
Searching For
Habitable Worlds
A Special Panel Discussion
Laramie • Wyoming

1
00:00:08,490 --> 00:00:12,459
[Music]

2
00:00:18,080 --> 00:00:15,799
hello and welcome my name is Hannah Jane

3
00:00:20,359 --> 00:00:18,090
Condell and I'm an associate professor

4
00:00:21,529 --> 00:00:20,369
at the University of Wyoming and today

5
00:00:23,480 --> 00:00:21,539
we're coming to you from the University

6
00:00:25,429 --> 00:00:23,490
of Wyoming campus here in Laramie

7
00:00:28,910 --> 00:00:25,439
Wyoming where we just concluded

8
00:00:31,130 --> 00:00:28,920
habitable worlds 2017 a system science

9
00:00:34,010 --> 00:00:31,140
workshop this was a week-long conference

10
00:00:35,650 --> 00:00:34,020
supported in part by NASA throughout

11
00:00:37,760 --> 00:00:35,660
this week we've been having

12
00:00:41,060 --> 00:00:37,770
cross-disciplinary discussions between

13
00:00:43,970 --> 00:00:41,070

astronomers planetary scientists earth

14
00:00:45,560 --> 00:00:43,980
scientists and others about what kinds

15
00:00:48,200 --> 00:00:45,570
of planets might be capable of

16
00:00:50,930 --> 00:00:48,210
supporting life and how we might be able

17
00:00:54,380 --> 00:00:50,940
to actually find them I'd like to

18
00:00:56,959 --> 00:00:54,390
introduce Elizabeth Tasker of JAXA Japan

19
00:00:58,130 --> 00:00:56,969
aerospace exploration agency who will be

20
00:01:00,410 --> 00:00:58,140
moderating today's panel discussion

21
00:01:03,709 --> 00:01:00,420
about habitability and life in the

22
00:01:06,740 --> 00:01:03,719
universe thank you very much so we have

23
00:01:09,530 --> 00:01:06,750
now found over three and a half thousand

24
00:01:12,980 --> 00:01:09,540
exoplanets planets orbiting stars beyond

25
00:01:14,570 --> 00:01:12,990
our own Sun and roughly one third of

26
00:01:17,570 --> 00:01:14,580
these have sizes that are less than

27
00:01:19,249 --> 00:01:17,580
about twice the size of the earth so

28
00:01:21,980 --> 00:01:19,259
this has led to the next inevitable

29
00:01:24,980 --> 00:01:21,990
question could any of these actually be

30
00:01:27,050 --> 00:01:24,990
a habitable planets so with me today I

31
00:01:29,749 --> 00:01:27,060
have three scientists who are working on

32
00:01:32,749 --> 00:01:29,759
this exact issue with NASA on my far

33
00:01:35,780 --> 00:01:32,759
left I have dad irani an astrobiologist

34
00:01:38,660 --> 00:01:35,790
at NASA Goddard Space Flight Center next

35
00:01:41,120 --> 00:01:38,670
to her is Andrew rush be a nasa nexus

36
00:01:44,870 --> 00:01:41,130
postdoctoral fellow in residence at nasa

37
00:01:48,130 --> 00:01:44,880
ames and co-host of the XO cast podcast

38
00:01:50,300 --> 00:01:48,140

and on my right I have a key Robert

39
00:01:52,760 --> 00:01:50,310
astrophysicist at NASA Goddard Space

40
00:01:53,510 --> 00:01:52,770
Flight Center and the study scientist

41
00:01:58,310 --> 00:01:53,520
for the Louvois

42
00:02:00,230 --> 00:01:58,320
survey concept study so let's start with

43
00:02:02,330 --> 00:02:00,240
a question about habitability itself

44
00:02:04,490 --> 00:02:02,340
this is a term that we all have some

45
00:02:06,800 --> 00:02:04,500
familiarity with but what does it really

46
00:02:09,930 --> 00:02:06,810
mean when we talk about a habitable

47
00:02:14,820 --> 00:02:11,700
well I suppose I'll start since I have a

48
00:02:16,710 --> 00:02:14,830
mic when we think about habitability in

49
00:02:18,660 --> 00:02:16,720
terms of exoplanets what we're really

50
00:02:21,150 --> 00:02:18,670
thinking about is planets that have

51
00:02:23,070 --> 00:02:21,160
liquid water on their surface because we

52
00:02:25,710 --> 00:02:23,080
know that liquid water is a requirement

53
00:02:27,210 --> 00:02:25,720
of all life on earth and so this is our

54
00:02:29,340 --> 00:02:27,220
starting point for when we start to

55
00:02:34,080 --> 00:02:29,350
think about what habitability might mean

56
00:02:36,840 --> 00:02:34,090
elsewhere in the galaxy yes and so we're

57
00:02:38,670 --> 00:02:36,850
very focused on the question of liquid

58
00:02:40,740 --> 00:02:38,680
water because as Jo said it seems

59
00:02:43,650 --> 00:02:40,750
essential but I guess it's important to

60
00:02:46,680 --> 00:02:43,660
understand that it that is probably a

61
00:02:49,110 --> 00:02:46,690
necessary but not sufficient condition

62
00:02:51,210 --> 00:02:49,120
for a planet to actually be a have a

63
00:02:53,760 --> 00:02:51,220

living biosphere so and we're only

64
00:02:56,160 --> 00:02:53,770
really just actually starting to

65
00:02:58,080 --> 00:02:56,170
understand all the different factors

66
00:03:00,750 --> 00:02:58,090
that come into play that make the earth

67
00:03:06,240 --> 00:03:00,760
habitable over billions and billions of

68
00:03:07,230 --> 00:03:06,250
years yeah as Aki mentioned when we look

69
00:03:08,790 --> 00:03:07,240
at when we think about a habitable

70
00:03:11,820 --> 00:03:08,800
planet we really only have one to go on

71
00:03:13,440 --> 00:03:11,830
and that's the earth so usually when we

72
00:03:15,090 --> 00:03:13,450
frame a question about habitability it's

73
00:03:18,330 --> 00:03:15,100
thinking about an earth-like planet it's

74
00:03:21,000 --> 00:03:18,340
sometimes used in place of that phrase

75
00:03:22,500 --> 00:03:21,010
so liquid water is important having an

76
00:03:24,120 --> 00:03:22,510
atmosphere that's something like the

77
00:03:26,160 --> 00:03:24,130
earth is sometimes considered to be

78
00:03:29,220 --> 00:03:26,170
important but again not a necessary

79
00:03:31,590 --> 00:03:29,230
prerequisite so it's a very complex and

80
00:03:34,620 --> 00:03:31,600
interconnected phrase that actually has

81
00:03:36,900 --> 00:03:34,630
a lot to unpack now when we hear about

82
00:03:39,840 --> 00:03:36,910
exoplanet discoveries on the news we

83
00:03:42,210 --> 00:03:39,850
often hear this term habitable zone now

84
00:03:44,250 --> 00:03:42,220
what does this actually mean when we are

85
00:03:48,070 --> 00:03:44,260
looking for exoplanets and considering

86
00:03:55,850 --> 00:03:53,270
it's it it's a it's a the habitable zone

87
00:03:58,100 --> 00:03:55,860
okay it's straight-up definition it

88
00:04:02,120 --> 00:03:58,110

probably it is it is the region around a

89
00:04:05,270 --> 00:04:02,130
star where a planet might be able to

90
00:04:07,100 --> 00:04:05,280
have liquid water on its surface or I

91
00:04:11,030 --> 00:04:07,110
think somebody at this workshop put it

92
00:04:13,070 --> 00:04:11,040
differently a few days ago it's outside

93
00:04:15,200 --> 00:04:13,080
of the habitable zone we know that the

94
00:04:17,570 --> 00:04:15,210
planets cannot have liquid water on

95
00:04:21,860 --> 00:04:17,580
their surface so it's basically a

96
00:04:23,690 --> 00:04:21,870
balance between how much the light

97
00:04:27,290 --> 00:04:23,700
coming from the star it C would warm you

98
00:04:28,730 --> 00:04:27,300
up and how much you radiate away how

99
00:04:30,620 --> 00:04:28,740
much the planet rady you know radiates

100
00:04:32,540 --> 00:04:30,630
away so it's sort of like a it's like a

101
00:04:34,280 --> 00:04:32,550
it's like a like a warm zone around a

102
00:04:36,680 --> 00:04:34,290
campfire so if you have a really bright

103
00:04:38,660 --> 00:04:36,690
you have a really bright star you know

104
00:04:40,790 --> 00:04:38,670
the habitable zone would move away from

105
00:04:42,020 --> 00:04:40,800
the star to cool things down so it

106
00:04:45,050 --> 00:04:42,030
didn't get too hot if you have a really

107
00:04:47,090 --> 00:04:45,060
small cool star like a what we call em

108
00:04:49,280 --> 00:04:47,100
dwarf stars the habitable zone has to

109
00:04:52,100 --> 00:04:49,290
sort of huddle in towards the campfire

110
00:04:55,070 --> 00:04:52,110
just to keep the planet warm and it's

111
00:04:57,140 --> 00:04:55,080
it's um it's probably not the only place

112
00:04:58,670 --> 00:04:57,150
obviously though around a star that you

113
00:05:01,460 --> 00:04:58,680

could have liquid water or maybe

114
00:05:04,490 --> 00:05:01,470
habitable conditions it it is basically

115
00:05:07,490 --> 00:05:04,500
though probably the only kind of planet

116
00:05:08,600 --> 00:05:07,500
planets in the habitable zone exoplanets

117
00:05:10,040 --> 00:05:08,610
in the habitable zone with like water on

118
00:05:12,050 --> 00:05:10,050
their surface are probably the only kind

119
00:05:14,090 --> 00:05:12,060
of habitable environment that we'll be

120
00:05:18,320 --> 00:05:14,100
able to detect that we will be able to

121
00:05:19,450 --> 00:05:18,330
see from interstellar distances yeah

122
00:05:22,100 --> 00:05:19,460
that's a great description the

123
00:05:24,560 --> 00:05:22,110
astronomical observable nature of this

124
00:05:26,270 --> 00:05:24,570
is what makes it very useful but just to

125
00:05:28,160 --> 00:05:26,280
build on - and what you said about small

126
00:05:30,350 --> 00:05:28,170
stars and larger stars and how that

127
00:05:32,720 --> 00:05:30,360
affects the distance this distance also

128
00:05:35,150 --> 00:05:32,730
changes over time as the star itself you

129
00:05:37,970 --> 00:05:35,160
know ages so the red dwarf stars that

130
00:05:40,610 --> 00:05:37,980
arc you mentioned they they evolve very

131
00:05:42,530 --> 00:05:40,620
slowly so they may have habitable zones

132
00:05:42,890 --> 00:05:42,540
that are relatively stable in time and

133
00:05:46,210 --> 00:05:42,900
space

134
00:05:48,530 --> 00:05:46,220
and whereas sun-like stars like the Sun

135
00:05:50,090 --> 00:05:48,540
they actually evolve relatively quickly

136
00:05:53,060 --> 00:05:50,100
and astronomical terms which means

137
00:05:55,370 --> 00:05:53,070
they're habitable zone moves outwards

138
00:05:57,230 --> 00:05:55,380

over time which has implications for any

139
00:06:00,380 --> 00:05:57,240
planets that we might be considering to

140
00:06:03,030 --> 00:06:00,390
be habitable within those zones

141
00:06:04,260 --> 00:06:03,040
yeah all of that is great and in

142
00:06:07,020 --> 00:06:04,270
addition to that I would just emphasize

143
00:06:09,060 --> 00:06:07,030
the practicality of the definition of

144
00:06:12,240 --> 00:06:09,070
the habitable zone the habitable zone

145
00:06:13,920 --> 00:06:12,250
allows us to focus our searches when we

146
00:06:16,680 --> 00:06:13,930
start to look for life on distant

147
00:06:18,360 --> 00:06:16,690
planets it gives us a place for where we

148
00:06:20,280 --> 00:06:18,370
can start looking where we know that

149
00:06:23,340 --> 00:06:20,290
this condition of surface liquid water

150
00:06:25,890 --> 00:06:23,350
is possible and so it's it's useful from

151
00:06:27,450 --> 00:06:25,900
a pragmatic standpoint because it allows

152
00:06:29,880 --> 00:06:27,460
us to you know not have to search

153
00:06:32,670 --> 00:06:29,890
everywhere but just search in a smaller

154
00:06:34,230 --> 00:06:32,680
area around the star so what we're

155
00:06:36,240 --> 00:06:34,240
saying is the habitable zone is more

156
00:06:38,700 --> 00:06:36,250
like a searching zone for finding

157
00:06:40,590 --> 00:06:38,710
possible habitable planets as opposed to

158
00:06:42,330 --> 00:06:40,600
offering any guarantee that a planet

159
00:06:46,710 --> 00:06:42,340
within the habitable zone will in fact

160
00:06:48,510 --> 00:06:46,720
be habitable absolutely yes now based on

161
00:06:50,909 --> 00:06:48,520
what you said about how it has to be

162
00:06:52,590 --> 00:06:50,919
like this warm region around the star I

163
00:06:55,050 --> 00:06:52,600

think we've assumed earth-like

164
00:06:56,850 --> 00:06:55,060
conditions for changing that radiation

165
00:06:59,400 --> 00:06:56,860
the planets receiving at that campfire

166
00:07:02,460 --> 00:06:59,410
points to what the surface conditions

167
00:07:04,050 --> 00:07:02,470
will be like so that means that the

168
00:07:05,760 --> 00:07:04,060
surface conditions on the planet if

169
00:07:08,190 --> 00:07:05,770
they're not like earth could be quite

170
00:07:12,920 --> 00:07:08,200
different so what do we know currently

171
00:07:17,450 --> 00:07:12,930
about surfaces of these exoplanets

172
00:07:19,710 --> 00:07:17,460
approximately nothing right now the

173
00:07:22,800 --> 00:07:19,720
techniques that we use to discover

174
00:07:24,570 --> 00:07:22,810
exoplanets today they're they're what we

175
00:07:25,980 --> 00:07:24,580
call indirect techniques so what we're

176
00:07:27,690 --> 00:07:25,990
actually doing we're not so much we're

177
00:07:31,860 --> 00:07:27,700
not so much seeing the planet itself

178
00:07:35,190 --> 00:07:31,870
we're seeing the impact the effect of

179
00:07:36,870 --> 00:07:35,200
that planet on its host star and so for

180
00:07:38,700 --> 00:07:36,880
example one of the most common

181
00:07:42,360 --> 00:07:38,710
techniques is the transit technique so

182
00:07:45,719 --> 00:07:42,370
this is when if you're do that transit

183
00:07:49,920 --> 00:07:45,729
of Venus that happened not too long ago

184
00:07:52,110 --> 00:07:49,930
but if we have the right orientation to

185
00:07:54,210 --> 00:07:52,120
this to the system sometimes a planet

186
00:07:56,700 --> 00:07:54,220
will pass in front of its star and we'll

187
00:07:58,380 --> 00:07:56,710
see a dip in its light and that's how

188
00:08:00,530 --> 00:07:58,390

like that the vast majority of

189
00:08:04,050 --> 00:08:00,540
exoplanets have been discovered to date

190
00:08:05,550 --> 00:08:04,060
but as far as we get their size from

191
00:08:07,770 --> 00:08:05,560
that measurement and in with other

192
00:08:09,690 --> 00:08:07,780
techniques we can get maybe a mass but

193
00:08:12,439 --> 00:08:09,700
that's mostly what we've got right now

194
00:08:14,640 --> 00:08:12,449
so really

195
00:08:19,620 --> 00:08:14,650
exoplanets right now are largely small

196
00:08:20,700 --> 00:08:19,630
black shadows to us and we really find

197
00:08:23,189 --> 00:08:20,710
out what they're really like we need to

198
00:08:25,650 --> 00:08:23,199
turn those small black shadows into a

199
00:08:27,210 --> 00:08:25,660
rainbow of colored dots in the sky and

200
00:08:32,370 --> 00:08:27,220
actually start to understand what they

201
00:08:34,230 --> 00:08:32,380
are like and I love that answer and I

202
00:08:36,120 --> 00:08:34,240
love the phrase small black shadows and

203
00:08:38,850 --> 00:08:36,130
one of the ways that we're starting to

204
00:08:40,219 --> 00:08:38,860
prepare for making these observations of

205
00:08:43,199 --> 00:08:40,229
exoplanets that would turn them into

206
00:08:45,720 --> 00:08:43,209
rainbow dots is using models to try to

207
00:08:47,850 --> 00:08:45,730
predict what their surfaces and

208
00:08:49,620 --> 00:08:47,860
atmospheres might be made out of so that

209
00:08:53,280 --> 00:08:49,630
we can anticipate what we might be

210
00:08:54,750 --> 00:08:53,290
looking for that's a great point and I'm

211
00:08:57,960 --> 00:08:54,760
pleased you put up atmospheres actually

212
00:08:58,889 --> 00:08:57,970
because I future missions are public and

213
00:09:01,889 --> 00:08:58,899

be able to give us some information

214
00:09:04,290 --> 00:09:01,899
about planetary atmospheres and from the

215
00:09:05,610 --> 00:09:04,300
lessons we've learned about the earth we

216
00:09:07,980 --> 00:09:05,620
know that the atmosphere and the surface

217
00:09:10,019 --> 00:09:07,990
and the oceans are intimately connected

218
00:09:11,850 --> 00:09:10,029
and if we can determine something about

219
00:09:13,079 --> 00:09:11,860
the composition of the atmosphere we

220
00:09:14,730 --> 00:09:13,089
might be able to say something about

221
00:09:16,530 --> 00:09:14,740
what's going on in the surface of the

222
00:09:19,740 --> 00:09:16,540
planets or in its oceans if it has any

223
00:09:21,540 --> 00:09:19,750
oceans or even in its interior so at the

224
00:09:23,250 --> 00:09:21,550
moment yes we know approximately nothing

225
00:09:25,350 --> 00:09:23,260
about their services especially if

226
00:09:28,410 --> 00:09:25,360
they're small planets but that might

227
00:09:30,360 --> 00:09:28,420
change very soon so to really discover

228
00:09:33,090 --> 00:09:30,370
if these four black shadows in the

229
00:09:34,710 --> 00:09:33,100
habitable zone earth-like enough that

230
00:09:36,930 --> 00:09:34,720
liquid water could exist on their

231
00:09:39,300 --> 00:09:36,940
surface we need to get a glimpse of

232
00:09:41,040 --> 00:09:39,310
what's going on down there what future

233
00:09:45,900 --> 00:09:41,050
missions do we have in the works that

234
00:09:50,460 --> 00:09:45,910
will give us a bit more information all

235
00:09:52,500 --> 00:09:50,470
right so first up coming is the will be

236
00:09:56,190 --> 00:09:52,510
the James Webb Space Telescope so this

237
00:09:59,250 --> 00:09:56,200
is NASA's next really sort of a large

238
00:10:04,949 --> 00:09:59,260

strategic mission launch date in we are

239
00:10:06,389 --> 00:10:04,959
in 20 it's in 2018 29:20 19 it is a it

240
00:10:08,790 --> 00:10:06,399
has a large six and a half metre

241
00:10:11,310 --> 00:10:08,800
telescope diameter telescope it will

242
00:10:15,600 --> 00:10:11,320
observe at infrared wavelengths so these

243
00:10:18,660 --> 00:10:15,610
are his heat radiation basically and it

244
00:10:20,699 --> 00:10:18,670
was not in fact originally planned or

245
00:10:25,079 --> 00:10:20,709
designed to study planets around other

246
00:10:25,230 --> 00:10:25,089
stars but it can and it can do it will

247
00:10:26,730 --> 00:10:25,240
be

248
00:10:31,070 --> 00:10:26,740
wants to do it quite well and it will it

249
00:10:34,530 --> 00:10:31,080
will be our first pulse our first real

250
00:10:37,500 --> 00:10:34,540
tool that will allow us to actually

251
00:10:41,040 --> 00:10:37,510
probe the atmospheres of a lot of

252
00:10:44,269 --> 00:10:41,050
planets around other stars a lot of warm

253
00:10:48,449 --> 00:10:44,279
jupiter-sized planets and warm Saturn's

254
00:10:51,180 --> 00:10:48,459
Neptune's and probably down to what we

255
00:10:52,949 --> 00:10:51,190
would call super Earths so planets that

256
00:10:56,420 --> 00:10:52,959
are you know a little you know a couple

257
00:10:58,620 --> 00:10:56,430
of times more bigger than the earth so

258
00:11:02,400 --> 00:10:58,630
that's that's what's that's the first

259
00:11:04,440 --> 00:11:02,410
thing coming up but it will the James

260
00:11:06,900 --> 00:11:04,450
Webb Space Telescope it will study the

261
00:11:09,329 --> 00:11:06,910
atmospheres of exoplanets by measuring

262
00:11:10,650 --> 00:11:09,339
the light when I went to when a planet

263
00:11:12,389 --> 00:11:10,660

passes in front of its star it'll

264
00:11:15,480 --> 00:11:12,399
measure the light that passed through

265
00:11:19,889 --> 00:11:15,490
the atmosphere of the planet and it's

266
00:11:21,840 --> 00:11:19,899
that's called transit spectroscopy I we

267
00:11:24,780 --> 00:11:21,850
think that if we really want to get down

268
00:11:27,440 --> 00:11:24,790
to those true earth twins those earth

269
00:11:29,579 --> 00:11:27,450
sized planets around sun-like stars

270
00:11:32,880 --> 00:11:29,589
we're probably going to need a different

271
00:11:36,000 --> 00:11:32,890
technique where we finally just block

272
00:11:38,190 --> 00:11:36,010
out the star like putting your hand over

273
00:11:39,660 --> 00:11:38,200
the star to see something faint right

274
00:11:44,000 --> 00:11:39,670
next to it and actually take a real

275
00:11:48,600 --> 00:11:44,010
picture of the planet so and see it as

276
00:11:50,340 --> 00:11:48,610
hopefully pale blue dots and so but to

277
00:11:53,370 --> 00:11:50,350
do that you have to suppress the light

278
00:11:57,930 --> 00:11:53,380
from that bright star by ten billion

279
00:11:59,940 --> 00:11:57,940
times that's a lot and but we we have I

280
00:12:01,650 --> 00:11:59,950
think we know how to do this there are

281
00:12:04,170 --> 00:12:01,660
instruments called coronagraphs and

282
00:12:08,400 --> 00:12:04,180
others called star shades that are being

283
00:12:12,300 --> 00:12:08,410
developed by nasa and what's coming up

284
00:12:14,160 --> 00:12:12,310
next is on the w first mission that is

285
00:12:17,880 --> 00:12:14,170
supposed to launch in the sort of mid

286
00:12:20,460 --> 00:12:17,890
2020s will carry NASA's first really

287
00:12:23,060 --> 00:12:20,470
advanced coronagraph into space this is

288
00:12:26,910 --> 00:12:23,070

a technology demonstration instrument

289
00:12:29,250 --> 00:12:26,920
that will hopefully advance advanced

290
00:12:33,840 --> 00:12:29,260
this technique this hardware this tool

291
00:12:37,949 --> 00:12:33,850
to the point where after that we will be

292
00:12:39,030 --> 00:12:37,959
able to to design and build some of

293
00:12:41,370 --> 00:12:39,040
these other mission cons

294
00:12:43,290 --> 00:12:41,380
that we've been talking about this week

295
00:12:45,600 --> 00:12:43,300
one of them is called have X the

296
00:12:47,550 --> 00:12:45,610
habitable exoplanet imaging mission and

297
00:12:49,230 --> 00:12:47,560
the other one we've talked about is

298
00:12:51,660 --> 00:12:49,240
called leVoir and that stands for a

299
00:12:53,730 --> 00:12:51,670
large UV optical infrared surveyor and

300
00:12:55,889 --> 00:12:53,740
that's the study scientist for that

301
00:12:58,019 --> 00:12:55,899
mission concept but both of those

302
00:13:00,499 --> 00:12:58,029
missions those are really aimed there

303
00:13:04,530 --> 00:13:00,509
killer app is to actually go out there

304
00:13:05,970 --> 00:13:04,540
take pictures of those small small

305
00:13:08,670 --> 00:13:05,980
planets and the habitable zones of

306
00:13:10,410 --> 00:13:08,680
nearby sun-like stars and take do

307
00:13:12,210 --> 00:13:10,420
spectroscopy on their atmospheres and

308
00:13:14,999 --> 00:13:12,220
find out what are the molecules in those

309
00:13:17,220 --> 00:13:15,009
atmospheres and maybe even see like the

310
00:13:19,439 --> 00:13:17,230
colors of their surfaces and maybe if

311
00:13:21,749 --> 00:13:19,449
they have continents or oceans and make

312
00:13:24,960 --> 00:13:21,759
maps and everything so but that's a

313
00:13:26,639 --> 00:13:24,970

that's a down the road of peace so based

314
00:13:28,800 --> 00:13:26,649
on what you said I'm hearing two

315
00:13:30,389 --> 00:13:28,810
different techniques for really trying

316
00:13:32,689 --> 00:13:30,399
to explore the surface of these planets

317
00:13:35,370 --> 00:13:32,699
one is this atmosphere spectroscopy

318
00:13:37,199 --> 00:13:35,380
where the Starlight filters through the

319
00:13:39,689 --> 00:13:37,209
planet's atmosphere and due to certain

320
00:13:41,519 --> 00:13:39,699
molecules in that atmosphere certain

321
00:13:43,920 --> 00:13:41,529
wavelengths are missing because those

322
00:13:46,160 --> 00:13:43,930
molecules absorb so you get would you

323
00:13:49,470 --> 00:13:46,170
describe it as a fingerprint perhaps of

324
00:13:51,240 --> 00:13:49,480
molecules in that atmosphere yeah

325
00:13:53,400 --> 00:13:51,250
certainly yeah that that's yeah

326
00:13:56,220 --> 00:13:53,410
spectroscopy is is is that it's

327
00:13:59,129 --> 00:13:56,230
basically um you know molecules

328
00:14:01,639 --> 00:13:59,139
molecules will will will absorb well

329
00:14:04,939 --> 00:14:01,649
like suck up certain colors of light and

330
00:14:07,800 --> 00:14:04,949
different molecules you know suck up

331
00:14:09,329 --> 00:14:07,810
specific colors and that makes a

332
00:14:12,750 --> 00:14:09,339
fingerprint of that molecule and the

333
00:14:14,460 --> 00:14:12,760
light that you collect so yeah and then

334
00:14:16,439 --> 00:14:14,470
the second technique was actually to say

335
00:14:18,750 --> 00:14:16,449
let's look at the planet directly so

336
00:14:20,460 --> 00:14:18,760
direct imaging and the challenge there

337
00:14:22,860 --> 00:14:20,470
is that stars are really bright and

338
00:14:24,629 --> 00:14:22,870

planets are really dim so you have to

339
00:14:26,309 --> 00:14:24,639
use this chronograph to block out the

340
00:14:29,009 --> 00:14:26,319
star's light so that we can see the

341
00:14:30,840 --> 00:14:29,019
planets yeah and actually there's kind

342
00:14:33,420 --> 00:14:30,850
of a subtle point about this too is that

343
00:14:36,059 --> 00:14:33,430
so the Earth's really faint like I said

344
00:14:38,280 --> 00:14:36,069
it's ten billion times fainter than the

345
00:14:41,730 --> 00:14:38,290
Sun but astronomers we have observed

346
00:14:44,400 --> 00:14:41,740
things in the sky that faint before we

347
00:14:47,490 --> 00:14:44,410
definitely have so that is not the real

348
00:14:51,360 --> 00:14:47,500
problem is how close that faint dot is

349
00:14:52,590 --> 00:14:51,370
to this crazy bright star so for example

350
00:14:54,720 --> 00:14:52,600
if you are looking at the earth

351
00:14:57,840 --> 00:14:54,730
at the solar system from a distance of

352
00:15:01,530 --> 00:14:57,850
33 light years the the separation

353
00:15:03,780 --> 00:15:01,540
between the Sun and the earth is what is

354
00:15:06,030 --> 00:15:03,790
a 0.1 arc seconds okay what is that

355
00:15:08,370 --> 00:15:06,040
really that is its approximate that's

356
00:15:11,900 --> 00:15:08,380
about the width of a human hair at the

357
00:15:16,710 --> 00:15:11,910
distance of two football fields so

358
00:15:18,480 --> 00:15:16,720
that's what we have to do great

359
00:15:21,360 --> 00:15:18,490
so Elizabeth I know we're talking about

360
00:15:23,220 --> 00:15:21,370
future missions and surface environments

361
00:15:25,170 --> 00:15:23,230
but I feel like I should just mention

362
00:15:27,360 --> 00:15:25,180
the fact that the the Kepler space

363
00:15:29,400 --> 00:15:27,370

mission which just recently ended has

364
00:15:31,680 --> 00:15:29,410
got a wealth of data that's still

365
00:15:34,290 --> 00:15:31,690
available to be analyzed and while we

366
00:15:36,450 --> 00:15:34,300
can't certainly see the surface of the

367
00:15:39,240 --> 00:15:36,460
planets that Kepler has detected having

368
00:15:41,700 --> 00:15:39,250
a large sample of planets can provide us

369
00:15:43,710 --> 00:15:41,710
with a huge amount of information about

370
00:15:46,230 --> 00:15:43,720
their population and we've already

371
00:15:48,120 --> 00:15:46,240
getting to the point where we can start

372
00:15:50,220 --> 00:15:48,130
noticing trends in how planets are built

373
00:15:51,930 --> 00:15:50,230
where they're built and what we might

374
00:15:54,300 --> 00:15:51,940
not be able to see their their surfaces

375
00:15:56,400 --> 00:15:54,310
we can use models for example computer

376
00:15:57,930 --> 00:15:56,410
simulations with the information that

377
00:15:59,940 --> 00:15:57,940
we're getting from these large databases

378
00:16:01,770 --> 00:15:59,950
that can come from Kepler and the

379
00:16:05,220 --> 00:16:01,780
upcoming test mission they're transiting

380
00:16:07,170 --> 00:16:05,230
exoplanet survey satellite to improve

381
00:16:09,950 --> 00:16:07,180
our understanding of the general

382
00:16:11,790 --> 00:16:09,960
processes that build the planets

383
00:16:13,410 --> 00:16:11,800
absolutely so we're not done with a

384
00:16:15,150 --> 00:16:13,420
current data we've got and we've got

385
00:16:16,350 --> 00:16:15,160
similar data coming up but could you

386
00:16:20,640 --> 00:16:16,360
tell us a bit more about the test

387
00:16:22,860 --> 00:16:20,650
mission I'm by no means an expert so I

388
00:16:25,800 --> 00:16:22,870

can't go into any detail about it but it

389
00:16:29,280 --> 00:16:25,810
will it's it's going to be a satellite

390
00:16:33,930 --> 00:16:29,290
level survey I think almost the entire

391
00:16:37,050 --> 00:16:33,940
sky to look for to look for exoplanets

392
00:16:39,570 --> 00:16:37,060
using the transit method I Aki mentioned

393
00:16:41,730 --> 00:16:39,580
and it's going to provide some

394
00:16:43,800 --> 00:16:41,740
interesting follow-up planets almost

395
00:16:46,230 --> 00:16:43,810
certainly for things like James Webb and

396
00:16:49,460 --> 00:16:46,240
W first and the future missions as well

397
00:16:51,600 --> 00:16:49,470
as adding to that this growing pool of

398
00:16:55,680 --> 00:16:51,610
exoplanet statistics and data that we

399
00:16:57,540 --> 00:16:55,690
already have well those are great

400
00:16:59,850 --> 00:16:57,550
answers is there's not allowed to add in

401
00:17:02,160 --> 00:16:59,860
terms of future missions but I think

402
00:17:04,380 --> 00:17:02,170
it's really exciting to think about the

403
00:17:05,100 --> 00:17:04,390
fact that if there is a habitable planet

404
00:17:07,980 --> 00:17:05,110
in

405
00:17:10,230 --> 00:17:07,990
nearby galaxies we have the potential to

406
00:17:11,939 --> 00:17:10,240
actually know about it in just a couple

407
00:17:14,130 --> 00:17:11,949
years to maybe a few decades from now

408
00:17:15,630 --> 00:17:14,140
and for the first time in human history

409
00:17:17,850 --> 00:17:15,640
we might know that we're not alone in

410
00:17:21,390 --> 00:17:17,860
the universe I think it's incredibly

411
00:17:23,460 --> 00:17:21,400
exciting so that is that is quite the

412
00:17:25,410 --> 00:17:23,470
goal but here's the question when we get

413
00:17:27,179 --> 00:17:25,420

these new instruments online and we're

414
00:17:29,580 --> 00:17:27,189
starting to see something about their

415
00:17:31,020 --> 00:17:29,590
surface conditions either by looking at

416
00:17:32,730 --> 00:17:31,030
their atmosphere and seeing the

417
00:17:34,830 --> 00:17:32,740
molecules that are there or even

418
00:17:37,169 --> 00:17:34,840
catching a sight of the light emitted by

419
00:17:38,760 --> 00:17:37,179
the planet through direct imaging how

420
00:17:44,400 --> 00:17:38,770
would we know that the planet was

421
00:17:46,530 --> 00:17:44,410
habitable so as we mentioned earlier to

422
00:17:49,169 --> 00:17:46,540
be habitable you need to have surface

423
00:17:50,789 --> 00:17:49,179
liquid water that's central to our

424
00:17:53,789 --> 00:17:50,799
understanding of planetary habitability

425
00:17:55,560 --> 00:17:53,799
and we can use different techniques to

426
00:17:57,990 --> 00:17:55,570
try to probe whether there's liquid

427
00:17:59,490 --> 00:17:58,000
water on the surface of an exoplanet for

428
00:18:02,490 --> 00:17:59,500
example we could look for the

429
00:18:04,289 --> 00:18:02,500
fingerprints of water in the light

430
00:18:06,120 --> 00:18:04,299
spectrum that we get from the planets

431
00:18:07,530 --> 00:18:06,130
and if we see water vapor in the

432
00:18:09,060 --> 00:18:07,540
atmosphere that might be a clue that

433
00:18:11,669 --> 00:18:09,070
there might be abundant water on the

434
00:18:15,030 --> 00:18:11,679
surface we could also look for direct

435
00:18:17,340 --> 00:18:15,040
signs of liquid surface water everyone

436
00:18:19,320 --> 00:18:17,350
who's stood at a beach at sunset is

437
00:18:21,570 --> 00:18:19,330
familiar with glint when you see the Sun

438
00:18:22,470 --> 00:18:21,580

setting and you see all the beautiful

439
00:18:24,180 --> 00:18:22,480
rays of light

440
00:18:26,850 --> 00:18:24,190
you know scattering off the surface of

441
00:18:28,590 --> 00:18:26,860
the ocean this is called glint and we

442
00:18:31,530 --> 00:18:28,600
could actually look for glint on an

443
00:18:33,840 --> 00:18:31,540
exoplanet you see glint most strongly

444
00:18:36,060 --> 00:18:33,850
when a planet is at Crescent phase so

445
00:18:38,250 --> 00:18:36,070
when the planet is less than half way

446
00:18:40,320 --> 00:18:38,260
illuminated that's the most optical time

447
00:18:42,210 --> 00:18:40,330
to see glint and so we were able to

448
00:18:44,340 --> 00:18:42,220
catch these planets during Crescent

449
00:18:45,960 --> 00:18:44,350
phase we might see this glint effect

450
00:18:47,340 --> 00:18:45,970
that would allow us to say oh hey we

451
00:18:49,740 --> 00:18:47,350
think there's an ocean on that planet

452
00:18:51,990 --> 00:18:49,750
this planet might be habitable another

453
00:18:55,049 --> 00:18:52,000
way of doing this is again with modeling

454
00:18:57,480 --> 00:18:55,059
if we could use the spectrum or that the

455
00:18:59,700 --> 00:18:57,490
fingerprint of the planet to identify

456
00:19:01,980 --> 00:18:59,710
greenhouse gases in that planet's

457
00:19:04,230 --> 00:19:01,990
atmosphere we could then try to

458
00:19:06,450 --> 00:19:04,240
constrain how much greenhouse gases we

459
00:19:08,340 --> 00:19:06,460
think are present and then use climate

460
00:19:10,470 --> 00:19:08,350
models to try to infer what the likely

461
00:19:12,780 --> 00:19:10,480
surface temperature of that planet might

462
00:19:14,490 --> 00:19:12,790
be and so that might give us a hint as

463
00:19:17,280 --> 00:19:14,500

to whether liquid surface water is

464
00:19:18,330 --> 00:19:17,290
likely to be stable on the planet so

465
00:19:19,060 --> 00:19:18,340
there's there's all sorts of different

466
00:19:23,259 --> 00:19:19,070
techniques

467
00:19:24,519 --> 00:19:23,269
we're gonna use to tackle this that's a

468
00:19:26,350 --> 00:19:24,529
fantastic answer I don't know what I

469
00:19:27,700 --> 00:19:26,360
what more I can add to it apart from to

470
00:19:30,430 --> 00:19:27,710
maybe throw a bit of a spanner in the

471
00:19:32,019 --> 00:19:30,440
works and and think about some of the

472
00:19:33,940 --> 00:19:32,029
outer solar system moons that we have in

473
00:19:35,409 --> 00:19:33,950
our solar system that are in the

474
00:19:38,860 --> 00:19:35,419
habitable zone and they don't have any

475
00:19:40,180 --> 00:19:38,870
surface liquid water but many planetary

476
00:19:41,830 --> 00:19:40,190
scientists and many folks who've been

477
00:19:45,879 --> 00:19:41,840
here at the conference would consider

478
00:19:48,519 --> 00:19:45,889
them possibly to be to host a habitable

479
00:19:51,730 --> 00:19:48,529
warm liquid water ocean beneath a thick

480
00:19:53,740 --> 00:19:51,740
ice crust so it really speaks to the

481
00:19:55,570 --> 00:19:53,750
complexities of trying to detect

482
00:19:58,509 --> 00:19:55,580
habitable environments from a great

483
00:19:59,619 --> 00:19:58,519
distance when there's no surface liquid

484
00:20:00,970 --> 00:19:59,629
water and they're outside the habitable

485
00:20:03,340 --> 00:20:00,980
zone they're very very small moons

486
00:20:05,350 --> 00:20:03,350
covered in ice and so it's it's possible

487
00:20:09,999 --> 00:20:05,360
that we might be missing a few habitable

488
00:20:11,980 --> 00:20:10,009

environments in our search here yeah I

489
00:20:15,009 --> 00:20:11,990
mean that and that reminds me of

490
00:20:17,710 --> 00:20:15,019
something that I often say when I'm you

491
00:20:19,450 --> 00:20:17,720
know talking to even two astronomers

492
00:20:22,299 --> 00:20:19,460
actually to just to remind everybody

493
00:20:25,330 --> 00:20:22,309
that the earth is special in the solar

494
00:20:27,190 --> 00:20:25,340
system it's there there you know there

495
00:20:29,049 --> 00:20:27,200
may be other habitable environments we

496
00:20:32,289 --> 00:20:29,059
even within the solar system in the

497
00:20:34,539 --> 00:20:32,299
Europa under the ice shell of Europa or

498
00:20:37,930 --> 00:20:34,549
and Enceladus on the moons of the outer

499
00:20:40,450 --> 00:20:37,940
moons around outer planets but the earth

500
00:20:43,360 --> 00:20:40,460
is the only is the only world in the

501
00:20:46,690 --> 00:20:43,370
solar system that has surface life that

502
00:20:48,610 --> 00:20:46,700
is so abundant it is changing the total

503
00:20:51,669 --> 00:20:48,620
bulk chemistry of the whole atmosphere

504
00:20:53,830 --> 00:20:51,679
and to a great extent it's not that

505
00:20:55,450 --> 00:20:53,840
astronomers or but astrobiologists don't

506
00:20:56,230 --> 00:20:55,460
think that there can be other kinds of

507
00:20:59,830 --> 00:20:56,240
life out there

508
00:21:02,369 --> 00:20:59,840
it's just earth-like a life is probably

509
00:21:04,869 --> 00:21:02,379
the only kind of life that we can detect

510
00:21:06,519 --> 00:21:04,879
from interstellar distances it has to be

511
00:21:09,460 --> 00:21:06,529
surface light it has to be life that's

512
00:21:13,810 --> 00:21:09,470
so abundant that is actually changing

513
00:21:16,210 --> 00:21:13,820

the atmosphere of the planet I'm hearing

514
00:21:18,279 --> 00:21:16,220
is that habitability is not enough what

515
00:21:20,710 --> 00:21:18,289
we're looking at is detectability of

516
00:21:22,810 --> 00:21:20,720
that habitability and I think that is a

517
00:21:24,460 --> 00:21:22,820
topic that came up quite a few times a

518
00:21:26,740 --> 00:21:24,470
conference like yes we could imagine

519
00:21:28,750 --> 00:21:26,750
these subsurface environments that could

520
00:21:31,149 --> 00:21:28,760
support life but at the end of the day

521
00:21:32,320 --> 00:21:31,159
if you can't detect those remotely that

522
00:21:34,840 --> 00:21:32,330
is without sending

523
00:21:36,399 --> 00:21:34,850
some kind of probe then effectively the

524
00:21:40,330 --> 00:21:36,409
client is uninhabitable as far as we're

525
00:21:41,500 --> 00:21:40,340
concerned so what I'm also seeing is

526
00:21:43,600 --> 00:21:41,510
that planets are these very

527
00:21:45,789 --> 00:21:43,610
interconnected systems we're looking for

528
00:21:47,380 --> 00:21:45,799
maybe for a biological signature but

529
00:21:49,539 --> 00:21:47,390
we're also going to be seeing you know

530
00:21:51,669 --> 00:21:49,549
signs of the oceans signs of the geology

531
00:21:53,830 --> 00:21:51,679
or the planets and these are all

532
00:21:56,169 --> 00:21:53,840
intertwined not only in the signature

533
00:21:58,509 --> 00:21:56,179
that we detect but also in supporting

534
00:22:00,399 --> 00:21:58,519
one another and allowing biology to

535
00:22:04,299 --> 00:22:00,409
exist through having an active

536
00:22:06,430 --> 00:22:04,309
geological planets so when we get a a

537
00:22:09,580 --> 00:22:06,440
signature from the atmosphere or a glint

538
00:22:11,350 --> 00:22:09,590

how do we untangle what we're seeing and

539
00:22:15,549 --> 00:22:11,360
maybe distinguish habitable from

540
00:22:17,919 --> 00:22:15,559
inhabited what a great question well it

541
00:22:20,710 --> 00:22:17,929
all comes back to modeling again planets

542
00:22:23,289 --> 00:22:20,720
are extremely complicated systems of

543
00:22:25,570 --> 00:22:23,299
many interacting processes as you said

544
00:22:27,850 --> 00:22:25,580
and it is very hard to disentangle these

545
00:22:29,620 --> 00:22:27,860
processes when we look at the history of

546
00:22:32,470 --> 00:22:29,630
life on Earth we see that life is

547
00:22:34,000 --> 00:22:32,480
inextricably linked to the conditions of

548
00:22:37,389 --> 00:22:34,010
our planet in the atmosphere of our

549
00:22:39,639 --> 00:22:37,399
planet we are ultimately trying to

550
00:22:41,409 --> 00:22:39,649
search for these things called bio

551
00:22:43,779 --> 00:22:41,419
signatures in the atmospheres of

552
00:22:46,870 --> 00:22:43,789
exoplanets which are gases that are

553
00:22:48,279 --> 00:22:46,880
produced by life on a planet that build

554
00:22:50,169 --> 00:22:48,289
up in a planet's atmosphere to

555
00:22:54,190 --> 00:22:50,179
detectable quantities that we could look

556
00:22:55,720 --> 00:22:54,200
for with our telescopes one excellent

557
00:22:59,919 --> 00:22:55,730
example of a bio signature is something

558
00:23:01,419 --> 00:22:59,929
that we all need we are all taking

559
00:23:03,730 --> 00:23:01,429
advantage of the fact right now that

560
00:23:06,220 --> 00:23:03,740
life is a planetary process because

561
00:23:08,139 --> 00:23:06,230
we're all breathing oxygen and the

562
00:23:10,570 --> 00:23:08,149
oxygen that we're breathing was produced

563
00:23:12,460 --> 00:23:10,580

by life it's produced by photosynthesis

564
00:23:15,810 --> 00:23:12,470
it's you know it's a metabolic

565
00:23:19,289 --> 00:23:15,820
by-product that plant life and you know

566
00:23:22,000 --> 00:23:19,299
bacterial life that photosynthesizes

567
00:23:24,100 --> 00:23:22,010
emits this oxygen that has built up in

568
00:23:27,070 --> 00:23:24,110
our planet's atmosphere and dramatically

569
00:23:28,930 --> 00:23:27,080
has you know altered the character of

570
00:23:31,330 --> 00:23:28,940
our planet's atmosphere over geological

571
00:23:32,560 --> 00:23:31,340
timescales and so this is what Aki was

572
00:23:34,299 --> 00:23:32,570
talking about earlier when we think

573
00:23:37,000 --> 00:23:34,309
about life we're really thinking about

574
00:23:39,159 --> 00:23:37,010
something that could modify its

575
00:23:41,200 --> 00:23:39,169
environment on a global level and we're

576
00:23:43,870 --> 00:23:41,210
looking for those global modifications

577
00:23:45,670 --> 00:23:43,880
there's some cases where it's a little

578
00:23:48,280 --> 00:23:45,680
bit more tricky to disentangle the

579
00:23:49,770 --> 00:23:48,290
biology from the non biology for example

580
00:23:53,050 --> 00:23:49,780
there's methane in our atmosphere

581
00:23:55,330 --> 00:23:53,060
nothing can be produced by both life and

582
00:23:56,560 --> 00:23:55,340
non-life it can be produced by geology

583
00:23:58,900 --> 00:23:56,570
and biology

584
00:24:00,820 --> 00:23:58,910
so if you see methane in a planet's

585
00:24:02,110 --> 00:24:00,830
atmosphere its it's a little tricky to

586
00:24:05,620 --> 00:24:02,120
try to figure out where it might be

587
00:24:08,830 --> 00:24:05,630
coming from but at the same time life

588
00:24:10,690 --> 00:24:08,840

that produces methane modifies the

589
00:24:12,730 --> 00:24:10,700
planets habitability because methane is

590
00:24:14,500 --> 00:24:12,740
a greenhouse gas and so if you have a

591
00:24:16,030 --> 00:24:14,510
lot of methane producing organisms you

592
00:24:17,770 --> 00:24:16,040
might actually start to produce

593
00:24:19,960 --> 00:24:17,780
feedbacks on the temperature of the

594
00:24:21,340 --> 00:24:19,970
planet it's the same with oxygen oxygen

595
00:24:23,100 --> 00:24:21,350
actually modifies the planet's

596
00:24:26,080 --> 00:24:23,110
habitability because it can form ozone

597
00:24:28,960 --> 00:24:26,090
so ozone in our atmosphere forms from

598
00:24:29,770 --> 00:24:28,970
oxygen through complicated chemistry and

599
00:24:32,080 --> 00:24:29,780
ozone

600
00:24:34,210 --> 00:24:32,090
blocks damaging ultraviolet radiation

601
00:24:36,760 --> 00:24:34,220
from reaching the surface so in a way it

602
00:24:39,910 --> 00:24:36,770
the oxygen in our atmosphere protects us

603
00:24:43,050 --> 00:24:39,920
so it really is hard to disentangle all

604
00:24:46,690 --> 00:24:43,060
these things are so interconnected

605
00:24:48,640 --> 00:24:46,700
fantastic answer and the disentangling

606
00:24:50,710 --> 00:24:48,650
of life and the planet and planetary

607
00:24:53,080 --> 00:24:50,720
processes can even be a little bit more

608
00:24:54,520 --> 00:24:53,090
subtle than you know the gases in the

609
00:24:56,500 --> 00:24:54,530
atmosphere for example if we look at the

610
00:24:58,330 --> 00:24:56,510
carbonate silicate cycle which is a

611
00:25:02,170 --> 00:24:58,340
geological cycle that regulates how much

612
00:25:03,850 --> 00:25:02,180
co2 is in the atmosphere life affects

613
00:25:07,390 --> 00:25:03,860

that cycle and pretty much every stage

614
00:25:09,340 --> 00:25:07,400
so in the atmosphere how how the the

615
00:25:11,350 --> 00:25:09,350
surface is weathered and how that

616
00:25:13,840 --> 00:25:11,360
liberates materials that are then washed

617
00:25:15,520 --> 00:25:13,850
into the ocean which life in the ocean

618
00:25:17,260 --> 00:25:15,530
then then then modifies the amount of

619
00:25:19,570 --> 00:25:17,270
co2 in the atmosphere at every single

620
00:25:22,150 --> 00:25:19,580
stage in this process life is involved

621
00:25:23,650 --> 00:25:22,160
somehow and in some of my work that it's

622
00:25:25,720 --> 00:25:23,660
actually very difficult to remove life

623
00:25:27,690 --> 00:25:25,730
from this process because ideally we'd

624
00:25:29,740 --> 00:25:27,700
like to we'd like to understand if

625
00:25:31,510 --> 00:25:29,750
something like the carbonate silicate

626
00:25:34,240 --> 00:25:31,520
cycle could operate on a planet without

627
00:25:35,950 --> 00:25:34,250
life but we only have one planet to go

628
00:25:38,980 --> 00:25:35,960
on and it's very difficult to remove

629
00:25:40,390 --> 00:25:38,990
life for example plant life on the

630
00:25:43,900 --> 00:25:40,400
surface out of other planet is very

631
00:25:45,910 --> 00:25:43,910
effective at accelerating chemical

632
00:25:47,710 --> 00:25:45,920
weathering so that's the breaking down

633
00:25:49,570 --> 00:25:47,720
of them of the rocks of the of the

634
00:25:51,850 --> 00:25:49,580
continental crust and this is useful

635
00:25:53,920 --> 00:25:51,860
because that materials and washed into

636
00:25:56,440 --> 00:25:53,930
the ocean where organisms like for manna

637
00:25:58,510 --> 00:25:56,450
for a tiny little sea creatures then use

638
00:25:59,830 --> 00:25:58,520

that to to build our shells and

639
00:26:02,350 --> 00:25:59,840
they do that they extract co2 from the

640
00:26:07,180 --> 00:26:02,360
atmosphere so it's it's so difficult to

641
00:26:09,460 --> 00:26:07,190
remove life from from the process yep so

642
00:26:12,160 --> 00:26:09,470
yeah so I'm I'm more of an astronomer in

643
00:26:15,250 --> 00:26:12,170
than an astrobiologist and so for my

644
00:26:16,930 --> 00:26:15,260
more simple thinking about this this is

645
00:26:19,120 --> 00:26:16,940
how I kind of how I think about what we

646
00:26:20,650 --> 00:26:19,130
need to do what we're going to do okay

647
00:26:22,900 --> 00:26:20,660
so we're gonna we're going to make as

648
00:26:24,850 --> 00:26:22,910
many a bunch of measurements about these

649
00:26:26,530 --> 00:26:24,860
exoplanets hopefully what are the what

650
00:26:28,210 --> 00:26:26,540
are the gases and their atmospheres what

651
00:26:30,610 --> 00:26:28,220
are their surface temperatures that that

652
00:26:33,160 --> 00:26:30,620
up that uh we're gonna make a model and

653
00:26:36,160 --> 00:26:33,170
try to explain what we see and we'll

654
00:26:38,770 --> 00:26:36,170
start with okay is this physics mmm no

655
00:26:41,350 --> 00:26:38,780
is this chemistry mm-hmm

656
00:26:43,330 --> 00:26:41,360
no ok still can't explain it what's what

657
00:26:44,200 --> 00:26:43,340
other what other science is left in the

658
00:26:46,510 --> 00:26:44,210
building well

659
00:26:47,800 --> 00:26:46,520
biology haha that's that's what we're

660
00:26:49,600 --> 00:26:47,810
gonna and that is how kind of how it's

661
00:26:51,970 --> 00:26:49,610
gonna be we're gonna basically you know

662
00:26:53,920 --> 00:26:51,980
try to explain try to explain what we

663
00:26:56,140 --> 00:26:53,930

see with non-life with physics and

664
00:26:58,810 --> 00:26:56,150
chemistry until we can't until we fail

665
00:27:02,320 --> 00:26:58,820
and then we will have succeeded in

666
00:27:07,000 --> 00:27:02,330
finding bio signatures kind of how I

667
00:27:10,810 --> 00:27:07,010
like to think about it I I think that's

668
00:27:12,220 --> 00:27:10,820
a great answer so I see we're using the

669
00:27:19,000 --> 00:27:12,230
earth a lot I mean we've only got

670
00:27:21,520 --> 00:27:19,010
obviously one planet so so we already

671
00:27:23,590 --> 00:27:21,530
got one planet where we've got life

672
00:27:25,300 --> 00:27:23,600
there and therefore we're using the

673
00:27:27,160 --> 00:27:25,310
signatures that we know are coming from

674
00:27:29,710 --> 00:27:27,170
life and how they interact with our own

675
00:27:32,890 --> 00:27:29,720
geochemical cycles to help build our

676
00:27:35,320 --> 00:27:32,900
model but the earth itself has changed

677
00:27:37,780 --> 00:27:35,330
over time in particular we're talking

678
00:27:40,810 --> 00:27:37,790
about oxygen as strong by a signature

679
00:27:43,540 --> 00:27:40,820
but life was on the planet before it

680
00:27:45,460 --> 00:27:43,550
started producing oxygen so are we able

681
00:27:48,390 --> 00:27:45,470
to learn not just from the current earth

682
00:27:51,760 --> 00:27:48,400
but maybe also from the early Earth

683
00:27:54,190 --> 00:27:51,770
absolutely early Earth is so valuable

684
00:27:55,900 --> 00:27:54,200
from the perspective of people trying to

685
00:27:58,660 --> 00:27:55,910
understand what habitability means in a

686
00:28:00,640 --> 00:27:58,670
more general sense because our planet

687
00:28:02,830 --> 00:28:00,650
today is just you know one data point

688
00:28:04,960 --> 00:28:02,840

one example of what habitability might

689
00:28:07,480 --> 00:28:04,970
look like but if we go back in time to

690
00:28:09,460 --> 00:28:07,490
Earth's past we can actually have you

691
00:28:11,140 --> 00:28:09,470
know this array of planets that we know

692
00:28:11,799 --> 00:28:11,150
are possible we know we're both

693
00:28:14,139 --> 00:28:11,809
habitable

694
00:28:15,430 --> 00:28:14,149
and inhabited and also looked radically

695
00:28:18,009 --> 00:28:15,440
different from the planet that we live

696
00:28:20,799 --> 00:28:18,019
on today for example if you go back on

697
00:28:22,779 --> 00:28:20,809
earth before about 2.5 billion years ago

698
00:28:24,129 --> 00:28:22,789
you would need to bring an oxygen tank

699
00:28:25,539 --> 00:28:24,139
with you because there would be no

700
00:28:27,339 --> 00:28:25,549
oxidant in the air for you to breathe

701
00:28:29,200 --> 00:28:27,349
and said the atmosphere would have been

702
00:28:31,989 --> 00:28:29,210
more rich potentially in gases like

703
00:28:34,089 --> 00:28:31,999
carbon dioxide and methane produced by

704
00:28:37,719 --> 00:28:34,099
methane producing life carbon dioxide

705
00:28:40,180 --> 00:28:37,729
also comes out of volcanoes so the rise

706
00:28:42,969 --> 00:28:40,190
of oxygen at about 2.5 billion years ago

707
00:28:44,379 --> 00:28:42,979
put this you know canonical biosignature

708
00:28:46,659 --> 00:28:44,389
of oxygen into our planet's atmosphere

709
00:28:48,629 --> 00:28:46,669
but thinking about what habitability

710
00:28:50,619 --> 00:28:48,639
means in absence of that and

711
00:28:53,320 --> 00:28:50,629
biosignatures an absence of that oxygen

712
00:28:56,379 --> 00:28:53,330
it's really important to study early

713
00:28:58,539 --> 00:28:56,389

earth would we recognize a planet like

714
00:29:00,810 --> 00:28:58,549
early Earth is habitable and inhabited

715
00:29:03,310 --> 00:29:00,820
it's it's tricky because like I said

716
00:29:06,249 --> 00:29:03,320
methane can be produced by both life and

717
00:29:08,200 --> 00:29:06,259
non-life and methane was potentially the

718
00:29:10,119 --> 00:29:08,210
dominant bio signature of early Earth's

719
00:29:11,680 --> 00:29:10,129
atmosphere so what we're trying to do

720
00:29:13,829 --> 00:29:11,690
now is we're trying to use computer

721
00:29:15,969 --> 00:29:13,839
models as well as studies of

722
00:29:19,570 --> 00:29:15,979
microorganisms that produce methane and

723
00:29:20,859 --> 00:29:19,580
studies of for example hydrothermal vent

724
00:29:22,930 --> 00:29:20,869
systems that produce methane

725
00:29:25,930 --> 00:29:22,940
geologically to try to understand are

726
00:29:27,820 --> 00:29:25,940
there ways of teasing apart biological

727
00:29:29,950 --> 00:29:27,830
from non-biological methane that may

728
00:29:31,889 --> 00:29:29,960
have dominated on early Earth and

729
00:29:34,029 --> 00:29:31,899
potentially early earth-like exoplanets

730
00:29:35,440 --> 00:29:34,039
early Earth we like to say is the most

731
00:29:37,749 --> 00:29:35,450
alien world that we have geochemical

732
00:29:47,529 --> 00:29:37,759
data for so we might as well use it as

733
00:29:48,180 --> 00:29:47,539
an analogue for alien exoplanets yeah

734
00:29:51,330 --> 00:29:48,190
actually

735
00:29:54,180 --> 00:29:51,340
interesting I that we have the one

736
00:29:56,789 --> 00:29:54,190
example of a habitable and inhabited

737
00:29:59,159 --> 00:29:56,799
planet it's very difficult I think for

738
00:30:01,980 --> 00:29:59,169

us to imagine what a habitable planet

739
00:30:05,310 --> 00:30:01,990
that is not inhabited actually looks

740
00:30:06,539 --> 00:30:05,320
like we just we don't have we don't

741
00:30:10,470 --> 00:30:06,549
really know what that looks like we need

742
00:30:12,720 --> 00:30:10,480
to model more but but it is fantastic

743
00:30:14,490 --> 00:30:12,730
though that you think that the earth has

744
00:30:16,379 --> 00:30:14,500
been so different it's been inhabited

745
00:30:18,180 --> 00:30:16,389
for most of its history and it was been

746
00:30:20,669 --> 00:30:18,190
really different the whole time and it's

747
00:30:22,379 --> 00:30:20,679
funny because you know it's only

748
00:30:25,110 --> 00:30:22,389
relatively recently that astronomers

749
00:30:28,499 --> 00:30:25,120
like myself have realized that the

750
00:30:30,840 --> 00:30:28,509
modern earth isn't the only earth and in

751
00:30:32,580 --> 00:30:30,850
in I think in earlier days when we were

752
00:30:34,470 --> 00:30:32,590
thinking about designing experiments and

753
00:30:36,659 --> 00:30:34,480
hardware to execute those experiments we

754
00:30:39,539 --> 00:30:36,669
were I think we are far too focused on

755
00:30:41,789 --> 00:30:39,549
the current state of the of what the

756
00:30:43,350 --> 00:30:41,799
earth looks like that is that is

757
00:30:45,480 --> 00:30:43,360
changing and I think that isn't

758
00:30:46,879 --> 00:30:45,490
extremely it's an extremely healthy

759
00:30:49,019 --> 00:30:46,889
development that's come out of

760
00:30:51,899 --> 00:30:49,029
increasing levels of communication

761
00:30:55,259 --> 00:30:51,909
between astronomers planetary scientists

762
00:30:58,049 --> 00:30:55,269
astrobiologists and earth scientists I

763
00:31:01,110 --> 00:30:58,059

am far more confident now that we can

764
00:31:03,629 --> 00:31:01,120
design the experiment and the tool to do

765
00:31:07,470 --> 00:31:03,639
that experiment successfully now's and

766
00:31:08,970 --> 00:31:07,480
you know than 10 or 15 years ago just to

767
00:31:10,950 --> 00:31:08,980
build on that actually and even if we

768
00:31:12,600 --> 00:31:10,960
we're not thinking about life here we

769
00:31:15,090 --> 00:31:12,610
can still think about the early earth as

770
00:31:18,060 --> 00:31:15,100
a repository of information about how

771
00:31:19,619 --> 00:31:18,070
planets get built so there's in the

772
00:31:21,060 --> 00:31:19,629
geological literature there's a lot of

773
00:31:22,799 --> 00:31:21,070
debate about you know when the oceans

774
00:31:25,139 --> 00:31:22,809
and the continents formed and those

775
00:31:26,639 --> 00:31:25,149
those two elements of the planetary

776
00:31:28,830 --> 00:31:26,649
system going to be very important for

777
00:31:30,539 --> 00:31:28,840
thinking about habitability as well so

778
00:31:32,009 --> 00:31:30,549
standing up my geologist colleagues

779
00:31:34,350 --> 00:31:32,019
there's a lot that can we can learn

780
00:31:36,480 --> 00:31:34,360
about general planetary processes from

781
00:31:39,659 --> 00:31:36,490
looking at the early Earth and how

782
00:31:41,369 --> 00:31:39,669
planets are built make another point

783
00:31:43,169 --> 00:31:41,379
that I took from judges comments about

784
00:31:45,240 --> 00:31:43,179
the early Earth is at this stage we're

785
00:31:48,690 --> 00:31:45,250
not really talking about very complex

786
00:31:51,149 --> 00:31:48,700
life if I'm correct the addition of

787
00:31:53,820 --> 00:31:51,159
oxygen allowed us altima to build much

788
00:31:56,369 --> 00:31:53,830

more sophisticated biological organisms

789
00:31:58,049 --> 00:31:56,379
so when we talk about searching for life

790
00:32:00,259 --> 00:31:58,059
on other planets we're not necessarily

791
00:32:01,919 --> 00:32:00,269
dashing for you know the full-on

792
00:32:04,850 --> 00:32:01,929
intelligent life with the star

793
00:32:07,560 --> 00:32:04,860
books but actually even very small

794
00:32:09,539 --> 00:32:07,570
microbial organisms can really strongly

795
00:32:11,909 --> 00:32:09,549
affect a planet and produce a bio

796
00:32:14,129 --> 00:32:11,919
signature oh yeah that's right I mean

797
00:32:15,659 --> 00:32:14,139
microbes are great at modifying the

798
00:32:17,580 --> 00:32:15,669
environment we think we're good at

799
00:32:19,799 --> 00:32:17,590
modifying the environment but microbes

800
00:32:21,299 --> 00:32:19,809
are fantastic at it because we're

801
00:32:25,350 --> 00:32:21,309
breathing their products right now right

802
00:32:27,090 --> 00:32:25,360
we're breathing oxygen so you're

803
00:32:28,739 --> 00:32:27,100
absolutely correct when you say that

804
00:32:30,570 --> 00:32:28,749
we're not necessarily looking for

805
00:32:33,090 --> 00:32:30,580
intelligent life intelligent life and

806
00:32:35,100 --> 00:32:33,100
even just complex life like macroscopic

807
00:32:37,470 --> 00:32:35,110
life that you don't need a microscope to

808
00:32:39,659 --> 00:32:37,480
see might be rare if we look at the

809
00:32:42,389 --> 00:32:39,669
evolution of life on Earth we would see

810
00:32:44,580 --> 00:32:42,399
that life has been microbial for the

811
00:32:46,470 --> 00:32:44,590
vast majority of Earth's history that we

812
00:32:48,119 --> 00:32:46,480
know life has been here you would have

813
00:32:50,129 --> 00:32:48,129

had to go back in time with a microscope

814
00:32:52,739 --> 00:32:50,139
in addition to an oxygen tank if you

815
00:32:56,310 --> 00:32:52,749
want to survive to see that the planet

816
00:32:58,619 --> 00:32:56,320
is actually inhabited so all you really

817
00:32:59,970 --> 00:32:58,629
need is you need to detect metabolic

818
00:33:02,039 --> 00:32:59,980
byproducts that are going into the

819
00:33:04,109 --> 00:33:02,049
atmosphere and if you have a robust by

820
00:33:05,460 --> 00:33:04,119
signature that's modifying its global

821
00:33:07,950 --> 00:33:05,470
environment with these metabolic

822
00:33:12,320 --> 00:33:07,960
byproducts then then we can start

823
00:33:17,940 --> 00:33:15,840
so I we've taken a lot of lessons from

824
00:33:19,590 --> 00:33:17,950
the earth but there are actually seven

825
00:33:22,680 --> 00:33:19,600
other planets in our solar system too

826
00:33:24,810 --> 00:33:22,690
and while none of them have the strong

827
00:33:27,600 --> 00:33:24,820
signature for life that we could detect

828
00:33:29,430 --> 00:33:27,610
in the atmosphere can we take any

829
00:33:32,009 --> 00:33:29,440
lessons from them in particular how

830
00:33:34,710 --> 00:33:32,019
about signatures that might look like

831
00:33:36,480 --> 00:33:34,720
life but actually aren't are there any

832
00:33:38,190 --> 00:33:36,490
evidence of that in our solar system

833
00:33:47,230 --> 00:33:38,200
that we could use as a warning when

834
00:33:51,850 --> 00:33:47,240
looking at exoplanets I won't end

835
00:33:53,260 --> 00:33:51,860
take on well there's there's the

836
00:33:55,810 --> 00:33:53,270
controversy with the Allen Hills

837
00:33:58,900 --> 00:33:55,820
meteorite which was a Martian meteorite

838
00:34:00,700 --> 00:33:58,910

that landed in Antarctica and at first

839
00:34:02,740 --> 00:34:00,710
people thought that they may have found

840
00:34:04,120 --> 00:34:02,750
Martian microbes in this meteorite and

841
00:34:06,100 --> 00:34:04,130
there was like there's a huge amount of

842
00:34:07,510 --> 00:34:06,110
publicity and excitement because we

843
00:34:11,290 --> 00:34:07,520
thought we had discovered life that had

844
00:34:12,879 --> 00:34:11,300
originated on Mars but subsequently

845
00:34:14,080 --> 00:34:12,889
after that there was quite a bit of

846
00:34:16,330 --> 00:34:14,090
controversy

847
00:34:18,010 --> 00:34:16,340
not everyone now believes that that in

848
00:34:19,629 --> 00:34:18,020
fact is Martian microbes that were

849
00:34:22,570 --> 00:34:19,639
preserved in that meteorite but perhaps

850
00:34:24,940 --> 00:34:22,580
some sort of non-biological mimic of

851
00:34:27,100 --> 00:34:24,950
microbes or some sort of earthly process

852
00:34:29,649 --> 00:34:27,110
may have produced those features so I

853
00:34:31,389 --> 00:34:29,659
think learning from the Allen Hills

854
00:34:35,139 --> 00:34:31,399
meteorite is very important because it

855
00:34:36,700 --> 00:34:35,149
shows us that we might get fooled when

856
00:34:39,580 --> 00:34:36,710
we start to look for life on other

857
00:34:42,040 --> 00:34:39,590
planets and if we're predisposed to

858
00:34:43,600 --> 00:34:42,050
seeing life we might fool ourselves

859
00:34:45,820 --> 00:34:43,610
because we might think oh this is what

860
00:34:48,639 --> 00:34:45,830
life looks like this looks like life but

861
00:34:50,770 --> 00:34:48,649
maybe it's not so we we also have to be

862
00:34:53,460 --> 00:34:50,780
thinking about what are called bio

863
00:34:55,480 --> 00:34:53,470

signature false positives which are

864
00:34:58,180 --> 00:34:55,490
non-biological processes that might

865
00:34:59,590 --> 00:34:58,190
mimic biosignatures and we're spending a

866
00:35:01,780 --> 00:34:59,600
lot of time right now trying to think

867
00:35:03,670 --> 00:35:01,790
about how to tease apart true

868
00:35:09,700 --> 00:35:03,680
biosignatures from false positive bio

869
00:35:10,960 --> 00:35:09,710
signatures we can also think about the

870
00:35:12,400 --> 00:35:10,970
solar system in terms of the habitable

871
00:35:15,370 --> 00:35:12,410
zone concept that we introduced earlier

872
00:35:17,230 --> 00:35:15,380
so imagine if we were viewing a whole

873
00:35:18,910 --> 00:35:17,240
solar system from a great distance and

874
00:35:21,460 --> 00:35:18,920
we were looking at the habitable zone of

875
00:35:22,090 --> 00:35:21,470
the Sun we might see three planets in

876
00:35:24,160 --> 00:35:22,100
there

877
00:35:25,990 --> 00:35:24,170
we might see Venus we might see earth

878
00:35:27,490 --> 00:35:26,000
and we might see Mars now depending on

879
00:35:30,160 --> 00:35:27,500
where you set your limits and I think

880
00:35:32,080 --> 00:35:30,170
that illustrates the some of the issues

881
00:35:33,760 --> 00:35:32,090
that we've raised with the habitable

882
00:35:35,380 --> 00:35:33,770
zone because we know Venus isn't

883
00:35:36,609 --> 00:35:35,390
inhabitable because of the atmospheric

884
00:35:38,830 --> 00:35:36,619
processes that are going on to very

885
00:35:40,390 --> 00:35:38,840
thick co2 atmosphere and we know Mars

886
00:35:42,250 --> 00:35:40,400
isn't really a habitable because it's

887
00:35:44,320 --> 00:35:42,260
very thin atmosphere and very cold and

888
00:35:47,020 --> 00:35:44,330

geologically inactive so that can

889
00:35:49,240 --> 00:35:47,030
provide us with you know a warning in in

890
00:35:51,010 --> 00:35:49,250
that respect and we can also look at the

891
00:35:53,440 --> 00:35:51,020
solar system a bit more generally in

892
00:35:55,690 --> 00:35:53,450
terms of the population of other star

893
00:35:58,840 --> 00:35:55,700
systems we have to say is our solar

894
00:36:00,080 --> 00:35:58,850
system somehow weird and I personally I

895
00:36:02,840 --> 00:36:00,090
think it is kind of weird because

896
00:36:04,670 --> 00:36:02,850
we found a lot of these these these

897
00:36:06,770 --> 00:36:04,680
worlds that are classed as either mini

898
00:36:08,210 --> 00:36:06,780
Neptune's or super Earths RQ mentioned

899
00:36:09,530 --> 00:36:08,220
earlier and we don't have one of those

900
00:36:11,360 --> 00:36:09,540
in our solar system and I'm really sad

901
00:36:13,790 --> 00:36:11,370
about that because they seem very

902
00:36:16,340 --> 00:36:13,800
interesting planets to study that

903
00:36:18,650 --> 00:36:16,350
provide that transition between small

904
00:36:21,140 --> 00:36:18,660
rocky planets and the much larger gas

905
00:36:22,940 --> 00:36:21,150
giants so even if we're not thinking

906
00:36:24,800 --> 00:36:22,950
about life maybe in this context we can

907
00:36:26,990 --> 00:36:24,810
think about the general lessons we can

908
00:36:29,900 --> 00:36:27,000
learn from our solar system in terms of

909
00:36:31,640 --> 00:36:29,910
planets the planetary processes yeah I

910
00:36:33,230 --> 00:36:31,650
mean for sure and I guess we said

911
00:36:35,360 --> 00:36:33,240
earlier somehow that you know the earth

912
00:36:37,460 --> 00:36:35,370
defines the habitable zone but actually

913
00:36:40,220 --> 00:36:37,470

I want to modify that and as you said

914
00:36:41,110 --> 00:36:40,230
it's actually it's you know it's Venus

915
00:36:43,910 --> 00:36:41,120
Earth and Mars

916
00:36:46,310 --> 00:36:43,920
tell us about the habitable zone define

917
00:36:48,470 --> 00:36:46,320
a habitable zone and again like you said

918
00:36:50,510 --> 00:36:48,480
it's very obvious that just being in the

919
00:36:55,100 --> 00:36:50,520
habitable zone is not enough to make you

920
00:36:56,480 --> 00:36:55,110
habitable but we learn a lot about what

921
00:36:57,860 --> 00:36:56,490
we do we've learned a lot about the

922
00:37:03,050 --> 00:36:57,870
concept of habitability though by

923
00:37:05,360 --> 00:37:03,060
studying studying planet Venus and Mars

924
00:37:09,140 --> 00:37:05,370
through time like for example we know

925
00:37:11,540 --> 00:37:09,150
that Mars Mars had liquid water on its

926
00:37:13,430 --> 00:37:11,550
surface early in its history flowing

927
00:37:13,940 --> 00:37:13,440
across the surface it was a habitable

928
00:37:16,970 --> 00:37:13,950
planet

929
00:37:18,950 --> 00:37:16,980
so we by understanding by studying like

930
00:37:21,320 --> 00:37:18,960
what happened to Mars to make it not

931
00:37:24,200 --> 00:37:21,330
habitable over time we learn a lot about

932
00:37:27,200 --> 00:37:24,210
what that word means about what the word

933
00:37:29,510 --> 00:37:27,210
habitable means similarly for Venus I

934
00:37:31,580 --> 00:37:29,520
think you're the one who told me I think

935
00:37:33,170 --> 00:37:31,590
first like that Venus in its early

936
00:37:37,460 --> 00:37:33,180
history was a lot more earth-like and

937
00:37:40,040 --> 00:37:37,470
that was news to me for sure and again

938
00:37:42,620 --> 00:37:40,050

that looking at what happened for a

939
00:37:46,130 --> 00:37:42,630
planet to to lose its habitable

940
00:37:49,910 --> 00:37:46,140
capability it really teaches us a lot

941
00:37:50,390 --> 00:37:49,920
about what we need about about where to

942
00:37:56,810 --> 00:37:50,400
look

943
00:37:59,630 --> 00:37:56,820
does and you know I'm just just many

944
00:38:02,420 --> 00:37:59,640
many things and actually I'm really I'm

945
00:38:05,090 --> 00:38:02,430
really encouraged that I think that

946
00:38:06,950 --> 00:38:05,100
we're starting to you know break down

947
00:38:10,640 --> 00:38:06,960
this sort of artificial distinction

948
00:38:12,100 --> 00:38:10,650
between planets and exoplanets that

949
00:38:14,760 --> 00:38:12,110
they're just

950
00:38:17,530 --> 00:38:14,770
just getting there just planets you know

951
00:38:20,980 --> 00:38:17,540
everywhere and there are a great many of

952
00:38:23,470 --> 00:38:20,990
them they span a huge range of diversity

953
00:38:24,700 --> 00:38:23,480
far more than what we and the ones we

954
00:38:26,380 --> 00:38:24,710
have in aren't just the ones in our

955
00:38:29,920 --> 00:38:26,390
solar system actually it's kind of

956
00:38:31,780 --> 00:38:29,930
amazing how well the planet formation

957
00:38:33,280 --> 00:38:31,790
process actually works my personal

958
00:38:35,830 --> 00:38:33,290
research is actually in planet formation

959
00:38:38,230 --> 00:38:35,840
and you know and when I was an undergrad

960
00:38:40,930 --> 00:38:38,240
we thought that everything had to be

961
00:38:43,000 --> 00:38:40,940
just right to make the solar system the

962
00:38:45,720 --> 00:38:43,010
models could just barely do it and in

963
00:38:48,370 --> 00:38:45,730

fact they kind of couldn't even do that

964
00:38:51,580 --> 00:38:48,380
but it seems so inevitable that you

965
00:38:54,970 --> 00:38:51,590
would have small rocky planets closest

966
00:38:56,320 --> 00:38:54,980
are big giant gas ball further from the

967
00:38:58,420 --> 00:38:56,330
start and it didn't seem like you could

968
00:39:00,270 --> 00:38:58,430
make any planetary system different than

969
00:39:04,120 --> 00:39:00,280
that that it would be impossible and

970
00:39:06,010 --> 00:39:04,130
then the first exoplanets were

971
00:39:08,470 --> 00:39:06,020
discovered they were Jupiter's orbiting

972
00:39:11,050 --> 00:39:08,480
closer to their star than mercury orbits

973
00:39:13,480 --> 00:39:11,060
the Sun and then Kepler came along and

974
00:39:15,520 --> 00:39:13,490
just exploded it there are all sizes of

975
00:39:18,580 --> 00:39:15,530
planets out there at all distances it's

976
00:39:22,240 --> 00:39:18,590
a spectrum it's not kind of binary like

977
00:39:24,820 --> 00:39:22,250
it is in the in the solar system and in

978
00:39:26,380 --> 00:39:24,830
some ways that you've given how much

979
00:39:28,540 --> 00:39:26,390
nature surpassed our theoretical

980
00:39:30,370 --> 00:39:28,550
expectations is also one of the things

981
00:39:32,160 --> 00:39:30,380
that makes me sort of hopeful that we

982
00:39:34,240 --> 00:39:32,170
are going to succeed in finding

983
00:39:39,010 --> 00:39:34,250
habitable worlds out there and maybe

984
00:39:42,190 --> 00:39:39,020
even inhabited ones so rolling on with

985
00:39:43,660 --> 00:39:42,200
that actually to say well there's a lot

986
00:39:46,120 --> 00:39:43,670
of logic in looking for earth-like life

987
00:39:48,160 --> 00:39:46,130
because we have so much data and in fact

988
00:39:50,860 --> 00:39:48,170

the only data we have is a earth like

989
00:39:52,930 --> 00:39:50,870
life easy impossible to envisage a

990
00:39:55,360 --> 00:39:52,940
planet very unlike the earth supporting

991
00:39:59,020 --> 00:39:55,370
life or maybe supporting very unlike

992
00:40:01,090 --> 00:39:59,030
earth life I think it's possible to

993
00:40:03,250 --> 00:40:01,100
envision it for example again if we look

994
00:40:05,140 --> 00:40:03,260
at the outer solar system moons not very

995
00:40:07,870 --> 00:40:05,150
much likely earth but potentially able

996
00:40:10,870 --> 00:40:07,880
to support life but in terms of looking

997
00:40:11,950 --> 00:40:10,880
for life that's not like the life on the

998
00:40:14,110 --> 00:40:11,960
earth that's where it becomes

999
00:40:15,730 --> 00:40:14,120
problematic because we just don't know

1000
00:40:19,690 --> 00:40:15,740
how to do it you know sure we can

1001
00:40:22,270 --> 00:40:19,700
imagine maybe a some exotic bye-bye okay

1002
00:40:24,160 --> 00:40:22,280
sorry some exotic biochemistry but we

1003
00:40:25,880 --> 00:40:24,170
wouldn't know how to test for it so it's

1004
00:40:27,890 --> 00:40:25,890
I would argue it's not necessary sign

1005
00:40:28,880 --> 00:40:27,900
to actually try and try and look for

1006
00:40:30,800 --> 00:40:28,890
something that we wouldn't know how to

1007
00:40:35,390 --> 00:40:30,810
detect so it wouldn't know how to find

1008
00:40:38,480 --> 00:40:35,400
in the first place I think that's a good

1009
00:40:41,330 --> 00:40:38,490
answer I think we need to start use

1010
00:40:44,930 --> 00:40:41,340
earth as a starting point maybe someday

1011
00:40:46,730 --> 00:40:44,940
we will find exotic life but we can only

1012
00:40:48,620 --> 00:40:46,740
stretch our imaginations so far I think

1013
00:40:51,140 --> 00:40:48,630

before we start to come up with things

1014
00:40:56,870 --> 00:40:51,150
that might not be actually chemically or

1015
00:40:59,270 --> 00:40:56,880
physically possible that being said you

1016
00:41:02,240 --> 00:40:59,280
know when the tools that we want to

1017
00:41:04,280 --> 00:41:02,250
design to find earth-like planets or

1018
00:41:06,680 --> 00:41:04,290
even the earth through time like planets

1019
00:41:09,620 --> 00:41:06,690
I mean they will give us the ability to

1020
00:41:11,780 --> 00:41:09,630
you know to just collect the basic data

1021
00:41:15,260 --> 00:41:11,790
that might have the signature of

1022
00:41:17,090 --> 00:41:15,270
weirdness of something weird in there so

1023
00:41:19,970 --> 00:41:17,100
it's not like we won't have the

1024
00:41:21,320 --> 00:41:19,980
capability actually of detecting life

1025
00:41:22,490 --> 00:41:21,330
that was different from the earth but

1026
00:41:23,420 --> 00:41:22,500
what we would have way to have some data

1027
00:41:25,910 --> 00:41:23,430
that we were just really weird

1028
00:41:27,200 --> 00:41:25,920
impossible to explain and we'd spend the

1029
00:41:29,060 --> 00:41:27,210
theist would spend I don't know how long

1030
00:41:32,090 --> 00:41:29,070
just trying to like figure out what it

1031
00:41:34,960 --> 00:41:32,100
meant and maybe they never could but

1032
00:41:37,640 --> 00:41:34,970
it's possible maybe they could too so

1033
00:41:39,290 --> 00:41:37,650
it's a very last question from me before

1034
00:41:41,030 --> 00:41:39,300
we turn over to the audience we've

1035
00:41:43,850 --> 00:41:41,040
talked about the planet but what about

1036
00:41:45,260 --> 00:41:43,860
the star so does the star matter we

1037
00:41:47,330 --> 00:41:45,270
found a lot of planets in particular

1038
00:41:49,280 --> 00:41:47,340

around stars that aren't so much like

1039
00:41:50,780 --> 00:41:49,290
our own Sun in particular these red

1040
00:41:53,000 --> 00:41:50,790
dwarfs that were mentioned earlier and

1041
00:41:54,680 --> 00:41:53,010
because they're small and dim it

1042
00:41:57,320 --> 00:41:54,690
actually makes the planets easier to

1043
00:41:59,450 --> 00:41:57,330
find but is that where our consideration

1044
00:42:01,340 --> 00:41:59,460
needs to stop just say okay there are

1045
00:42:03,350 --> 00:42:01,350
some stars where we can find planets

1046
00:42:05,870 --> 00:42:03,360
more easily or do we have to take it

1047
00:42:07,550 --> 00:42:05,880
further and say the star itself also

1048
00:42:08,600 --> 00:42:07,560
affects the planet and we need to

1049
00:42:15,320 --> 00:42:08,610
consider it when talking about

1050
00:42:18,500 --> 00:42:15,330
habitability yes irrefutably yes yeah

1051
00:42:20,630 --> 00:42:18,510
and red dwarfs are our favorite because

1052
00:42:22,310 --> 00:42:20,640
as you mentioned we can find planets

1053
00:42:23,420 --> 00:42:22,320
around them relatively easily and there

1054
00:42:25,550 --> 00:42:23,430
are a lot of them out there they're the

1055
00:42:27,680 --> 00:42:25,560
most common type of star in our galaxy

1056
00:42:30,020 --> 00:42:27,690
and for me personally I find them very

1057
00:42:32,600 --> 00:42:30,030
interesting because of how gradually

1058
00:42:33,800 --> 00:42:32,610
they evolve across their main sequence

1059
00:42:34,400 --> 00:42:33,810
like they're the main part of their

1060
00:42:36,590 --> 00:42:34,410
lifetime

1061
00:42:38,450 --> 00:42:36,600
and how how their luminosity their

1062
00:42:39,210 --> 00:42:38,460
brightness changes but there are a lot

1063
00:42:42,359 --> 00:42:39,220

of

1064
00:42:46,589 --> 00:42:42,369
understand and are not able to properly

1065
00:42:47,940 --> 00:42:46,599
model with with red dwarfs flowering for

1066
00:42:50,430 --> 00:42:47,950
example they very some of them are very

1067
00:42:53,190 --> 00:42:50,440
very active and emit very high energy

1068
00:42:55,109 --> 00:42:53,200
flares might impact the surface of the

1069
00:42:58,020 --> 00:42:55,119
planet which would have deleterious

1070
00:42:59,820 --> 00:42:58,030
effects on any life on the surface but

1071
00:43:01,410 --> 00:42:59,830
then we're not too sure about that there

1072
00:43:02,720 --> 00:43:01,420
could be other other elements to the

1073
00:43:05,849 --> 00:43:02,730
planetary system that might shield

1074
00:43:08,010 --> 00:43:05,859
organisms from from those effects so

1075
00:43:10,620 --> 00:43:08,020
it's it's early days and observations

1076
00:43:13,800 --> 00:43:10,630
and models and theories all needs are

1077
00:43:15,150 --> 00:43:13,810
going to help us to better understand

1078
00:43:17,700 --> 00:43:15,160
all the effect of star and planet

1079
00:43:20,760 --> 00:43:17,710
interactions yeah and I should say the

1080
00:43:23,040 --> 00:43:20,770
first the first you know potentially

1081
00:43:25,650 --> 00:43:23,050
habitable exoplanets so we're going to

1082
00:43:28,410 --> 00:43:25,660
be studying their atmospheres in detail

1083
00:43:30,390 --> 00:43:28,420
we'll be around red dwarf stars that is

1084
00:43:31,920 --> 00:43:30,400
just that is just that's just the way it

1085
00:43:34,109 --> 00:43:31,930
is because of the capabilities of the

1086
00:43:35,880 --> 00:43:34,119
tools that we have coming up because as

1087
00:43:37,530 --> 00:43:35,890
you say they're easier it's easier to

1088
00:43:42,390 --> 00:43:37,540

see a small planet around a small star

1089
00:43:42,930 --> 00:43:42,400
than a big star but that being said I we

1090
00:43:44,339 --> 00:43:42,940
just

1091
00:43:47,010 --> 00:43:44,349
they're very those stars are very

1092
00:43:48,930 --> 00:43:47,020
different from the Sun and there are

1093
00:43:50,609 --> 00:43:48,940
several wheat we this whole week we've

1094
00:43:52,800 --> 00:43:50,619
been talking about you know several

1095
00:43:56,640 --> 00:43:52,810
different reasons why that might really

1096
00:43:58,349 --> 00:43:56,650
not be a nice place to live so I think

1097
00:44:01,260 --> 00:43:58,359
we're gonna study them we absolutely

1098
00:44:03,320 --> 00:44:01,270
have to and we will but we can't stop

1099
00:44:06,900 --> 00:44:03,330
there we also need to build the

1100
00:44:08,940 --> 00:44:06,910
capabilities and the tools to study the

1101
00:44:10,890 --> 00:44:08,950
study the systems that are more like the

1102
00:44:13,550 --> 00:44:10,900
solar system with you know an

1103
00:44:16,620 --> 00:44:13,560
earth-sized planet and a sun-like star

1104
00:44:18,839 --> 00:44:16,630
because is for the moment anyway that is

1105
00:44:21,599 --> 00:44:18,849
the only you know star planet pairing

1106
00:44:24,960 --> 00:44:21,609
that we know for sure can be habitable

1107
00:44:27,240 --> 00:44:24,970
and inhabited so we really do we have to

1108
00:44:29,220 --> 00:44:27,250
do we have to we have to explore the

1109
00:44:31,109 --> 00:44:29,230
print you know the range of things that

1110
00:44:33,390 --> 00:44:31,119
can happen but we also need to look for

1111
00:44:36,000 --> 00:44:33,400
the what we are look for us look for

1112
00:44:38,520 --> 00:44:36,010
ourselves it's almost the same argument

1113
00:44:45,270 --> 00:44:38,530

with looking for exotic life as looking

1114
00:44:47,580 --> 00:44:45,280
for an exotic habitable environment Hey

1115
00:44:49,080 --> 00:44:47,590
discussion so far so at this point we're

1116
00:44:52,920 --> 00:44:49,090
gonna take some questions from our live

1117
00:44:55,800 --> 00:44:52,930
audience here Sarah Brothers National

1118
00:44:58,320 --> 00:44:55,810
Academies so in this panel you have

1119
00:45:02,160 --> 00:44:58,330
really emphasized the importance of

1120
00:45:04,410 --> 00:45:02,170
liquid water as kind of a definition of

1121
00:45:07,740 --> 00:45:04,420
a habitable planet or a necessity of

1122
00:45:09,840 --> 00:45:07,750
habitability but if we step back and

1123
00:45:11,550 --> 00:45:09,850
look at kind of the two most basic

1124
00:45:14,190 --> 00:45:11,560
assumptions we can make which is that

1125
00:45:15,810 --> 00:45:14,200
life is carbon-based probably the only

1126
00:45:18,150 --> 00:45:15,820
thing we would recognize at this moment

1127
00:45:21,450 --> 00:45:18,160
and then through its process as it

1128
00:45:24,990 --> 00:45:21,460
creates really complex molecules why

1129
00:45:31,080 --> 00:45:25,000
water why not something like the liquid

1130
00:45:31,559 --> 00:45:31,090
methane and ethane we see on Titan those

1131
00:45:33,120 --> 00:45:31,569
interests

1132
00:45:35,339 --> 00:45:33,130
actually I mean someone was talking

1133
00:45:37,709 --> 00:45:35,349
about that water is you know you know I

1134
00:45:40,439 --> 00:45:37,719
guess for you know for for chemical

1135
00:45:44,579 --> 00:45:40,449
reactions to go you need a liquid a

1136
00:45:46,829 --> 00:45:44,589
solvent and water is a special it's

1137
00:45:49,979 --> 00:45:46,839
better than the liquid methane because

1138
00:45:52,349 --> 00:45:49,989

it you know as I kind of realized today

1139
00:45:55,349 --> 00:45:52,359
in fact it is liquid at a very wide

1140
00:45:58,739 --> 00:45:55,359
range of temperatures unlike unlike

1141
00:46:00,839 --> 00:45:58,749
methane for example liquid methane yeah

1142
00:46:02,279 --> 00:46:00,849
yeah water is frankly kind of weird you

1143
00:46:04,109 --> 00:46:02,289
know and when we think about Isis as

1144
00:46:06,359 --> 00:46:04,119
well and how how they can exist in lots

1145
00:46:08,849 --> 00:46:06,369
of weird exotic States and it's just a

1146
00:46:11,219 --> 00:46:08,859
very effective solvent and it's

1147
00:46:12,779 --> 00:46:11,229
ubiquitous it's very common we've

1148
00:46:15,209 --> 00:46:12,789
detected it interstellar space we detect

1149
00:46:16,799 --> 00:46:15,219
a around have we do I might not make

1150
00:46:18,870 --> 00:46:16,809
that statement and I don't know if we've

1151
00:46:20,549 --> 00:46:18,880
detected around other other stars yet we

1152
00:46:22,019 --> 00:46:20,559
have okay yeah so we've detected around

1153
00:46:23,670 --> 00:46:22,029
other stars and in interstellar medium

1154
00:46:25,019 --> 00:46:23,680
so we know it's out there and we know

1155
00:46:29,789 --> 00:46:25,029
it's common and we know it's effective

1156
00:46:31,079 --> 00:46:29,799
at being a solvent I have anything I

1157
00:46:33,180 --> 00:46:31,089
would add is the place where we've also

1158
00:46:35,249 --> 00:46:33,190
seen liquid methane would be and the

1159
00:46:37,049 --> 00:46:35,259
Saturn moon Titan and it should be noted

1160
00:46:38,939 --> 00:46:37,059
that of course it's incredibly cold to

1161
00:46:41,759 --> 00:46:38,949
have liquid methane and chemical

1162
00:46:43,829 --> 00:46:41,769
reactions don't occur quickly when it's

1163
00:46:46,349 --> 00:46:43,839

very cold so although you could imagine

1164
00:46:48,299 --> 00:46:46,359
another solvent that had the same three

1165
00:46:50,640 --> 00:46:48,309
phases so you know liquid solid and a

1166
00:46:53,160 --> 00:46:50,650
gas on a planet if the temperature

1167
00:46:54,959 --> 00:46:53,170
needed to do that was very very low it

1168
00:46:58,589 --> 00:46:54,969
would be hard to have fast enough

1169
00:47:04,500 --> 00:46:58,599
reactions to build up molecules and

1170
00:47:06,930 --> 00:47:04,510
things thank you

1171
00:47:09,150 --> 00:47:06,940
all right next question I am Mike Wong

1172
00:47:10,950 --> 00:47:09,160
from Cal Tech as Andrew mentioned

1173
00:47:13,349 --> 00:47:10,960
there's been a lot of buzz in the space

1174
00:47:16,050 --> 00:47:13,359
community around Jupiter's moon Europa

1175
00:47:17,880 --> 00:47:16,060
and Saturn's moon Enceladus as possible

1176
00:47:19,800 --> 00:47:17,890
habitable environments so I was

1177
00:47:22,140 --> 00:47:19,810
wondering with the new telescopes that

1178
00:47:24,150 --> 00:47:22,150
are coming online in the next couple of

1179
00:47:31,170 --> 00:47:24,160
years and decades what are the prospects

1180
00:47:34,680 --> 00:47:31,180
for detecting exomoons yeah we um it's

1181
00:47:36,510 --> 00:47:34,690
that's that's hard I mean the planet is

1182
00:47:39,510 --> 00:47:36,520
just attacking the planets it's hard

1183
00:47:43,080 --> 00:47:39,520
enough but the moons we did we did try a

1184
00:47:44,609 --> 00:47:43,090
simulation with this this blue for a

1185
00:47:47,580 --> 00:47:44,619
mission concept that I've been working

1186
00:47:50,010 --> 00:47:47,590
on that is a really that is a really

1187
00:47:54,210 --> 00:47:50,020
ambitious mission it's a large that has

1188
00:47:56,160 --> 00:47:54,220

a very large telescope diameter and I

1189
00:47:58,170 --> 00:47:56,170
think with this we did a simulation

1190
00:48:00,390 --> 00:47:58,180
where we look to see if we could if you

1191
00:48:02,940 --> 00:48:00,400
put like a warm put a Jupiter at one

1192
00:48:04,349 --> 00:48:02,950
astronomical unit from a from a star

1193
00:48:08,220 --> 00:48:04,359
right you know basically where the earth

1194
00:48:11,010 --> 00:48:08,230
is from the Sun and had it orbited by an

1195
00:48:15,750 --> 00:48:11,020
earth-like moon he called this model and

1196
00:48:17,750 --> 00:48:15,760
or of course could you to tell that

1197
00:48:20,970 --> 00:48:17,760
there was a moon there and could you

1198
00:48:23,070 --> 00:48:20,980
separate the spectra the the light from

1199
00:48:25,560 --> 00:48:23,080
the moon and the light from the Jupiter

1200
00:48:28,050 --> 00:48:25,570
the warm Jupiter and I think we

1201
00:48:31,470 --> 00:48:28,060
concluded that you could tell that the

1202
00:48:34,109 --> 00:48:31,480
moon was there you could detect it but

1203
00:48:36,120 --> 00:48:34,119
you couldn't cleanly separate the light

1204
00:48:38,849 --> 00:48:36,130
from one or the other you know from the

1205
00:48:40,830 --> 00:48:38,859
moon from the planet so that would to

1206
00:48:43,590 --> 00:48:40,840
really do that well that's a that's

1207
00:48:46,020 --> 00:48:43,600
another level generation beyond you know

1208
00:48:47,359 --> 00:48:46,030
even the large lu4 telescope them that

1209
00:48:52,830 --> 00:48:47,369
we've been talking about

1210
00:48:54,900 --> 00:48:52,840
thanks next question hi I'm Joe Hren Oh

1211
00:48:56,550 --> 00:48:54,910
from George Mason University and I was

1212
00:48:58,980 --> 00:48:56,560
curious what do you all think that

1213
00:49:02,400 --> 00:48:58,990

exoplanet research can teach us about

1214
00:49:06,750 --> 00:49:02,410
the future of the earth that's a great

1215
00:49:07,259 --> 00:49:06,760
question that really is if we look at

1216
00:49:08,489 --> 00:49:07,269
the soleus

1217
00:49:10,559 --> 00:49:08,499
for example if we look at it I know

1218
00:49:11,880 --> 00:49:10,569
you'll keep soul systems not an exit

1219
00:49:13,739 --> 00:49:11,890
plan of course but we look to Venus

1220
00:49:15,479 --> 00:49:13,749
Venus might be an indicator of the

1221
00:49:19,049 --> 00:49:15,489
future of the earth unfortunately and it

1222
00:49:22,439 --> 00:49:19,059
doesn't doesn't look too great but again

1223
00:49:25,919 --> 00:49:22,449
we can we can use the vast number of

1224
00:49:27,870 --> 00:49:25,929
planets we know about and put them into

1225
00:49:29,999 --> 00:49:27,880
a modeling framework that can help us to

1226
00:49:31,979 --> 00:49:30,009
understand the processes that control

1227
00:49:34,380 --> 00:49:31,989
planetary evolution and by that I mean

1228
00:49:36,389 --> 00:49:34,390
how planets change over time we can find

1229
00:49:38,849 --> 00:49:36,399
planets in different stages potentially

1230
00:49:41,370 --> 00:49:38,859
of their geochemical evolution how their

1231
00:49:44,609 --> 00:49:41,380
atmospheres have have changed in

1232
00:49:46,589 --> 00:49:44,619
response to either interior processes

1233
00:49:49,380 --> 00:49:46,599
going on in the planet itself or from

1234
00:49:51,389 --> 00:49:49,390
interactions with the star so we have a

1235
00:49:53,189 --> 00:49:51,399
we have a snapshot in time when it comes

1236
00:49:54,599 --> 00:49:53,199
to the solar system at the moment we can

1237
00:49:56,519 --> 00:49:54,609
investigate the early Earth but we can

1238
00:49:58,759 --> 00:49:56,529

look to other star systems out of

1239
00:50:01,589 --> 00:49:58,769
different ages to see how how planets

1240
00:50:03,389 --> 00:50:01,599
might have changed over time in those

1241
00:50:05,579 --> 00:50:03,399
particular environments and make some

1242
00:50:06,749 --> 00:50:05,589
inferences about what the future what

1243
00:50:09,049 --> 00:50:06,759
the future might be in store for Earth

1244
00:50:11,219 --> 00:50:09,059
but of course we have to consider human

1245
00:50:12,749 --> 00:50:11,229
influences on on the planet as well

1246
00:50:14,099 --> 00:50:12,759
which isn't something that AXA planets

1247
00:50:17,879 --> 00:50:14,109
at this stage can't really teach us

1248
00:50:19,079 --> 00:50:17,889
anything about what I think will be

1249
00:50:20,969 --> 00:50:19,089
great about finding earth-like

1250
00:50:23,399 --> 00:50:20,979
exoplanets is that it will put our

1251
00:50:26,759 --> 00:50:23,409
planet into a cosmic context where we

1252
00:50:29,569 --> 00:50:26,769
will finally understand how precious is

1253
00:50:32,069 --> 00:50:29,579
earth how common do Earth's occur how

1254
00:50:34,499 --> 00:50:32,079
common is life or how rare and precious

1255
00:50:36,899 --> 00:50:34,509
is life these are very very deep

1256
00:50:38,789 --> 00:50:36,909
questions that discovering other

1257
00:50:43,769 --> 00:50:38,799
inhabited worlds will finally tell us

1258
00:50:46,829 --> 00:50:43,779
the answers to yeah I mean you know on

1259
00:50:48,089 --> 00:50:46,839
the one hand I think all of us on the

1260
00:50:50,609 --> 00:50:48,099
stage and at this conference we're

1261
00:50:52,109 --> 00:50:50,619
fundamentally optimistic about that we

1262
00:50:54,989 --> 00:50:52,119
think there are habitable planets out

1263
00:50:57,299 --> 00:50:54,999

there and yet at the same time I look at

1264
00:50:59,729 --> 00:50:57,309
the solar system and I and I think like

1265
00:51:02,549 --> 00:50:59,739
wow you know earth this is like Earth

1266
00:51:04,229 --> 00:51:02,559
this is Hawaii we have the best spot in

1267
00:51:07,589 --> 00:51:04,239
the whole solar system and everything

1268
00:51:09,719 --> 00:51:07,599
else everything else is not nearly as

1269
00:51:12,029 --> 00:51:09,729
nice so then sometimes I think okay

1270
00:51:14,370 --> 00:51:12,039
maybe we are you know maybe we are rare

1271
00:51:16,469 --> 00:51:14,380
and I go back and forth on this you know

1272
00:51:18,709 --> 00:51:16,479
are we got are there lots of EXO Earth's

1273
00:51:20,640 --> 00:51:18,719
out there or are there very few

1274
00:51:22,200 --> 00:51:20,650
sometimes I you know

1275
00:51:24,029 --> 00:51:22,210
so many exoplanets out there that makes

1276
00:51:25,680 --> 00:51:24,039
me optimistic on the handling and I look

1277
00:51:29,400 --> 00:51:25,690
at the solar system and it's just not

1278
00:51:33,359 --> 00:51:29,410
you know we have the best spot for Shore

1279
00:51:35,789 --> 00:51:33,369
and I think that actually finding out

1280
00:51:37,380 --> 00:51:35,799
what those XO earths are like what their

1281
00:51:39,120 --> 00:51:37,390
their surfaces are like their conditions

1282
00:51:40,829 --> 00:51:39,130
are atmosphere everything like that's

1283
00:51:43,950 --> 00:51:40,839
what we need to do for to like settle

1284
00:51:45,539 --> 00:51:43,960
this for me you know to find out you

1285
00:51:51,180 --> 00:51:45,549
have to really find out are we you know

1286
00:51:53,010 --> 00:51:51,190
are we common or are we rare and you

1287
00:51:56,250 --> 00:51:53,020
know and for me also too I mean oh I'm

1288
00:51:58,920 --> 00:51:56,260

interested I'm interested in um I'm

1289
00:52:00,359 --> 00:51:58,930
interested in habitable planets that are

1290
00:52:03,359 --> 00:52:00,369
inhabited I'm also interested in

1291
00:52:05,849 --> 00:52:03,369
habitable planets that are not inhabited

1292
00:52:10,230 --> 00:52:05,859
not currently inhabited because you know

1293
00:52:16,309 --> 00:52:10,240
III think someday they will be you know

1294
00:52:19,349 --> 00:52:16,319
so we will make them inhabited thank you

1295
00:52:21,120 --> 00:52:19,359
next question by Sean da Michael Goldman

1296
00:52:22,740 --> 00:52:21,130
NASA Goddard and I actually have a whole

1297
00:52:24,510 --> 00:52:22,750
series of questions that have come in

1298
00:52:26,789 --> 00:52:24,520
from the public using the ask NASA

1299
00:52:28,589 --> 00:52:26,799
hashtag on Twitter and Facebook so if

1300
00:52:30,329 --> 00:52:28,599
you're watching this live you can also

1301
00:52:32,670 --> 00:52:30,339
get your questions into the panel that

1302
00:52:34,019 --> 00:52:32,680
way the first question is actually

1303
00:52:35,910 --> 00:52:34,029
follow-on to the thing that was just

1304
00:52:37,200 --> 00:52:35,920
being discussed how many planets would

1305
00:52:39,299 --> 00:52:37,210
we need to survey with these telescopes

1306
00:52:44,960 --> 00:52:39,309
before we can strongly state whether

1307
00:52:46,220 --> 00:52:44,970
life is abundant okay I think

1308
00:52:48,109 --> 00:52:46,230
actually kind of a it's a two-stage

1309
00:52:52,099 --> 00:52:48,119
question I think the first thing we need

1310
00:52:54,050 --> 00:52:52,109
to ask is you know of those rocky

1311
00:52:57,080 --> 00:52:54,060
planets in the habitable zone how many

1312
00:52:57,859 --> 00:52:57,090
of them are actually habitable so that's

1313
00:53:00,770 --> 00:52:57,869

stage one

1314
00:53:03,560 --> 00:53:00,780
you know that's water so say for example

1315
00:53:05,150 --> 00:53:03,570
you know ten percent if ten percent of

1316
00:53:07,820 --> 00:53:05,160
those rocks in the habitable zone

1317
00:53:09,620 --> 00:53:07,830
actually are you know have habitable

1318
00:53:13,310 --> 00:53:09,630
surface conditions are nice and warm and

1319
00:53:15,530 --> 00:53:13,320
wet you would need to observe you would

1320
00:53:20,060 --> 00:53:15,540
need to study about thirty of them both

1321
00:53:23,450 --> 00:53:20,070
to be sure that you would get one true

1322
00:53:25,310 --> 00:53:23,460
EXO earth true Earth twin at the sort of

1323
00:53:27,260 --> 00:53:25,320
ninety-five percent confidence level so

1324
00:53:28,640 --> 00:53:27,270
you know so but we really want to do

1325
00:53:33,109 --> 00:53:28,650
here is you want to study we want to be

1326
00:53:35,990 --> 00:53:33,119
able to to sort of characterize in many

1327
00:53:37,550 --> 00:53:36,000
different ways actually you know at

1328
00:53:40,640 --> 00:53:37,560
several dozen so I'm going to say I

1329
00:53:42,890 --> 00:53:40,650
think several several dozens of rocky

1330
00:53:45,859 --> 00:53:42,900
planet candidates the habitable zones of

1331
00:53:46,970 --> 00:53:45,869
nearby stars several dozens but of

1332
00:53:48,920 --> 00:53:46,980
course that's just that's stage one

1333
00:53:51,710 --> 00:53:48,930
that's about is our there that's about

1334
00:53:54,290 --> 00:53:51,720
finding out what the sort of the

1335
00:53:57,260 --> 00:53:54,300
frequency of habitable conditions is

1336
00:54:01,010 --> 00:53:57,270
Stage two would be of those how many of

1337
00:54:02,690 --> 00:54:01,020
them are inhabited and I don't know how

1338
00:54:04,490 --> 00:54:02,700

many we need to look at to see that we

1339
00:54:06,079 --> 00:54:04,500
just don't know we just don't know

1340
00:54:08,450 --> 00:54:06,089
enough about how life arose on this

1341
00:54:10,960 --> 00:54:08,460
planet you know whether it's inevitable

1342
00:54:15,349 --> 00:54:10,970
or extremely rare or anything it's just

1343
00:54:17,839 --> 00:54:15,359
anyway sounds like we need to do the

1344
00:54:19,849 --> 00:54:17,849
experiment actually observe the planets

1345
00:54:21,589 --> 00:54:19,859
I mean at least one thing we do know

1346
00:54:23,810 --> 00:54:21,599
from life on earth is that it appears

1347
00:54:26,690 --> 00:54:23,820
that life on Earth arose very early in

1348
00:54:30,020 --> 00:54:26,700
Earth's history so perhaps that means

1349
00:54:32,510 --> 00:54:30,030
that once conditions are right for the

1350
00:54:34,400 --> 00:54:32,520
origin of life maybe maybe it's not so

1351
00:54:36,050 --> 00:54:34,410
hard for it to occur but again we don't

1352
00:54:37,849 --> 00:54:36,060
know we don't know what's gonna happen

1353
00:54:42,770 --> 00:54:37,859
on an exoplanet so we need to do this

1354
00:54:43,400 --> 00:54:42,780
experiment to actually find out next

1355
00:54:45,349 --> 00:54:43,410
question

1356
00:54:46,910 --> 00:54:45,359
hi is Sonny Harmon from Columbia

1357
00:54:48,529 --> 00:54:46,920
University I was curious

1358
00:54:50,480 --> 00:54:48,539
we've had a lot of discussion about it

1359
00:54:52,730 --> 00:54:50,490
this week and I was hoping you guys

1360
00:54:55,160 --> 00:54:52,740
could recap what each of you think is

1361
00:54:56,660 --> 00:54:55,170
the biggest hurdle in our search for and

1362
00:55:03,710 --> 00:54:56,670
characterization of habitable and

1363
00:55:05,029 --> 00:55:03,720

potentially inhabited planets they were

1364
00:55:07,849 --> 00:55:05,039
looking for the

1365
00:55:11,239 --> 00:55:07,859
hurdle in characterizing habitable

1366
00:55:13,759 --> 00:55:11,249
versus inhabited planets or both I think

1367
00:55:19,549 --> 00:55:13,769
just in general in general just in

1368
00:55:21,799 --> 00:55:19,559
general it's gonna be hard we're gonna

1369
00:55:24,109 --> 00:55:21,809
need a lot of Technology Development

1370
00:55:26,150 --> 00:55:24,119
we're gonna need large missions in order

1371
00:55:28,609 --> 00:55:26,160
to do this and so what we need in order

1372
00:55:30,559 --> 00:55:28,619
to answer these questions of are there

1373
00:55:32,890 --> 00:55:30,569
other habitable planets and is there

1374
00:55:35,479 --> 00:55:32,900
life elsewhere in the galaxy we need

1375
00:55:38,719 --> 00:55:35,489
large missions that are dedicated to

1376
00:55:40,370 --> 00:55:38,729
answering this question we it will be

1377
00:55:43,579 --> 00:55:40,380
hard to do it without it because if life

1378
00:55:45,199 --> 00:55:43,589
is not very common we need a large

1379
00:55:46,640 --> 00:55:45,209
sample size of Earth's and in order to

1380
00:55:48,739 --> 00:55:46,650
get that large sample size of you know

1381
00:55:50,359 --> 00:55:48,749
potential earths you need a big

1382
00:55:54,289 --> 00:55:50,369
light-collecting bucket in order to see

1383
00:55:56,329 --> 00:55:54,299
as many as you possibly can yeah that's

1384
00:55:58,549 --> 00:55:56,339
a great point I guess if I was to sum it

1385
00:56:00,229 --> 00:55:58,559
up I would say technology right that's

1386
00:56:02,809 --> 00:56:00,239
that's unfortunately the biggest hurdle

1387
00:56:07,130 --> 00:56:02,819
that we have at the moment but also in

1388
00:56:08,479 --> 00:56:07,140

terms of life origin of life studies we

1389
00:56:09,949 --> 00:56:08,489
could we could do with a lot more well

1390
00:56:13,519 --> 00:56:09,959
there's some great work already being

1391
00:56:15,799 --> 00:56:13,529
done but finding out as our key eluded

1392
00:56:17,630 --> 00:56:15,809
to the conditions and processes that

1393
00:56:20,620 --> 00:56:17,640
allowed life to emerge on this planet

1394
00:56:22,669 --> 00:56:20,630
would provide a huge boon to us

1395
00:56:24,709 --> 00:56:22,679
understanding the potential habitability

1396
00:56:29,630 --> 00:56:24,719
order potential for planets to be

1397
00:56:31,459 --> 00:56:29,640
inhabited out there in the galaxy yeah I

1398
00:56:32,870 --> 00:56:31,469
think oh yeah mom it's Giada on this one

1399
00:56:38,870 --> 00:56:32,880
mostly what we need is what's the

1400
00:56:40,609 --> 00:56:38,880
biggest hurdle resources because I and

1401
00:56:43,429 --> 00:56:40,619
we do need technology development but we

1402
00:56:45,679 --> 00:56:43,439
you know I we we basically know what we

1403
00:56:47,359 --> 00:56:45,689
need to do you know on the technology

1404
00:56:52,069 --> 00:56:47,369
development path you know what there's a

1405
00:56:56,029 --> 00:56:52,079
plan we just need the support and to do

1406
00:56:57,979 --> 00:56:56,039
it okay I have a lightning round

1407
00:56:59,719 --> 00:56:57,989
question again from the ask NASA hashtag

1408
00:57:01,789 --> 00:56:59,729
so I think I'd like to just hear all the

1409
00:57:04,339 --> 00:57:01,799
panelists answer to this one without you

1410
00:57:06,169 --> 00:57:04,349
know just your gut reaction in your

1411
00:57:08,839 --> 00:57:06,179
opinion are we more likely to find life

1412
00:57:11,319 --> 00:57:08,849
beyond Earth on exoplanets first or in

1413
00:57:15,170 --> 00:57:11,329

the outer part of our own solar system

1414
00:57:16,820 --> 00:57:15,180
I'm going to say solar system I'm a so

1415
00:57:21,410 --> 00:57:16,830
outer solar system evangelist as you

1416
00:57:23,240 --> 00:57:21,420
might picked up from the panel I love

1417
00:57:24,560 --> 00:57:23,250
the solar system I have a special place

1418
00:57:27,080 --> 00:57:24,570
in my heart for all the solar system

1419
00:57:29,030 --> 00:57:27,090
planets but deep in my heart I am biased

1420
00:57:30,650 --> 00:57:29,040
towards exoplanets there's there's more

1421
00:57:34,850 --> 00:57:30,660
exoplanets than there are solar system

1422
00:57:36,380 --> 00:57:34,860
worlds yeah I think I'm gonna go with

1423
00:57:38,150 --> 00:57:36,390
Giada on that one actually two

1424
00:57:43,490 --> 00:57:38,160
exoplanets just because there's so many

1425
00:57:45,890 --> 00:57:43,500
more places to look you know and I think

1426
00:57:48,650 --> 00:57:45,900
I am going to unfortunately tie this and

1427
00:57:50,570 --> 00:57:48,660
say solar system alright so there you

1428
00:57:53,600 --> 00:57:50,580
have it two two and two and then the

1429
00:57:55,640 --> 00:57:53,610
last question from ask NASA some people

1430
00:57:57,470 --> 00:57:55,650
are kind of ho-hum about finding

1431
00:58:00,230 --> 00:57:57,480
microbes beyond Earth we want to find

1432
00:58:04,270 --> 00:58:00,240
intelligent life so why should we be

1433
00:58:08,930 --> 00:58:06,530
well the small stuff still teaches us

1434
00:58:10,760 --> 00:58:08,940
our place in the cosmos it teaches us if

1435
00:58:13,370 --> 00:58:10,770
intelligent life is rare if we start

1436
00:58:14,930 --> 00:58:13,380
pointing our telescopes at every you

1437
00:58:16,850 --> 00:58:14,940
know potential earth-like planet out

1438
00:58:17,990 --> 00:58:16,860

there and maybe we see biosignatures in

1439
00:58:20,570 --> 00:58:18,000
their atmospheres but we don't see any

1440
00:58:22,100 --> 00:58:20,580
techno signatures you know radio signals

1441
00:58:24,620 --> 00:58:22,110
coming from those planets perhaps that

1442
00:58:30,890 --> 00:58:24,630
suggests that maybe intelligent life is

1443
00:58:32,450 --> 00:58:30,900
rare but simple life is common yeah and

1444
00:58:35,150 --> 00:58:32,460
I guess I'll point out that you know big

1445
00:58:38,600 --> 00:58:35,160
things arise from small things so you

1446
00:58:40,400 --> 00:58:38,610
know we you know the doesn't don't go to

1447
00:58:44,870 --> 00:58:40,410
pooh-poohing the bacteria we wouldn't be

1448
00:58:47,420 --> 00:58:44,880
here without them well it's been a great

1449
00:58:49,310 --> 00:58:47,430
discussion and I'm very pleased to have

1450
00:58:52,550 --> 00:58:49,320
had the opportunity to listen to all you

1451
00:58:54,760 --> 00:58:52,560
discuss these great ideas and thank you

1452
00:59:01,500 --> 00:58:54,770
to each one of you for coming