing

1122
00:39:47,920 --> 00:39:46,010
in that space and and seeing scientists

1123
00:39:49,359 --> 00:39:47,930
java arnie here at Goddard is another

1124
00:39:51,190 --> 00:39:49,369
example of someone that's tremendous at

1125
00:39:53,049 --> 00:39:51,200
communicating science C having

1126
00:39:55,270 --> 00:39:53,059
colleagues that really value the same

1127
00:39:56,829 --> 00:39:55,280
things you do is so important for a

1128
00:39:58,750 --> 00:39:56,839
number of reasons one I'm learning from

1129
00:40:01,059 --> 00:39:58,760
watching you and Java and RAM and other

1130
00:40:04,569 --> 00:40:01,069
people communicate and I'm gonna be

1131
00:40:06,789 --> 00:40:04,579
better as a result number two it can be

1132
00:40:09,880 --> 00:40:06,799
hard sometimes to communicate both both

1133
00:40:11,529 --> 00:40:09,890
the the actual act of communication can

1134
00:40:14,589 --> 00:40:11,539
be difficult because we're trying to

1135
00:40:16,210 --> 00:40:14,599
distill really complex stuff and into in

1136
00:40:17,740 --> 00:40:16,220
the language that we can share with

1137
00:40:20,890 --> 00:40:17,750
people beyond the scientific and the

1138
00:40:22,779 --> 00:40:20,900

Disciplinary Enterprise but it's also

1139
00:40:25,240 --> 00:40:22,789
difficult sometimes because it's not

1140
00:40:27,609 --> 00:40:25,250
always valued by our other peers and so

1141
00:40:30,190 --> 00:40:27,619
having that network of people that can

1142
00:40:32,079 --> 00:40:30,200
support you when it's hard and when you

1143
00:40:33,910 --> 00:40:32,089
might be struggling to get the support

1144
00:40:36,670 --> 00:40:33,920
from your institution or from your

1145
00:40:38,260 --> 00:40:36,680
colleagues and and up against the the

1146
00:40:40,029 --> 00:40:38,270
publisher parish pressure which is very

1147
00:40:42,789 --> 00:40:40,039
real in the sciences and having that

1148
00:40:47,140 --> 00:40:42,799
some that moral support is tremendously

1149
00:40:49,359 --> 00:40:47,150
important but then lastly like I I have

1150
00:40:52,120 --> 00:40:49,369
gotten so lucky

1151
00:40:55,059 --> 00:40:52,130
by having colleagues that I love to work

1152
00:40:57,370 --> 00:40:55,069
with that I became basically friends

1153
00:40:58,839 --> 00:40:57,380
with before we were professional

1154
00:41:01,000 --> 00:40:58,849
colleagues right and and it's through

1155
00:41:03,400 --> 00:41:01,010
Fame lab and at grad Khan and the summer

1156
00:41:06,309 --> 00:41:03,410
and winter schools in astrobiology that

1157
00:41:08,890 --> 00:41:06,319
I developed an inherent trust in people

1158
00:41:11,260 --> 00:41:08,900
not just in general but specific people

1159
00:41:12,970 --> 00:41:11,270
like Graham and Sanjay and Giada and

1160
00:41:14,680 --> 00:41:12,980
Sarah Walker and Bay to land like

1161
00:41:17,980 --> 00:41:14,690
there's this wonderful group of people

1162
00:41:19,809 --> 00:41:17,990
that I trust as people as individuals

1163
00:41:22,210 --> 00:41:19,819

that I know have high moral standing

1164
00:41:25,079 --> 00:41:22,220
because I was I developed sort of that

1165
00:41:28,990 --> 00:41:25,089
outside of having to go ask them for

1166
00:41:32,349 --> 00:41:29,000
advice or input or funding or whatever

1167
00:41:35,109 --> 00:41:32,359
in a more professional setting it it's

1168
00:41:36,609 --> 00:41:35,119
really been different for me interacting

1169
00:41:38,200 --> 00:41:36,619
with the people that that I've been

1170
00:41:39,480 --> 00:41:38,210
working with as astrobiologist since

1171
00:41:40,950 --> 00:41:39,490
grad school

1172
00:41:43,799 --> 00:41:40,960
compared to people I've met later in my

1173
00:41:45,540 --> 00:41:43,809
career where I I want to develop that

1174
00:41:48,329 --> 00:41:45,550
trust it's just harder to do once you're

1175
00:41:51,030 --> 00:41:48,339
more advanced in your career so all that

1176
00:41:53,099 --> 00:41:51,040
stuff I think I've benefited from in

1177
00:41:55,530 --> 00:41:53,109
many ways so thanks Graham for the

1178
00:41:58,049 --> 00:41:55,540
question and all your communication work

1179
00:42:00,930 --> 00:41:58,059
and all all the support we're giving

1180
00:42:02,579 --> 00:42:00,940
each other it really excites you as a

1181
00:42:04,440 --> 00:42:02,589
scientist when you share your interest

1182
00:42:06,180 --> 00:42:04,450
and then the public gets excited with

1183
00:42:08,220 --> 00:42:06,190
you it's just like I know it kind of

1184
00:42:10,200 --> 00:42:08,230
elevates you as a scientist and sharing

1185
00:42:12,089 --> 00:42:10,210
your knowledge and what you're excited

1186
00:42:15,660 --> 00:42:12,099
about it's it's a wonderful experience I

1187
00:42:17,640 --> 00:42:15,670
find and it's more fun you know like I

1188
00:42:20,130 --> 00:42:17,650

know scientists that don't always enjoy

1189
00:42:21,809 --> 00:42:20,140
interacting with other people if you're

1190
00:42:22,920 --> 00:42:21,819
maybe that's one of the questions you

1191
00:42:25,309 --> 00:42:22,930
want to ask yourself when I was asking

1192
00:42:28,349 --> 00:42:25,319
like finding a passion I also love

1193
00:42:30,630 --> 00:42:28,359
working with people and and and in that

1194
00:42:32,190 --> 00:42:30,640
sense astrobiology is great because it

1195
00:42:32,730 --> 00:42:32,200
forces you to do that whether you want

1196
00:42:34,650 --> 00:42:32,740
to or not

1197
00:42:36,299 --> 00:42:34,660
and some of the best questions I've had

1198
00:42:39,809 --> 00:42:36,309
in escapology have come from like

1199
00:42:41,299 --> 00:42:39,819
seven-year-olds yeah so it's it's

1200
00:42:45,359 --> 00:42:41,309
amazing

1201
00:42:47,549 --> 00:42:45,369
Omar a lady asks I'm studying general

1202
00:42:50,099 --> 00:42:47,559
biotechnology and I'm also interested in

1203
00:42:52,500 --> 00:42:50,109
botany and astronomy how would I turn

1204
00:42:58,049 --> 00:42:52,510
those interests into a career in

1205
00:42:59,309 --> 00:42:58,059
astrobiology Wow a part so for OMA I

1206
00:43:02,599 --> 00:42:59,319
think it's partially depends on what

1207
00:43:05,190 --> 00:43:02,609
what stage of the career you're at I

1208
00:43:06,920 --> 00:43:05,200
think and it also depends on like what

1209
00:43:10,380 --> 00:43:06,930
your specific tools are you know I

1210
00:43:11,549 --> 00:43:10,390
there's not a lot of botany astrobiology

1211
00:43:14,849 --> 00:43:11,559
although I'll give you a couple examples

1212
00:43:18,079 --> 00:43:14,859
of things that would qualify one is

1213
00:43:21,569 --> 00:43:18,089

people looking at how photosynthesis

1214
00:43:23,730 --> 00:43:21,579
sort of figure out the basic physics of

1215
00:43:26,400 --> 00:43:23,740
how photosynthesis works and then trying

1216
00:43:28,230 --> 00:43:26,410
to then apply those basic principles to

1217
00:43:29,870 --> 00:43:28,240
another planet around another star that

1218
00:43:31,680 --> 00:43:29,880
maybe has a different color distribution

1219
00:43:33,150 --> 00:43:31,690
coming from the star and hitting the

1220
00:43:36,000 --> 00:43:33,160
surface of the planet and then

1221
00:43:37,890 --> 00:43:36,010
predicting what the colors of plants

1222
00:43:39,359 --> 00:43:37,900
might be on that world especially the

1223
00:43:41,609 --> 00:43:39,369
Leafs that are that are that have the

1224
00:43:44,970 --> 00:43:41,619
pigments and them to collect like Nancy

1225
00:43:46,289 --> 00:43:44,980
Kang ki ang is one of the the people

1226
00:43:48,569 --> 00:43:46,299
that's leading thoughts on that

1227
00:43:50,220 --> 00:43:48,579
Nikki paronto is also looking at the

1228
00:43:51,079 --> 00:43:50,230
distribution of pigments in the field

1229
00:43:58,549 --> 00:43:51,089
that

1230
00:43:59,900 --> 00:43:58,559
those two individuals are doing

1231
00:44:01,489 --> 00:43:59,910
there's work out at least a call to

1232
00:44:02,660 --> 00:44:01,499
group also thinking about

1233
00:44:05,719 --> 00:44:02,670
building up a generalized set of

1234
00:44:06,680 --> 00:44:05,729
pigments a library of pigments to look

1235
00:44:08,719 --> 00:44:06,690
at that sort of stuff

1236
00:44:11,779 --> 00:44:08,729
now the biotechnology part of it that's

1237
00:44:13,839 --> 00:44:11,789
you know one thing that a lot of that

1238
00:44:16,729 --> 00:44:13,849

NASA is looking at our public

1239
00:44:18,319 --> 00:44:16,739
public-private partnerships and if

1240
00:44:20,239 --> 00:44:18,329
there's ways for I'm not a bio

1241
00:44:22,910 --> 00:44:20,249
technologist right so I don't I can't

1242
00:44:24,880 --> 00:44:22,920
give you something specific but I would

1243
00:44:27,109 --> 00:44:24,890
be surprised if there wasn't some

1244
00:44:30,200 --> 00:44:27,119
collaboration between biotechnology

1245
00:44:33,380 --> 00:44:30,210
firms that are doing some amazing stuff

1246
00:44:35,029 --> 00:44:33,390
in terms of mass producing using life to

1247
00:44:37,089 --> 00:44:35,039
help mass produce stuff that's otherwise

1248
00:44:40,539 --> 00:44:37,099
hard to make in large quantities

1249
00:44:42,890 --> 00:44:40,549
combined with some astrobiological need

1250
00:44:44,900 --> 00:44:42,900
for you know understanding how some

1251
00:44:46,309 --> 00:44:44,910
specific metabolism works or something

1252
00:44:48,019 --> 00:44:46,319
like that I don't know there's got to be

1253
00:44:50,839 --> 00:44:48,029
some collaboration there I don't know

1254
00:44:52,549 --> 00:44:50,849
what it is if we were in a room full of

1255
00:44:54,380 --> 00:44:52,559
astrobiologists I'd be turning to one of

1256
00:44:56,779 --> 00:44:54,390
the biologists in the room but those are

1257
00:44:58,819 --> 00:44:56,789
my top level answers online Thank You

1258
00:45:00,410 --> 00:44:58,829
Sean Graham asks if you had to make a

1259
00:45:02,719 --> 00:45:00,420
bet what do you think there's a next

1260
00:45:07,039 --> 00:45:02,729
major discovery in the realm of

1261
00:45:10,039 --> 00:45:07,049
astrobiology that's a tough one let me

1262
00:45:11,719 --> 00:45:10,049
let me think on that for a moment so we

1263
00:45:14,509 --> 00:45:11,729

kind of have a good estimate on ATIS of

1264
00:45:20,989 --> 00:45:14,519
birth for exoplanets the stuff coming up

1265
00:45:22,279 --> 00:45:20,999
soon so here let me let me throw out let

1266
00:45:24,499 --> 00:45:22,289
me throw out an observational we're

1267
00:45:25,700 --> 00:45:24,509
gonna be doing that Dec ago one of a few

1268
00:45:28,160 --> 00:45:25,710
ways for it let me answer it for the

1269
00:45:30,259 --> 00:45:28,170
exoplanets specifically when you had to

1270
00:45:31,700 --> 00:45:30,269
be JWST launches

1271
00:45:33,400 --> 00:45:31,710
it's gonna have the chance to look at

1272
00:45:36,319 --> 00:45:33,410
some of these potentially habitable

1273
00:45:38,329 --> 00:45:36,329
worlds around m-type stars now there's a

1274
00:45:39,799 --> 00:45:38,339
lot of folks that are modelers like me

1275
00:45:43,099 --> 00:45:39,809
that are worried about the habitability

1276
00:45:44,329 --> 00:45:43,109
of these planets because the energy from

1277
00:45:45,680 --> 00:45:44,339
there these are stars that are cooler

1278
00:45:47,809 --> 00:45:45,690
than the Sun they're smaller than the

1279
00:45:49,640 --> 00:45:47,819
Sun but they're a lot more like active

1280
00:45:52,880 --> 00:45:49,650
than the Sun and they give off a lot of

1281
00:45:54,440 --> 00:45:52,890
high-energy radiation as a result and

1282
00:45:56,630 --> 00:45:54,450
the planet is going to be pretty close

1283
00:45:57,859 --> 00:45:56,640
to the star because the Stars overall

1284
00:46:00,589 --> 00:45:57,869
cooler which means you have to get

1285
00:46:03,110 --> 00:46:00,599
closer to it to get energy from the star

1286
00:46:05,510 --> 00:46:03,120
to be warm and habitable but

1287
00:46:06,950 --> 00:46:05,520
high-energy is AB larger component of

1288
00:46:08,180 --> 00:46:06,960

that of the total energy from the star

1289
00:46:10,070 --> 00:46:08,190
so you're basically bombarding the

1290
00:46:10,730 --> 00:46:10,080
planet with high-energy radiation all

1291
00:46:12,920 --> 00:46:10,740
the time

1292
00:46:14,540 --> 00:46:12,930
there's modelers that that are worried

1293
00:46:16,160 --> 00:46:14,550
about that on a number a number of

1294
00:46:17,480 --> 00:46:16,170
reasons the most basic is you might

1295
00:46:19,430 --> 00:46:17,490
literally just look kind of like below

1296
00:46:21,140 --> 00:46:19,440
the atmosphere off the world and then

1297
00:46:23,000 --> 00:46:21,150
it's kind of hard to keep a notion on a

1298
00:46:24,500 --> 00:46:23,010
planet without an atmosphere and the

1299
00:46:27,830 --> 00:46:24,510
atmosphere pressure keeping the water

1300
00:46:30,110 --> 00:46:27,840
liquid water stable now that's all a

1301
00:46:32,000 --> 00:46:30,120
model prediction jod BST should be able

1302
00:46:33,860 --> 00:46:32,010
to look at these worlds and see at the

1303
00:46:36,110 --> 00:46:33,870
very least whether or not that model

1304
00:46:38,660 --> 00:46:36,120
prediction is correct if it is and those

1305
00:46:39,740 --> 00:46:38,670
those planets end up being airless it

1306
00:46:42,050 --> 00:46:39,750
means that they're they're gonna be

1307
00:46:43,970 --> 00:46:42,060
really bad about for life if those

1308
00:46:45,410 --> 00:46:43,980
planets have atmospheres then we're

1309
00:46:47,270 --> 00:46:45,420
gonna want to look for signs of life on

1310
00:46:51,770 --> 00:46:47,280
them and that that's gonna happen in a

1311
00:46:53,210 --> 00:46:51,780
few phases 1jd BST potentially this

1312
00:46:55,120 --> 00:46:53,220
aerial mission that Sandra I mentioned

1313
00:46:57,290 --> 00:46:55,130

earlier and eventually and especially

1314
00:46:59,840 --> 00:46:57,300
extremely large telescopes on the ground

1315
00:47:01,610 --> 00:46:59,850
are going to be able to look for signs

1316
00:47:04,370 --> 00:47:01,620
of life on those worlds in those

1317
00:47:06,050 --> 00:47:04,380
atmospheres so the next the next big

1318
00:47:08,960 --> 00:47:06,060
question for exoplanets are is really

1319
00:47:11,420 --> 00:47:08,970
like art and planets around these these

1320
00:47:13,370 --> 00:47:11,430
cooler m-type stars are they bare balls

1321
00:47:14,630 --> 00:47:13,380
of rock or do they retain our

1322
00:47:16,820 --> 00:47:14,640
atmospheres or find some way to

1323
00:47:19,130 --> 00:47:16,830
regenerate them after after this sort of

1324
00:47:21,410 --> 00:47:19,140
hyperactivity phase of this of the its

1325
00:47:24,470 --> 00:47:21,420
host stars died down a little bit that's

1326
00:47:26,330 --> 00:47:24,480
a huge question i I think we probably

1327
00:47:29,780 --> 00:47:26,340
can't answer it until Webb launches but

1328
00:47:31,930 --> 00:47:29,790
we should shortly thereafter I'm gonna

1329
00:47:36,710 --> 00:47:31,940
go with that off the top of my head

1330
00:47:38,870 --> 00:47:36,720
really let me shake ADATA asks if we

1331
00:47:40,910 --> 00:47:38,880
aimed a telescope at an exoplanet far

1332
00:47:42,560 --> 00:47:40,920
far away how would we know the chemical

1333
00:47:43,880 --> 00:47:42,570
composition of its atmosphere at present

1334
00:47:45,830 --> 00:47:43,890
a burst of the planet's atmosphere

1335
00:47:49,580 --> 00:47:45,840
composition at some distant time in the

1336
00:47:51,080 --> 00:47:49,590
past so that's it I like that because

1337
00:47:52,580 --> 00:47:51,090
one of the things we talk about it as

1338
00:47:54,470 --> 00:47:52,590

astronomers is like how far away the

1339
00:47:56,390 --> 00:47:54,480
targets are and how long ago the the

1340
00:47:59,980 --> 00:47:56,400
light left that world now I'll tell you

1341
00:48:02,960 --> 00:47:59,990
to be honest whether or not we found

1342
00:48:05,930 --> 00:48:02,970
life that was on a planet some number of

1343
00:48:07,130 --> 00:48:05,940
years ago that's now gone because the

1344
00:48:08,780 --> 00:48:07,140
light took so long to get here or

1345
00:48:11,870 --> 00:48:08,790
whether we found it in like literally

1346
00:48:13,460 --> 00:48:11,880
today existing today as an

1347
00:48:15,410 --> 00:48:13,470
astrobiologist that's just trying to eat

1348
00:48:18,450 --> 00:48:15,420
it the question of are we alone

1349
00:48:19,859 --> 00:48:18,460
it is it's not as important as just

1350
00:48:21,930 --> 00:48:19,869
finding the pal signatures in the first

1351
00:48:23,910 --> 00:48:21,940
place I'd be just as happy to find you

1352
00:48:26,220 --> 00:48:23,920
no evidence of life from a billion years

1353
00:48:28,140 --> 00:48:26,230
ago take Mars for example right we we

1354
00:48:29,789 --> 00:48:28,150
send Rovers to Mars all the time and

1355
00:48:32,549 --> 00:48:29,799
that's mostly to look for signs of

1356
00:48:35,099 --> 00:48:32,559
extinct life on Mars with with some

1357
00:48:36,839 --> 00:48:35,109
exceptions if we found evidence of

1358
00:48:38,220 --> 00:48:36,849
extinct life on Mars from 3 billion

1359
00:48:40,380 --> 00:48:38,230
years ago even if it wasn't crawling

1360
00:48:41,670 --> 00:48:40,390
around on the surface I would be you

1361
00:48:42,839 --> 00:48:41,680
know popping a bubble champagne and

1362
00:48:46,680 --> 00:48:42,849
celebrating because it would be huge

1363
00:48:49,170 --> 00:48:46,690

news for astrobiology that all said it

1364
00:48:50,339 --> 00:48:49,180
actually is not that big of a delay you

1365
00:48:51,690 --> 00:48:50,349
know a lot of times you hear about these

1366
00:48:53,759 --> 00:48:51,700
stories of light coming from distant

1367
00:48:56,549 --> 00:48:53,769
galaxies where the light left billions

1368
00:48:59,069 --> 00:48:56,559
of years ago because these observations

1369
00:49:01,200 --> 00:48:59,079
of exoplanets are so hard especially for

1370
00:49:03,509 --> 00:49:01,210
the potentially earth-like ones that are

1371
00:49:05,609 --> 00:49:03,519
small and relatively dim we're only

1372
00:49:07,079 --> 00:49:05,619
gonna be able to do this in our local

1373
00:49:08,819 --> 00:49:07,089
stellar neighborhood so we're not going

1374
00:49:11,099 --> 00:49:08,829
to be looking at this for distant

1375
00:49:12,450 --> 00:49:11,109
galaxies we're really not even looking

1376
00:49:14,489 --> 00:49:12,460
for it in stars that are on the other

1377
00:49:17,249 --> 00:49:14,499
side of our galaxy this is gonna be sort

1378
00:49:18,900 --> 00:49:17,259
of in our neighborhood I like the

1379
00:49:20,940 --> 00:49:18,910
analogy I get here is like we've been

1380
00:49:21,930 --> 00:49:20,950
living in this neighborhood as a planet

1381
00:49:22,499 --> 00:49:21,940
for like you know four-and-a-half

1382
00:49:24,269 --> 00:49:22,509
billion years

1383
00:49:25,739 --> 00:49:24,279
and we're finally gonna get out and

1384
00:49:27,779 --> 00:49:25,749
knock on the door of the neighbors and

1385
00:49:30,390 --> 00:49:27,789
just see who's home but it's only gonna

1386
00:49:32,789 --> 00:49:30,400
be within a radius of I think something

1387
00:49:35,690 --> 00:49:32,799
like you know 10 to a 50 light-years or

1388
00:49:38,249 --> 00:49:35,700

so and that even that's stretching it so

1389
00:49:39,720 --> 00:49:38,259
you know we're only going to be looking

1390
00:49:42,329 --> 00:49:39,730
for light that's coming from like a year

1391
00:49:47,130 --> 00:49:42,339
ago 250 years ago when it left that

1392
00:49:48,299 --> 00:49:47,140
exoplanet sonant if you had unlimited

1393
00:49:51,059 --> 00:49:48,309
resources

1394
00:49:57,210 --> 00:49:51,069
what astrobiology project would you

1395
00:50:03,089 --> 00:49:57,220
choose to do and why if I had unlimited

1396
00:50:05,720 --> 00:50:03,099
resources I well if it's truly unlimited

1397
00:50:08,249 --> 00:50:05,730
I don't have to choose and then I do a

1398
00:50:11,579 --> 00:50:08,259
coordinated search for life on Mars and

1399
00:50:13,289 --> 00:50:11,589
the icy worlds and on exoplanets and

1400
00:50:15,329 --> 00:50:13,299
everywhere in between

1401
00:50:18,059 --> 00:50:15,339
but but if I have to choose one project

1402
00:50:22,170 --> 00:50:18,069
I would I would do leVoir and for a

1403
00:50:23,430 --> 00:50:22,180
number of reasons the one of the things

1404
00:50:25,289 --> 00:50:23,440
that people get excited about when they

1405
00:50:26,789 --> 00:50:25,299
think about life beyond Earth is you

1406
00:50:29,049 --> 00:50:26,799
know

1407
00:50:32,289 --> 00:50:29,059
civilizations right like complex life

1408
00:50:35,890 --> 00:50:32,299
doing interviews and tweeting on another

1409
00:50:37,630 --> 00:50:35,900
world that's not possible in our solar

1410
00:50:39,309 --> 00:50:37,640
system right we there might be life on

1411
00:50:41,529 --> 00:50:39,319
Mars or on Europa or extinct life on

1412
00:50:44,260 --> 00:50:41,539
Mars but they're not tweeting or doing

1413
00:50:46,089 --> 00:50:44,270

anything remotely like it but is at

1414
00:50:47,740 --> 00:50:46,099
least the possibility that more complex

1415
00:50:49,210 --> 00:50:47,750
advanced forms of life exist on these

1416
00:50:51,190 --> 00:50:49,220
planets beyond Earth so there's I think

1417
00:50:52,269 --> 00:50:51,200
a huge public interest in doing the

1418
00:50:53,799 --> 00:50:52,279
search for life on exoplanets

1419
00:50:56,049 --> 00:50:53,809
specifically now we're not looking for

1420
00:50:57,549 --> 00:50:56,059
that intelligent life but we're looking

1421
00:50:59,740 --> 00:50:57,559
for the kinds of BIOS crews that would

1422
00:51:02,140 --> 00:50:59,750
at least allow for the second is just

1423
00:51:04,930 --> 00:51:02,150
the sheer sample size that we're gonna

1424
00:51:06,250 --> 00:51:04,940
get from from looking not just on one

1425
00:51:09,339 --> 00:51:06,260
target but looking on a number of

1426
00:51:11,289 --> 00:51:09,349
targets up to up to 50 or 60 potentially

1427
00:51:14,069 --> 00:51:11,299
earth-like worlds and looking for

1428
00:51:17,470 --> 00:51:14,079
biosignatures on a survey of samples and

1429
00:51:19,630 --> 00:51:17,480
thirdly I think this stuff we learn from

1430
00:51:22,029 --> 00:51:19,640
that mission regardless of whether or

1431
00:51:24,579 --> 00:51:22,039
not we find life on those planets is

1432
00:51:28,660 --> 00:51:24,589
going to profoundly impact the way we

1433
00:51:31,599 --> 00:51:28,670
think about earth-like planets we've

1434
00:51:33,250 --> 00:51:31,609
learned a lot about Earth by looking at

1435
00:51:36,640 --> 00:51:33,260
other planets in our solar system and

1436
00:51:38,890 --> 00:51:36,650
yet earth is the only planet for which

1437
00:51:40,059 --> 00:51:38,900
we have a stable liquid water ocean and

1438
00:51:43,059 --> 00:51:40,069

it's the only planet for which we have

1439
00:51:45,490 --> 00:51:43,069
life even if we don't find concrete

1440
00:51:47,140 --> 00:51:45,500
evidence of life on potentially

1441
00:51:49,750 --> 00:51:47,150
habitable which means ocean bearing or

1442
00:51:51,130 --> 00:51:49,760
potentially ocean drink worlds on these

1443
00:51:53,680 --> 00:51:51,140
exoplanets we look for it even if we

1444
00:51:55,569 --> 00:51:53,690
fail we are gonna learn so much more

1445
00:51:58,150 --> 00:51:55,579
about how planets with oceans will

1446
00:52:00,490 --> 00:51:58,160
liquid water oceans at the surface

1447
00:52:03,220 --> 00:52:00,500
operate that I think it's gonna really

1448
00:52:04,960 --> 00:52:03,230
impact the way we think about earth 50

1449
00:52:08,410 --> 00:52:04,970
years from now and that's even if we

1450
00:52:10,539 --> 00:52:08,420
fail in our search for life on top of

1451
00:52:11,740 --> 00:52:10,549
all that as an astrobiologist I love not

1452
00:52:13,660 --> 00:52:11,750
just the search for life but putting it

1453
00:52:16,150 --> 00:52:13,670
in the context of like the cosmic

1454
00:52:17,980 --> 00:52:16,160
origins in the history of how earth-like

1455
00:52:20,170 --> 00:52:17,990
planets came to be and lavars going to

1456
00:52:21,880 --> 00:52:20,180
do a number of things in terms of the

1457
00:52:24,279 --> 00:52:21,890
origins of stars and planets in the way

1458
00:52:26,019 --> 00:52:24,289
that matter gets recycled in a galaxy

1459
00:52:27,640 --> 00:52:26,029
and beyond a galaxy to even create the

1460
00:52:29,920 --> 00:52:27,650
conditions that are ripe for star

1461
00:52:31,420 --> 00:52:29,930
formation in the first place and it's

1462
00:52:33,549 --> 00:52:31,430
gonna help us with the other missions

1463
00:52:35,260 --> 00:52:33,559

we're doing to Europa and Mars because

1464
00:52:37,240 --> 00:52:35,270
we can point our telescopes at those

1465
00:52:37,730 --> 00:52:37,250
objects in the solar system we can look

1466
00:52:39,620 --> 00:52:37,740
for

1467
00:52:42,050 --> 00:52:39,630
I think on you know measure methane

1468
00:52:44,200 --> 00:52:42,060
concentrations in with good spatial

1469
00:52:47,510 --> 00:52:44,210
resolution across the Martian surface

1470
00:52:48,920 --> 00:52:47,520
and do that basically whatnot whenever

1471
00:52:52,010 --> 00:52:48,930
we want but but more or less whenever we

1472
00:52:53,900 --> 00:52:52,020
want we can help look for geysers on

1473
00:52:55,460 --> 00:52:53,910
Europa or Enceladus that we could send

1474
00:52:58,310 --> 00:52:55,470
other spacecraft to fly through and

1475
00:53:03,140 --> 00:52:58,320
collect samples for lavars kind of like

1476
00:53:04,820 --> 00:53:03,150
a super awesome fancy pocket knife for

1477
00:53:06,020 --> 00:53:04,830
astrobiology or whatever you need it's

1478
00:53:08,210 --> 00:53:06,030
gonna have a tool to help you out with

1479
00:53:09,920 --> 00:53:08,220
it which is the other reason if I could

1480
00:53:12,830 --> 00:53:09,930
do one thing for astrobiology that that

1481
00:53:16,070 --> 00:53:12,840
would be it fingers crossed where that

1482
00:53:19,010 --> 00:53:16,080
the mission flies indeed we have a

1483
00:53:20,630 --> 00:53:19,020
question from Facebook who asks where do

1484
00:53:23,180 --> 00:53:20,640
you think we will find extraterrestrial

1485
00:53:29,720 --> 00:53:23,190
life first somewhere in the solar system

1486
00:53:32,150 --> 00:53:29,730
or an extrasolar planet so let me let me

1487
00:53:35,810 --> 00:53:32,160
pack off my assumptions of whether or

1488
00:53:38,330 --> 00:53:35,820

not there is life on particular targets

1489
00:53:40,070 --> 00:53:38,340
let's just assume for the sake of my

1490
00:53:41,660 --> 00:53:40,080
answer that there's life on Mars that

1491
00:53:44,390 --> 00:53:41,670
there's life on Europa and there's life

1492
00:53:48,890 --> 00:53:44,400
on Enceladus and that there's there's

1493
00:53:50,900 --> 00:53:48,900
life on these exoplanets my guess is

1494
00:53:55,040 --> 00:53:50,910
that we probably have the best shot at

1495
00:53:56,990 --> 00:53:55,050
finding it on Europa first although it

1496
00:53:58,849 --> 00:53:57,000
you know the amazing thing about this is

1497
00:54:01,250 --> 00:53:58,859
we're talking about doing all this stuff

1498
00:54:02,870 --> 00:54:01,260
almost at the same time right like you

1499
00:54:05,090 --> 00:54:02,880
know that the NASA is talking about

1500
00:54:06,620 --> 00:54:05,100
sending and and private companies are

1501
00:54:08,870 --> 00:54:06,630
talking about sending people to Mars

1502
00:54:10,190 --> 00:54:08,880
in the next 20 to 30 years we're talking

1503
00:54:12,950 --> 00:54:10,200
about bringing samples back from Mars

1504
00:54:14,990 --> 00:54:12,960
and potentially analyzing samples at

1505
00:54:17,210 --> 00:54:15,000
Europa including liquid water Europa

1506
00:54:18,620 --> 00:54:17,220
maybe Enceladus and we're talking about

1507
00:54:20,750 --> 00:54:18,630
these big space telescopes that would

1508
00:54:22,550 --> 00:54:20,760
look for biosignatures on exoplanets all

1509
00:54:24,830 --> 00:54:22,560
that stuff you know you know it's not

1510
00:54:26,240 --> 00:54:24,840
like one's happening next year and the

1511
00:54:27,800 --> 00:54:26,250
others happening 50 years from now we're

1512
00:54:30,020 --> 00:54:27,810
talking about all of these missions on

1513
00:54:32,060 --> 00:54:30,030

the timescale of some time between ten

1514
00:54:34,670 --> 00:54:32,070
years from now and thirty years from now

1515
00:54:37,070 --> 00:54:34,680
and whether one's gonna be ten versus

1516
00:54:39,470 --> 00:54:37,080
thirty is dependent on like budgets and

1517
00:54:40,849 --> 00:54:39,480
you know the space politics and like

1518
00:54:41,960 --> 00:54:40,859
what missions get prioritized and stuff

1519
00:54:44,120 --> 00:54:41,970
like that

1520
00:54:45,570 --> 00:54:44,130
it could be any one of them first to be

1521
00:54:47,550 --> 00:54:45,580
honest

1522
00:54:51,390 --> 00:54:47,560
and and the thing that's really cool to

1523
00:54:54,450 --> 00:54:51,400
me is thinking about how exoplanet

1524
00:54:57,000 --> 00:54:54,460
discoveries are going to be informed by

1525
00:54:59,820 --> 00:54:57,010
what we do or do not find on Mars and

1526
00:55:02,390 --> 00:54:59,830
what we do or do not find in Europa and

1527
00:55:04,380 --> 00:55:02,400
Enceladus and vice versa how exoplanet

1528
00:55:05,940 --> 00:55:04,390
exploration is going to impact what we

1529
00:55:07,980 --> 00:55:05,950
think about the discoveries on Mars or

1530
00:55:09,110 --> 00:55:07,990
Europa Enceladus or other worlds closer

1531
00:55:11,430 --> 00:55:09,120
to home

1532
00:55:15,180 --> 00:55:11,440
that's that's one of the things that

1533
00:55:17,400 --> 00:55:15,190
that I think is currently under 30 - in

1534
00:55:20,970 --> 00:55:17,410
astrobiology because we've been thinking

1535
00:55:22,830 --> 00:55:20,980
so deeply about how to find life in any

1536
00:55:25,740 --> 00:55:22,840
particular target and the missions we

1537
00:55:28,320 --> 00:55:25,750
designed to do that I think we haven't

1538
00:55:29,670 --> 00:55:28,330

thought enough about what we'd learn

1539
00:55:32,040 --> 00:55:29,680
from one target and how that would

1540
00:55:34,200 --> 00:55:32,050
inform our search for life on another

1541
00:55:35,400 --> 00:55:34,210
target we're starting to but I think

1542
00:55:37,110 --> 00:55:35,410
that's that's one of the things if

1543
00:55:39,120 --> 00:55:37,120
you're a student and it's really

1544
00:55:40,290 --> 00:55:39,130
interested in astrobiology that someone

1545
00:55:42,600 --> 00:55:40,300
could come in and make it really cool

1546
00:55:44,910 --> 00:55:42,610
impact especially because some of these

1547
00:55:46,380 --> 00:55:44,920
agnostic quantitative bio signatures

1548
00:55:50,370 --> 00:55:46,390
that Sarah Walker and other people have

1549
00:55:52,860 --> 00:55:50,380
proposed actually open up the door for

1550
00:55:54,870 --> 00:55:52,870
us to be making more comparisons across

1551
00:55:57,300 --> 00:55:54,880
these very different targets with

1552
00:56:00,780 --> 00:55:57,310
otherwise very different observational

1553
00:56:02,550 --> 00:56:00,790
techniques wonderful well Sean we're out

1554
00:56:05,160 --> 00:56:02,560
of time for the rest of the questions

1555
00:56:07,140 --> 00:56:05,170
but hopefully canyou can join up on say

1556
00:56:08,880 --> 00:56:07,150
Gannett and answer them there I'm so

1557
00:56:10,140 --> 00:56:08,890
grateful for the time you took to spend

1558
00:56:13,710 --> 00:56:10,150
with us today I know you're an extremely

1559
00:56:15,330 --> 00:56:13,720
busy scientist and you know thanks from

1560
00:56:17,460 --> 00:56:15,340
all of us it's been a wonderful chat

1561
00:56:19,050 --> 00:56:17,470
with you this morning and afternoon or

1562
00:56:19,890 --> 00:56:19,060
evening depending on where you are and

1563
00:56:22,500 --> 00:56:19,900

where you're watching this

1564
00:56:24,990 --> 00:56:22,510
but take care of yourself and we all see

1565
00:56:26,880 --> 00:56:25,000
you we will all see you next month for

1566
00:56:29,210 --> 00:56:26,890
Aston astrobiologists and until then