# LUVOIR:
# The Astrobiology Telescope

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1
00:00:00,820 --> 00:00:08,049
[Music]

2
00:00:12,290 --> 00:00:09,950
people ask me like what I do for a

3
00:00:14,600 --> 00:00:12,300
living I used to say look for aliens but

4
00:00:16,070 --> 00:00:14,610
then they get like et in their head now

5
00:00:17,599 --> 00:00:16,080
I say I look for ways to look for aliens

6
00:00:19,970 --> 00:00:17,609
which is much closer to the truth and

7
00:00:21,710 --> 00:00:19,980
actually what I do is I I these days I

8
00:00:23,810 --> 00:00:21,720
sit at the interface between scientists

9
00:00:25,070 --> 00:00:23,820
like yourselves that try to think of

10
00:00:27,290 --> 00:00:25,080
what measurements we would need to make

11
00:00:29,060 --> 00:00:27,300
to look for life on an exoplanet a

12
00:00:30,259 --> 00:00:29,070
planet around another star and the

13
00:00:32,749 --> 00:00:30,269

engineers that we have at NASA Goddard

14
00:00:34,370 --> 00:00:32,759
that build giant space telescopes and so

15
00:00:35,750 --> 00:00:34,380
most of my talk today is going to be

16
00:00:37,700 --> 00:00:35,760
talking about the science that that

17
00:00:39,010 --> 00:00:37,710
telescope this particular one lulara

18
00:00:42,139 --> 00:00:39,020
could do and by the way that stands for

19
00:00:44,299 --> 00:00:42,149
large ultraviolet optical infrared

20
00:00:46,010 --> 00:00:44,309
telescope it will change its name again

21
00:00:47,690 --> 00:00:46,020
like at least once or twice if it

22
00:00:49,880 --> 00:00:47,700
actually happens but that's kind of like

23
00:00:51,410 --> 00:00:49,890
the standard name we do the boring names

24
00:00:53,060 --> 00:00:51,420
first and we named it after someone like

25
00:00:54,590 --> 00:00:53,070
when it gets closer to launch so who

26
00:00:59,180 --> 00:00:54,600
knows who that'll be named after we'll

27
00:01:00,229 --> 00:00:59,190
find out hopefully one day so I'm gonna

28
00:01:01,400 --> 00:01:00,239
start with a science and then I'll get

29
00:01:03,889 --> 00:01:01,410
to the telescope that's gonna make the

30
00:01:05,719 --> 00:01:03,899
science happen and I'd like to call of

31
00:01:07,789 --> 00:01:05,729
our the astrobiology telescope that's

32
00:01:10,010 --> 00:01:07,799
not an official thing that's just my

33
00:01:11,630 --> 00:01:10,020
thing and the reason is and there's a

34
00:01:13,190 --> 00:01:11,640
broader set of questions that

35
00:01:14,870 --> 00:01:13,200
astrobiologists look at like with

36
00:01:16,370 --> 00:01:14,880
regards to prebiotic chemistry and the

37
00:01:18,710 --> 00:01:16,380
origins of life as we're hearing about

38
00:01:20,570 --> 00:01:18,720

today but there's three critical

39
00:01:21,950 --> 00:01:20,580
questions to astrobiology that leVoir is

40
00:01:24,109 --> 00:01:21,960
going to address it's gonna address

41
00:01:25,929 --> 00:01:24,119
where did life come from what is the

42
00:01:27,770 --> 00:01:25,939
diversity of worlds especially the

43
00:01:29,149 --> 00:01:27,780
diversity of worlds beyond our solar

44
00:01:31,340 --> 00:01:29,159
system and how can that put our solar

45
00:01:32,899 --> 00:01:31,350
system into context and is there life

46
00:01:33,800 --> 00:01:32,909
beyond Earth so I'm just gonna go

47
00:01:36,080 --> 00:01:33,810
through these one by one

48
00:01:37,609 --> 00:01:36,090
and kind of outline the types of science

49
00:01:40,100 --> 00:01:37,619
we can do at the Space Telescope that

50
00:01:41,600 --> 00:01:40,110
address these questions so first where

51
00:01:42,859 --> 00:01:41,610
did life come from you know obviously

52
00:01:44,870 --> 00:01:42,869
we're not going to be doing chemistry in

53
00:01:46,910 --> 00:01:44,880
the lab however as Jill tarter would

54
00:01:49,370 --> 00:01:46,920
have told us that we're basically the

55
00:01:51,200 --> 00:01:49,380
the logical extension of hydrogen and

56
00:01:54,319 --> 00:01:51,210
helium evolving for so long that it

57
00:01:57,170 --> 00:01:54,329
begins to ask where it came from or as

58
00:01:58,670 --> 00:01:57,180
Carl Sagan said it before if you want to

59
00:02:00,410 --> 00:01:58,680
make an apple pie from scratch first you

60
00:02:01,580 --> 00:02:00,420
have to invent the universe and you have

61
00:02:04,069 --> 00:02:01,590
to admit and all the things that go into

62
00:02:05,330 --> 00:02:04,079
that apple pie and what levar or a Space

63
00:02:07,039 --> 00:02:05,340

Telescope can do here is it can actually

64
00:02:08,359 --> 00:02:07,049
start to probe the processes that led to

65
00:02:10,160 --> 00:02:08,369
the formation of elements that

66
00:02:12,589 --> 00:02:10,170
eventually get incorporated into the

67
00:02:13,230 --> 00:02:12,599
planets like Earth that that living

68
00:02:15,840 --> 00:02:13,240
things can

69
00:02:18,510 --> 00:02:15,850
exist on sohere's Andromeda one of our

70
00:02:20,550 --> 00:02:18,520
nearby galaxies Hubble has been able to

71
00:02:22,650 --> 00:02:20,560
resolve individual stars in Andromeda

72
00:02:24,630 --> 00:02:22,660
and it's been able to do that throughout

73
00:02:26,130 --> 00:02:24,640
the main sequence of stars which helps

74
00:02:29,610 --> 00:02:26,140
us understand the main sequence

75
00:02:31,470 --> 00:02:29,620
evolution of stars now what a telescope

76
00:02:33,690 --> 00:02:31,480
a larger telescope so Hubble can do that

77
00:02:34,890 --> 00:02:33,700
for very very close galaxies and the way

78
00:02:36,840 --> 00:02:34,900
to think about it is the bigger your

79
00:02:38,940 --> 00:02:36,850
telescope the greater your angular

80
00:02:40,290 --> 00:02:38,950
resolution you can see sort of closer

81
00:02:41,940 --> 00:02:40,300
thing things that are closer to each

82
00:02:44,100 --> 00:02:41,950
other you can separate out in your in

83
00:02:46,260 --> 00:02:44,110
your optical array so Hubble can see

84
00:02:48,240 --> 00:02:46,270
individual stars in our in our nearest

85
00:02:50,610 --> 00:02:48,250
part of our galactic neighborhood that

86
00:02:53,280 --> 00:02:50,620
get Newton most nearby galaxies Liu foir

87
00:02:55,290 --> 00:02:53,290
would extend that out for multiple mega

88
00:02:57,120 --> 00:02:55,300

parsecs and and that's important for a

89
00:02:59,820 --> 00:02:57,130
number of reasons one is it gets us just

90
00:03:02,160 --> 00:02:59,830
a larger sample set of galaxies to do

91
00:03:03,600 --> 00:03:02,170
this individual start probing on but the

92
00:03:05,760 --> 00:03:03,610
second is as that sample size goes up

93
00:03:07,770 --> 00:03:05,770
the diversity of galaxies goes up and in

94
00:03:09,840 --> 00:03:07,780
any physical system having being able to

95
00:03:11,040 --> 00:03:09,850
probe a wider diversity of targets is

96
00:03:12,870 --> 00:03:11,050
always going to be a good thing and

97
00:03:14,640 --> 00:03:12,880
that's that's a topic I'll come back to

98
00:03:15,990 --> 00:03:14,650
again and again is a sort of a diversity

99
00:03:17,910 --> 00:03:16,000
of targets that we want to be able to

100
00:03:20,280 --> 00:03:17,920
look at as astronomers when we're

101
00:03:21,690 --> 00:03:20,290
thinking about any physical process in

102
00:03:23,880 --> 00:03:21,700
particular what we're interested in is

103
00:03:25,770 --> 00:03:23,890
being able to not just get at GWAR dwarf

104
00:03:28,830 --> 00:03:25,780
and large spiral galaxies but also large

105
00:03:31,260 --> 00:03:28,840
elliptical galaxies another way to

106
00:03:32,790 --> 00:03:31,270
demonstrate this is this is a mother way

107
00:03:34,230 --> 00:03:32,800
for the non astronomers like Z equals

108
00:03:35,940 --> 00:03:34,240
two if you ever see these C numbers it

109
00:03:38,100 --> 00:03:35,950
just means how redshifted it is and the

110
00:03:40,500 --> 00:03:38,110
larger that Z number is the further away

111
00:03:42,660 --> 00:03:40,510
the galaxies would be so this would be

112
00:03:44,970 --> 00:03:42,670
like a low mass galaxy at a Z equals two

113
00:03:46,860 --> 00:03:44,980

redshift with Hubble okay so to show you

114
00:03:51,480 --> 00:03:46,870
what Lavar would do for a similar galaxy

115
00:03:53,430 --> 00:03:51,490
so this is pretty far away this is what

116
00:03:55,590 --> 00:03:53,440
the bar would see so not only are you

117
00:03:57,720 --> 00:03:55,600
blowing this up on the screen and making

118
00:03:59,550 --> 00:03:57,730
you know a bigger target to look at

119
00:04:00,750 --> 00:03:59,560
you're getting more spatial resolution

120
00:04:02,130 --> 00:04:00,760
like the other nickname for this

121
00:04:03,690 --> 00:04:02,140
telescope before the Louvre our study

122
00:04:05,700 --> 00:04:03,700
had happened was called the High

123
00:04:07,830 --> 00:04:05,710
Definition space telescope because the

124
00:04:09,780 --> 00:04:07,840
difference in pixels that we have

125
00:04:11,610 --> 00:04:09,790
between Hubble and moonflower is

126
00:04:12,920 --> 00:04:11,620
comparable to the difference between a

127
00:04:16,170 --> 00:04:12,930
high-definition and standard-definition

128
00:04:17,070 --> 00:04:16,180
television and this isn't just about the

129
00:04:19,140 --> 00:04:17,080
pretty pictures although these are

130
00:04:20,970 --> 00:04:19,150
pretty awesome it's also about probing

131
00:04:22,520 --> 00:04:20,980
the physical and chemical processes

132
00:04:24,840 --> 00:04:22,530
happening in these stellar environments

133
00:04:25,420 --> 00:04:24,850
and this is where the ultraviolet the

134
00:04:28,780 --> 00:04:25,430
move

135
00:04:30,820 --> 00:04:28,790
in lieu for comes in because if you can

136
00:04:33,010 --> 00:04:30,830
probe these stars into the ultraviolet

137
00:04:34,029 --> 00:04:33,020
or probe stars into the ultraviolet you

138
00:04:36,730 --> 00:04:34,039

can actually start to look at their

139
00:04:38,950 --> 00:04:36,740
elemental compositions and you can do

140
00:04:41,770 --> 00:04:38,960
everything from oxygen to magnesium all

141
00:04:44,800 --> 00:04:41,780
the way down through carbon and sulfur

142
00:04:46,510 --> 00:04:44,810
and iron down here and and now that's

143
00:04:48,189 --> 00:04:46,520
starting to get at the processes that

144
00:04:49,510 --> 00:04:48,199
make the elements that we are made of

145
00:04:51,279 --> 00:04:49,520
that Earth is made of and that other

146
00:04:53,560 --> 00:04:51,289
planets are made of and being able again

147
00:04:55,840 --> 00:04:53,570
to do this for a diversity of stellar

148
00:04:57,700 --> 00:04:55,850
targets in diverse diversity of galactic

149
00:05:00,520 --> 00:04:57,710
environments right we we talked today a

150
00:05:02,439 --> 00:05:00,530
lot a lot about how the environment of a

151
00:05:04,060 --> 00:05:02,449
chemical system is important right well

152
00:05:06,250 --> 00:05:04,070
that the same thing is true for stars

153
00:05:09,310 --> 00:05:06,260
but for starters the the environment is

154
00:05:10,779 --> 00:05:09,320
something on the galactic scale and that

155
00:05:12,820 --> 00:05:10,789
also becomes important when you think

156
00:05:15,540 --> 00:05:12,830
about cycling of matter between and

157
00:05:19,150 --> 00:05:15,550
amongst a galaxy one thing that's that's

158
00:05:20,740 --> 00:05:19,160
kind of well at least to me I shouldn't

159
00:05:23,080 --> 00:05:20,750
say it's at the forefront it's a it's at

160
00:05:24,490 --> 00:05:23,090
my forefront of knowledge because I

161
00:05:26,830 --> 00:05:24,500
didn't know any of the stuff I've talked

162
00:05:28,240 --> 00:05:26,840
about up through now before the Louvre

163
00:05:30,430 --> 00:05:28,250

our studies started because I'm an

164
00:05:32,320 --> 00:05:30,440
exoplanet scientist but one thing I've

165
00:05:34,360 --> 00:05:32,330
learned is that we now understand that

166
00:05:36,430 --> 00:05:34,370
matter actually can cycle beyond a

167
00:05:38,379 --> 00:05:36,440
galaxy and then flow back into it and

168
00:05:41,379 --> 00:05:38,389
it's actually that cycling that helps

169
00:05:42,670 --> 00:05:41,389
feed future star formation the analogy

170
00:05:44,219 --> 00:05:42,680
for me as an earth scientist is it's a

171
00:05:46,480 --> 00:05:44,229
little bit like plate tectonics

172
00:05:48,700 --> 00:05:46,490
overturning nutrients and refreshing

173
00:05:50,920 --> 00:05:48,710
your trains to to a biosphere you need

174
00:05:53,260 --> 00:05:50,930
the capability for elements to be able

175
00:05:55,899 --> 00:05:53,270
to be cycled past a galaxy and flow back

176
00:05:57,399 --> 00:05:55,909
into it now the way you probe that as

177
00:06:00,100 --> 00:05:57,409
you'll actually look for background

178
00:06:02,710 --> 00:06:00,110
high-energy stars that puncture the

179
00:06:03,909 --> 00:06:02,720
galaxy and lets you because they're kind

180
00:06:06,070 --> 00:06:03,919
of like beacons shining through the

181
00:06:08,529 --> 00:06:06,080
galaxy you use them as a background

182
00:06:10,839 --> 00:06:08,539
light source and then and then with that

183
00:06:12,640 --> 00:06:10,849
background light source you can assess

184
00:06:14,469 --> 00:06:12,650
the composition of the galaxy in various

185
00:06:17,500 --> 00:06:14,479
points and get it how much mass is there

186
00:06:19,689 --> 00:06:17,510
and also what it's made of now as you go

187
00:06:21,399 --> 00:06:19,699
to larger and larger telescopes you can

188
00:06:23,350 --> 00:06:21,409

see fainter and fainter background

189
00:06:24,820 --> 00:06:23,360
beacons and that means you get more and

190
00:06:28,120 --> 00:06:24,830
more background beacons and that means

191
00:06:29,710 --> 00:06:28,130
that if there's some non consistent

192
00:06:31,930 --> 00:06:29,720
shape to a galaxy and that extra

193
00:06:33,430 --> 00:06:31,940
galactic flow like we think there might

194
00:06:35,529 --> 00:06:33,440
be this is sort of an artist's rendering

195
00:06:36,459 --> 00:06:35,539
if you just have two points you can't

196
00:06:38,500 --> 00:06:36,469
really say much about this

197
00:06:39,190 --> 00:06:38,510
two-dimensional structure here but if

198
00:06:40,840 --> 00:06:39,200
you've got an

199
00:06:42,520 --> 00:06:40,850
points which is what a larger aperture

200
00:06:44,560 --> 00:06:42,530
telescope will allow because it's seeing

201
00:06:46,630 --> 00:06:44,570
the fainter stuff then you can probe

202
00:06:48,100 --> 00:06:46,640
more things so this is sort of the the

203
00:06:49,570 --> 00:06:48,110
second thing you gain when you go to

204
00:06:51,310 --> 00:06:49,580
larger telescopes right you get better

205
00:06:54,280 --> 00:06:51,320
angular resolution better spatial

206
00:06:56,020 --> 00:06:54,290
resolution but you also can see fainter

207
00:06:58,300 --> 00:06:56,030
targets that are either further away or

208
00:07:02,200 --> 00:06:58,310
in this case more faint targets within a

209
00:07:03,790 --> 00:07:02,210
particular field okay and then it's not

210
00:07:05,530 --> 00:07:03,800
just about the stars forming and what

211
00:07:09,430 --> 00:07:05,540
what how elements are cycled within the

212
00:07:11,650 --> 00:07:09,440
stars begin okay it's also about how

213
00:07:13,510 --> 00:07:11,660

that matter gets incorporated eventually

214
00:07:14,770 --> 00:07:13,520
into planets themselves and this is

215
00:07:15,940 --> 00:07:14,780
another thing though far we'll be doing

216
00:07:18,570 --> 00:07:15,950
it's going to be looking at the debris

217
00:07:20,260 --> 00:07:18,580
disks around stars especially younger

218
00:07:21,940 --> 00:07:20,270
for this science case at least

219
00:07:23,500 --> 00:07:21,950
especially younger planetary systems

220
00:07:26,140 --> 00:07:23,510
where there's still a lot of gas and

221
00:07:27,310 --> 00:07:26,150
dust in the system one one way I like

222
00:07:30,340 --> 00:07:27,320
looking at this is this is the beta

223
00:07:32,800 --> 00:07:30,350
Pictoris to disk which is really famous

224
00:07:34,450 --> 00:07:32,810
because it's got this cool structure and

225
00:07:36,700 --> 00:07:34,460
then and what we did was first we saw

226
00:07:38,740 --> 00:07:36,710
the the disk which extends really far

227
00:07:40,900 --> 00:07:38,750
out into this this planetary system and

228
00:07:42,490 --> 00:07:40,910
then we saw a planet here at two

229
00:07:45,850 --> 00:07:42,500
different parts of its orbit with

230
00:07:47,290 --> 00:07:45,860
another observation this zoom in is what

231
00:07:49,030 --> 00:07:47,300
levar will be able to do it'll be able

232
00:07:50,920 --> 00:07:49,040
to go further into the interior of this

233
00:07:52,750 --> 00:07:50,930
system and do two things one look for

234
00:07:55,000 --> 00:07:52,760
planets and in here closer to the star

235
00:07:57,010 --> 00:07:55,010
but second look at the dust and gas

236
00:07:58,960 --> 00:07:57,020
closer to the star as well and so we'll

237
00:08:01,870 --> 00:07:58,970
be able to track not just what this big

238
00:08:03,250 --> 00:08:01,880

picture disk looks like but also what

239
00:08:05,140 --> 00:08:03,260
this stuff closer to the star looks like

240
00:08:07,120 --> 00:08:05,150
where habitable planets are forming so

241
00:08:09,670 --> 00:08:07,130
we'd be able to we know a lot now today

242
00:08:12,550 --> 00:08:09,680
as astronomers about how planets form

243
00:08:14,140 --> 00:08:12,560
especially further out from the star but

244
00:08:15,640 --> 00:08:14,150
if you want to know what's happening

245
00:08:17,740 --> 00:08:15,650
close to the star where habitable

246
00:08:19,780 --> 00:08:17,750
planets form you actually need to get a

247
00:08:21,190 --> 00:08:19,790
different kind of telescope that can see

248
00:08:24,130 --> 00:08:21,200
closer to the star and that's one of the

249
00:08:26,860 --> 00:08:24,140
things levar what enable and and we're

250
00:08:28,540 --> 00:08:26,870
gonna do stuff like this close in our

251
00:08:32,380 --> 00:08:28,550
own solar system as well closer to home

252
00:08:34,089 --> 00:08:32,390
so this is a giant scatter plot of all

253
00:08:35,890 --> 00:08:34,099
the solar systems small bodies that

254
00:08:38,350 --> 00:08:35,900
levar will also be able to probe for its

255
00:08:39,490 --> 00:08:38,360
chemical composition yeah and I didn't

256
00:08:41,020 --> 00:08:39,500
mention this we're also going to be

257
00:08:42,550 --> 00:08:41,030
doing chemical analyses of these so

258
00:08:43,870 --> 00:08:42,560
almost every target we look at there's

259
00:08:45,940 --> 00:08:43,880
going to be a spectrometer on board

260
00:08:48,610 --> 00:08:45,950
that's gonna look at the the composition

261
00:08:50,860 --> 00:08:48,620
of all our targets whether it's stars or

262
00:08:52,240 --> 00:08:50,870
the debris disks and in this case small

263
00:08:52,690 --> 00:08:52,250

bodies in our solar system so here's

264
00:08:55,450 --> 00:08:52,700
Pluto

265
00:08:57,340 --> 00:08:55,460
we'd actually be able to characterize

266
00:08:58,960 --> 00:08:57,350
its atmosphere I'm going to show a

267
00:09:00,970 --> 00:08:58,970
picture of how impressive our Pluto

268
00:09:03,940 --> 00:09:00,980
observations would be in in a moment for

269
00:09:05,200 --> 00:09:03,950
smaller bodies like Sedna we also be

270
00:09:06,760 --> 00:09:05,210
able to look at their their sort of

271
00:09:08,620 --> 00:09:06,770
temporal and spatial variability and

272
00:09:10,960 --> 00:09:08,630
take multiple snapshots of the thing as

273
00:09:12,460 --> 00:09:10,970
it rotates or goes through seasons and

274
00:09:13,660 --> 00:09:12,470
then for really small stuff we could

275
00:09:15,430 --> 00:09:13,670
search at least for the objects

276
00:09:18,120 --> 00:09:15,440
themselves even if we can't sort of

277
00:09:21,610 --> 00:09:18,130
probe their their chemical composition

278
00:09:23,020 --> 00:09:21,620
so this is Pluto with Hubble this is

279
00:09:25,150 --> 00:09:23,030
what Pluto would look like with a 15

280
00:09:26,980 --> 00:09:25,160
meter loop are you don't get the cute

281
00:09:28,240 --> 00:09:26,990
heart that we got with a flyby mission

282
00:09:31,180 --> 00:09:28,250
right you can't quite make out that

283
00:09:32,860 --> 00:09:31,190
level of spatial detail but what you can

284
00:09:34,480 --> 00:09:32,870
do is you can tell that something is

285
00:09:35,950 --> 00:09:34,490
going on here right I mean part of the

286
00:09:37,450 --> 00:09:35,960
thing that was amazing about the New

287
00:09:39,790 --> 00:09:37,460
Horizons spacecraft when it when it

288
00:09:42,550 --> 00:09:39,800

passed by Pluto is I actually remember I

289
00:09:44,680 --> 00:09:42,560
got a I got a letter like three months

290
00:09:46,480 --> 00:09:44,690
before the flyby or maybe is a lot maybe

291
00:09:48,070 --> 00:09:46,490
six months before the life live from a

292
00:09:50,020 --> 00:09:48,080
great school kid who said like do you

293
00:09:51,940 --> 00:09:50,030
think there could be life on Pluto I'm

294
00:09:53,470 --> 00:09:51,950
like you know skeptical we're trying to

295
00:09:56,590 --> 00:09:53,480
be skeptical scientists right so I was

296
00:09:58,690 --> 00:09:56,600
like no Pluto's like a dumb boring ball

297
00:10:01,030 --> 00:09:58,700
of like rock and ice and it's dead and

298
00:10:02,290 --> 00:10:01,040
nothing's happening there and then I

299
00:10:03,700 --> 00:10:02,300
stopped because it was a grade schooler

300
00:10:06,130 --> 00:10:03,710
that I was kind of light and I was like

301
00:10:07,630 --> 00:10:06,140
okay let's let's try to be a little more

302
00:10:08,680 --> 00:10:07,640
optimistic and I and I thought about it

303
00:10:10,420 --> 00:10:08,690
for a while and I was like what's the

304
00:10:13,090 --> 00:10:10,430
optimist optimistic take care and I was

305
00:10:15,010 --> 00:10:13,100
like well we've seen a lot of water

306
00:10:17,230 --> 00:10:15,020
activity on places we never expected it

307
00:10:19,750 --> 00:10:17,240
before we actually haven't seen Pluto in

308
00:10:21,550 --> 00:10:19,760
detail before maybe there is some

309
00:10:23,650 --> 00:10:21,560
geological or subsurface kind of

310
00:10:25,390 --> 00:10:23,660
activity on Pluto and if there is then

311
00:10:27,820 --> 00:10:25,400
you know maybe there's a chance for life

312
00:10:29,620 --> 00:10:27,830
and the way we'll know as scientists is

313
00:10:31,210 --> 00:10:29,630

we'll do a test and it just so happens

314
00:10:32,260 --> 00:10:31,220
that in a few months from now we're

315
00:10:34,330 --> 00:10:32,270
going to have a test when this

316
00:10:36,670 --> 00:10:34,340
spacecraft flies by Pluto and sure

317
00:10:38,260 --> 00:10:36,680
enough like we flew by and Pluto is

318
00:10:40,030 --> 00:10:38,270
definitely geologically active there's

319
00:10:42,400 --> 00:10:40,040
like flows and like these huge flat

320
00:10:44,950 --> 00:10:42,410
areas that are some sort of like lake

321
00:10:45,660 --> 00:10:44,960
bed and like first of all the kid was

322
00:10:47,800 --> 00:10:45,670
right

323
00:10:49,150 --> 00:10:47,810
second of all like I mean I don't know

324
00:10:50,410 --> 00:10:49,160
if there's life on Pluto but like the

325
00:10:52,690 --> 00:10:50,420
kid was right that like I shouldn't have

326
00:10:53,800 --> 00:10:52,700
just dismissed it right away but this is

327
00:10:56,560 --> 00:10:53,810
the kind of thing you can do when you

328
00:10:58,300 --> 00:10:56,570
get imagery of targets you know and

329
00:11:00,400 --> 00:10:58,310
we'll be able to get to imagery at least

330
00:11:01,840 --> 00:11:00,410
this good for anything closer than Pluto

331
00:11:04,060 --> 00:11:01,850
which is basically the rest of the solar

332
00:11:06,220 --> 00:11:04,070
system so this is the kind of stuff we

333
00:11:08,260 --> 00:11:06,230
can do okay so

334
00:11:09,790 --> 00:11:08,270
this is moving closer to my sort of

335
00:11:11,590 --> 00:11:09,800
scientific wheel household I'm not quite

336
00:11:13,330 --> 00:11:11,600
there yet a second question that

337
00:11:14,980 --> 00:11:13,340
astrobiologists asked that Lavar can

338
00:11:18,190 --> 00:11:14,990

help address is what is the diversity of

339
00:11:19,630 --> 00:11:18,200
worlds and I love this quote the very

340
00:11:20,980 --> 00:11:19,640
nature of Sciences discoveries and the

341
00:11:22,870 --> 00:11:20,990
best of those discoveries are the ones

342
00:11:25,690 --> 00:11:22,880
you don't expect from the other graphs

343
00:11:28,090 --> 00:11:25,700
Tyson and the reason I put this quote up

344
00:11:30,430 --> 00:11:28,100
is because the history of exoplanet

345
00:11:35,970 --> 00:11:30,440
science has basically been a story of

346
00:11:38,140 --> 00:11:35,980
repeated appending of our expectations

347
00:11:40,150 --> 00:11:38,150
here's the world in our solar system

348
00:11:41,770 --> 00:11:40,160
this is and by the way if you ask me in

349
00:11:44,290 --> 00:11:41,780
Pluto's still is a planet I mean look at

350
00:11:46,660 --> 00:11:44,300
this thing how can this not be a planet

351
00:11:48,280 --> 00:11:46,670
right someone said like it has to pass

352
00:11:50,470 --> 00:11:48,290
the Captain Kirk test which is like

353
00:11:52,000 --> 00:11:50,480
doesn't look like if the enterprise or

354
00:11:53,110 --> 00:11:52,010
whatever came up on the planet would you

355
00:11:54,580 --> 00:11:53,120
say it's a planet and I don't think

356
00:11:57,730 --> 00:11:54,590
anyone would say that this is not a

357
00:12:00,280 --> 00:11:57,740
planet but that's a different talk okay

358
00:12:02,290 --> 00:12:00,290
so these worlds and including the

359
00:12:05,590 --> 00:12:02,300
history in particular of Earth and of

360
00:12:06,910 --> 00:12:05,600
Mars I mean to some degree Venus that's

361
00:12:08,500 --> 00:12:06,920
what a lot of our expectations were

362
00:12:10,150 --> 00:12:08,510
based on that I was saying on the bus on

363
00:12:12,490 --> 00:12:10,160

the way over here we had this image of

364
00:12:14,290 --> 00:12:12,500
peas and carrots being well separated in

365
00:12:16,600 --> 00:12:14,300
planetary systems you had small planets

366
00:12:18,580 --> 00:12:16,610
close in and gas giants further away and

367
00:12:19,810 --> 00:12:18,590
the two shall not ever mix right what we

368
00:12:22,600 --> 00:12:19,820
ended up with this is more like some

369
00:12:24,220 --> 00:12:22,610
like toddlers smoothie or babies

370
00:12:25,570 --> 00:12:24,230
smoothie of like mixed vegetables and

371
00:12:28,120 --> 00:12:25,580
fruits and ice and everything kind of

372
00:12:30,490 --> 00:12:28,130
yogurt I'll blend it together like you

373
00:12:31,810 --> 00:12:30,500
can get almost any kind of system out if

374
00:12:34,320 --> 00:12:31,820
you have the right starting conditions

375
00:12:37,810 --> 00:12:34,330
at the very first exoplanet we found

376
00:12:39,010 --> 00:12:37,820
Pegasus 51 peg B was a planet we didn't

377
00:12:40,510 --> 00:12:39,020
know as a planet at first because it was

378
00:12:42,220 --> 00:12:40,520
so different from our expectations it

379
00:12:43,600 --> 00:12:42,230
was a planet bigger than Jupiter the

380
00:12:46,030 --> 00:12:43,610
closer to the star the mercury is to the

381
00:12:48,670 --> 00:12:46,040
Sun you you literally couldn't make that

382
00:12:51,730 --> 00:12:48,680
planet in our models when when we

383
00:12:53,200 --> 00:12:51,740
discovered it we found the the most

384
00:12:55,090 --> 00:12:53,210
common kind of planet are these things

385
00:12:57,100 --> 00:12:55,100
called super Earths or sub Neptune's and

386
00:12:58,960 --> 00:12:57,110
that are bigger than Earth but smaller

387
00:13:01,000 --> 00:12:58,970
than Neptune we expected there to be

388
00:13:03,160 --> 00:13:01,010

sort of a desert in that part of

389
00:13:04,960 --> 00:13:03,170
parameter space and it based on our

390
00:13:06,640 --> 00:13:04,970
formation models it ended up being the

391
00:13:09,400 --> 00:13:06,650
most common kind of planet out there and

392
00:13:11,350 --> 00:13:09,410
these kinds of discoveries they're not

393
00:13:13,270 --> 00:13:11,360
just like oh it's cool because it like

394
00:13:14,090 --> 00:13:13,280
wasn't what we expected they ended up

395
00:13:15,680 --> 00:13:14,100
influencing

396
00:13:18,290 --> 00:13:15,690
saying the way we think about our home

397
00:13:20,269 --> 00:13:18,300
system right so if you if you ask the

398
00:13:22,970 --> 00:13:20,279
question today how did Mars form and get

399
00:13:24,559 --> 00:13:22,980
the size and orbit that it has now well

400
00:13:25,999 --> 00:13:24,569
you get a different answer because our

401
00:13:27,710 --> 00:13:26,009
models are now better because they've

402
00:13:29,660 --> 00:13:27,720
been validated against a greater

403
00:13:31,519 --> 00:13:29,670
diversity of targets right because we

404
00:13:34,009 --> 00:13:31,529
know how to Pater's exist and super has

405
00:13:35,990 --> 00:13:34,019
exist our models had to improve to

406
00:13:37,490 --> 00:13:36,000
recreate those planets and once we did

407
00:13:39,769 --> 00:13:37,500
that we were actually able to better

408
00:13:42,110 --> 00:13:39,779
recreate the formation of Mars in its

409
00:13:43,730 --> 00:13:42,120
current state so that's cool right that

410
00:13:46,129 --> 00:13:43,740
means like our understanding of home has

411
00:13:48,879 --> 00:13:46,139
improved by our looking at stuff in the

412
00:13:51,590 --> 00:13:48,889
stars and then my favorite is Kepler 16b

413
00:13:53,449 --> 00:13:51,600

so Kepler 16b is a planet and there's

414
00:13:56,110 --> 00:13:53,459
it's not the only one we found that is

415
00:13:58,790 --> 00:13:56,120
orbiting a binary star so this is like

416
00:13:59,990 --> 00:13:58,800
kind of hard to do this with alright so

417
00:14:01,400 --> 00:14:00,000
like you get two stars or like the

418
00:14:03,050 --> 00:14:01,410
center of the system and they're

419
00:14:05,030 --> 00:14:03,060
orbiting each other and then you got

420
00:14:06,259 --> 00:14:05,040
like a planet orbiting the two stars

421
00:14:08,360 --> 00:14:06,269
further out and if you were standing on

422
00:14:09,710 --> 00:14:08,370
the surface of that planet you could see

423
00:14:11,629 --> 00:14:09,720
like a double sunset right because the

424
00:14:13,120 --> 00:14:11,639
planets out here and so both the both

425
00:14:16,639 --> 00:14:13,130
the stars are setting at the same time

426
00:14:19,249 --> 00:14:16,649
and that's like really cool but again no

427
00:14:20,870 --> 00:14:19,259
one expected this to happen I was a joke

428
00:14:22,999 --> 00:14:20,880
I'd like to tell is is that you know

429
00:14:23,990 --> 00:14:23,009
some people expected it to happen but

430
00:14:28,939 --> 00:14:24,000
they were looking at a different source

431
00:14:30,769 --> 00:14:28,949
literature because and and you know I'm

432
00:14:32,809 --> 00:14:30,779
joking a bit but like sometimes we have

433
00:14:34,340 --> 00:14:32,819
to allow our imaginations to run wild a

434
00:14:37,370 --> 00:14:34,350
little bit to see what's possible out

435
00:14:39,350 --> 00:14:37,380
there and not be too constrained by by

436
00:14:41,360 --> 00:14:39,360
the things we think are permissible just

437
00:14:44,050 --> 00:14:41,370
you know by our finely tuned models that

438
00:14:46,460 --> 00:14:44,060

recreate the reality who we're living in

439
00:14:47,900 --> 00:14:46,470
but all the discoveries we have and by

440
00:14:49,699 --> 00:14:47,910
the way this is now what's called like

441
00:14:51,019 --> 00:14:49,709
the Kepler Ori so this is all the

442
00:14:53,689 --> 00:14:51,029
planets that the Kepler telescope has

443
00:14:56,269 --> 00:14:53,699
found or it actually had found as of I

444
00:14:57,829 --> 00:14:56,279
think 2013 or something like that so

445
00:14:59,749 --> 00:14:57,839
there's thousands of worlds literally

446
00:15:01,910 --> 00:14:59,759
thousands of worlds we found beyond our

447
00:15:04,610 --> 00:15:01,920
solar system the ones Kepler has found

448
00:15:06,769 --> 00:15:04,620
which number in the thousands by the way

449
00:15:07,639 --> 00:15:06,779
it all happens like in a patch of sky

450
00:15:10,309 --> 00:15:07,649
that's like the palm of your hand

451
00:15:12,170 --> 00:15:10,319
outstretched so you know if you've gone

452
00:15:13,999 --> 00:15:12,180
to the night sky even if you're in

453
00:15:15,920 --> 00:15:14,009
Atlanta or like me in DC and you can't

454
00:15:17,090 --> 00:15:15,930
see the stars - well you can do some

455
00:15:18,199 --> 00:15:17,100
astronomy just put your hand up there

456
00:15:20,600 --> 00:15:18,209
and know that there's thousands of

457
00:15:22,370 --> 00:15:20,610
planets hiding behind it and or if you

458
00:15:25,280 --> 00:15:22,380
can count the stars we now know that on

459
00:15:27,439 --> 00:15:25,290
average there is a planet for every star

460
00:15:29,090 --> 00:15:27,449
on average there is a planet

461
00:15:31,970 --> 00:15:29,100
in the habitable zone in rocky so a

462
00:15:33,829 --> 00:15:31,980
potentially habitable world around 1/4

463
00:15:36,530 --> 00:15:33,839

of one of those planets for every 10

464
00:15:39,439 --> 00:15:36,540
stars so if you if you can even just see

465
00:15:41,989 --> 00:15:39,449
like 10 stars in the Atlanta night sky

466
00:15:43,460 --> 00:15:41,999
you found 10 planets too and you

467
00:15:44,869 --> 00:15:43,470
probably found one planet that has

468
00:15:47,780 --> 00:15:44,879
conditions that could allow for life I

469
00:15:49,400 --> 00:15:47,790
couldn't make any of those statements 10

470
00:15:51,139 --> 00:15:49,410
years ago and have any degree of

471
00:15:53,599 --> 00:15:51,149
scientific credibility it was actually a

472
00:15:55,039 --> 00:15:53,609
totally unconstrained problem and now

473
00:15:57,530 --> 00:15:55,049
it's actually quite well constrained we

474
00:15:59,599 --> 00:15:57,540
might argue about the the how abundant

475
00:16:01,909 --> 00:15:59,609
the the potentially habitable worlds are

476
00:16:04,789 --> 00:16:01,919
but the argument isn't between you know

477
00:16:06,289 --> 00:16:04,799
you have to count 10 stars or a thousand

478
00:16:08,150 --> 00:16:06,299
stars the argument is like do you have

479
00:16:09,559 --> 00:16:08,160
to count like 5 stars or you have to

480
00:16:12,349 --> 00:16:09,569
count 10 or you have to couch money

481
00:16:13,549 --> 00:16:12,359
that's you know factor 2 is like the the

482
00:16:15,439 --> 00:16:13,559
range that we're talking about for

483
00:16:16,729 --> 00:16:15,449
uncertainties now not orders of

484
00:16:19,069 --> 00:16:16,739
magnitude which is what it was before

485
00:16:21,499 --> 00:16:19,079
Kepler now the other thing to point out

486
00:16:22,879 --> 00:16:21,509
here is that's all awesome everything I

487
00:16:24,679 --> 00:16:22,889
just talked about is like fascinating

488
00:16:26,419 --> 00:16:24,689

and cool and groundbreaking and and it's

489
00:16:27,829 --> 00:16:26,429
totally changing the way we think about

490
00:16:29,569 --> 00:16:27,839
how planets form and evolve and has

491
00:16:32,629 --> 00:16:29,579
influenced how we think about our home

492
00:16:35,059 --> 00:16:32,639
system but for the most part it's all

493
00:16:36,799 --> 00:16:35,069
about the planets sizes I say they're

494
00:16:38,659 --> 00:16:36,809
Astrophysical properties how big these

495
00:16:40,699 --> 00:16:38,669
planets are in some cases how massive

496
00:16:42,289 --> 00:16:40,709
they are and how what their orbits are

497
00:16:43,999 --> 00:16:42,299
like how far away they are from their

498
00:16:46,549 --> 00:16:44,009
host star and how elliptical those

499
00:16:48,919 --> 00:16:46,559
orbits are for the most part that's all

500
00:16:50,389 --> 00:16:48,929
we know we don't know much about their

501
00:16:52,189 --> 00:16:50,399
chemical composition we certainly don't

502
00:16:55,159 --> 00:16:52,199
know much about whether or not they have

503
00:16:56,779 --> 00:16:55,169
life and because of that are even if we

504
00:16:58,939 --> 00:16:56,789
talk about a habitable world or North

505
00:17:00,859 --> 00:16:58,949
like world all we're really saying is

506
00:17:03,229 --> 00:17:00,869
that we can't rule out the possibility

507
00:17:04,639 --> 00:17:03,239
that it has liquid water oceans and

508
00:17:06,230 --> 00:17:04,649
that's about all we can in even that's a

509
00:17:08,960 --> 00:17:06,240
model result it's not something we've

510
00:17:11,000 --> 00:17:08,970
actually measured okay so this is where

511
00:17:12,860 --> 00:17:11,010
louvre art comes in because it's gonna

512
00:17:14,090 --> 00:17:12,870
actually take pictures of these worlds

513
00:17:15,529 --> 00:17:14,100

it's not going to get like spatial

514
00:17:17,600 --> 00:17:15,539
resolution like I was showing for Pluto

515
00:17:19,069 --> 00:17:17,610
but it's gonna turn each not the

516
00:17:20,509 --> 00:17:19,079
specific worlds that Kepler found but

517
00:17:22,579 --> 00:17:20,519
it's gonna four planets around other

518
00:17:24,350 --> 00:17:22,589
stars get pictures of them they're each

519
00:17:26,090 --> 00:17:24,360
going to be sort of one point of light

520
00:17:27,139 --> 00:17:26,100
on on the detectors so that the

521
00:17:29,149 --> 00:17:27,149
telescope is just going to see a point

522
00:17:30,860 --> 00:17:29,159
of light for each planet but it's going

523
00:17:32,899 --> 00:17:30,870
to do this for hundreds of worlds and

524
00:17:35,930 --> 00:17:32,909
that hundreds of worlds is going to have

525
00:17:36,860 --> 00:17:35,940
a tremendous diversity to it in a number

526
00:17:38,629 --> 00:17:36,870
of ways we're gonna look at different

527
00:17:39,889 --> 00:17:38,639
size targets from things that are like

528
00:17:41,180 --> 00:17:39,899
Mars sized

529
00:17:43,640 --> 00:17:41,190
all the way up to

530
00:17:46,430 --> 00:17:43,650
gas giant Jupiter sighs we're gonna see

531
00:17:47,660 --> 00:17:46,440
planets that are really hot like too

532
00:17:49,880 --> 00:17:47,670
close to the Sun that have life

533
00:17:51,860 --> 00:17:49,890
regardless of their size and really cold

534
00:17:54,110 --> 00:17:51,870
that are way too far away to maintain

535
00:17:55,910 --> 00:17:54,120
life and well at least global life that

536
00:17:57,020 --> 00:17:55,920
we could detect with the telescope no

537
00:17:58,460 --> 00:17:57,030
offense you're opens if I say the

538
00:18:01,010 --> 00:17:58,470

habitable zone I'm not like dissing

539
00:18:03,410 --> 00:18:01,020
you're saying life can't be there

540
00:18:05,000 --> 00:18:03,420
because I think you can and we're gonna

541
00:18:06,410 --> 00:18:05,010
look at like planets around a diversity

542
00:18:08,000 --> 00:18:06,420
of stellar targets so like we live

543
00:18:09,590 --> 00:18:08,010
around a G star we're gonna look around

544
00:18:11,600 --> 00:18:09,600
a and F stars which are much which are

545
00:18:13,100 --> 00:18:11,610
hotter than the Sun and K stars and M

546
00:18:15,650 --> 00:18:13,110
stars which are cooler than the Sun the

547
00:18:17,260 --> 00:18:15,660
M stars are particularly wild like they

548
00:18:19,430 --> 00:18:17,270
have like all this high-energy radiation

549
00:18:20,750 --> 00:18:19,440
they could have tidally locked orbits

550
00:18:23,150 --> 00:18:20,760
where the same side of the planet is

551
00:18:25,370 --> 00:18:23,160
always facing the star and stars are

552
00:18:27,260 --> 00:18:25,380
like they're like a modelers paradise

553
00:18:28,730 --> 00:18:27,270
right now because like all these

554
00:18:31,220 --> 00:18:28,740
different things change when you grow

555
00:18:32,720 --> 00:18:31,230
around these m stars just enough to like

556
00:18:34,850 --> 00:18:32,730
can get you funding to do modelling

557
00:18:36,260 --> 00:18:34,860
research and they're the first things

558
00:18:38,270 --> 00:18:36,270
we're gonna be able to probe not with

559
00:18:40,370 --> 00:18:38,280
levar but with ground-based telescopes

560
00:18:42,050 --> 00:18:40,380
in the next decade and pretty soon the

561
00:18:42,950 --> 00:18:42,060
James Webb Space Telescope as well I'm

562
00:18:44,300 --> 00:18:42,960
not going to talk about that too much

563
00:18:46,100 --> 00:18:44,310

tonight but if you hear about them stars

564
00:18:48,800 --> 00:18:46,110
that's why they're like really in vogue

565
00:18:50,270 --> 00:18:48,810
right now okay but we're also gonna look

566
00:18:52,220 --> 00:18:50,280
at not just the ends but the KS and the

567
00:18:54,140 --> 00:18:52,230
G's and a is and F's too which is

568
00:18:57,440 --> 00:18:54,150
awesome because diversity is good when

569
00:18:58,700 --> 00:18:57,450
we're looking at physical systems okay

570
00:19:00,140 --> 00:18:58,710
not we're not just gonna see these

571
00:19:01,190 --> 00:19:00,150
things and this is this is something

572
00:19:03,920 --> 00:19:01,200
actually the James Webb Space Telescope

573
00:19:04,760 --> 00:19:03,930
and extremely large telescopes on the

574
00:19:06,830 --> 00:19:04,770
ground are going to start to

575
00:19:08,810 --> 00:19:06,840
revolutionize you might have heard of a

576
00:19:11,270 --> 00:19:08,820
European mission that was just selected

577
00:19:12,440 --> 00:19:11,280
a week or two ago called re L it also is

578
00:19:14,300 --> 00:19:12,450
going to be doing this sort of thing the

579
00:19:15,560 --> 00:19:14,310
the pivot point is we're going to move

580
00:19:17,600 --> 00:19:15,570
beyond just Astrophysical

581
00:19:20,180 --> 00:19:17,610
characterization and start to move into

582
00:19:21,380 --> 00:19:20,190
chemical characterization so if you want

583
00:19:23,930 --> 00:19:21,390
to look at a chemical system in the

584
00:19:25,370 --> 00:19:23,940
solar system ideally you'd like have

585
00:19:27,860 --> 00:19:25,380
something like a mass spectrometer that

586
00:19:29,390 --> 00:19:27,870
can I count the you know mass units that

587
00:19:30,740 --> 00:19:29,400
you have from a particular molecule or

588
00:19:32,510 --> 00:19:30,750

something like that you take a lab to

589
00:19:34,370 --> 00:19:32,520
the field when you can and if you can't

590
00:19:35,330 --> 00:19:34,380
you bring your samples back that's even

591
00:19:37,250 --> 00:19:35,340
better because then you have all your

592
00:19:39,710 --> 00:19:37,260
your lab equipment you know coming to

593
00:19:41,120 --> 00:19:39,720
the floor for all these exoplanets we're

594
00:19:42,110 --> 00:19:41,130
not going to be able to do that we're

595
00:19:44,480 --> 00:19:42,120
not going to be able to bring samples

596
00:19:46,190 --> 00:19:44,490
back we're not at least I'm not counting

597
00:19:47,780 --> 00:19:46,200
on us being able to land stuff and in

598
00:19:50,450 --> 00:19:47,790
these planets and like do chemical

599
00:19:53,030 --> 00:19:50,460
analyses in situ so all our chemical

600
00:19:54,420 --> 00:19:53,040
analyses have to be remote the way we do

601
00:19:55,920 --> 00:19:54,430
that is we take spectrum

602
00:19:57,540 --> 00:19:55,930
so this is just if I'm going to show a

603
00:19:59,160 --> 00:19:57,550
lot of spectra the rest of this this

604
00:20:00,960 --> 00:19:59,170
talk that's given like my main plotting

605
00:20:02,640 --> 00:20:00,970
device here and they're all just

606
00:20:04,740 --> 00:20:02,650
basically how many photons or how much

607
00:20:07,110 --> 00:20:04,750
energy you get from the star as a

608
00:20:09,420 --> 00:20:07,120
function of wavelength and for leVoir

609
00:20:12,210 --> 00:20:09,430
because it's the large UV optical

610
00:20:14,040 --> 00:20:12,220
infrared telescope this all these plots

611
00:20:15,960 --> 00:20:14,050
are gonna or that they should mostly if

612
00:20:17,610 --> 00:20:15,970
not all run from the ultraviolet through

613
00:20:18,780 --> 00:20:17,620

the near-infrared so there's visible

614
00:20:20,610 --> 00:20:18,790
wavelengths that we can see with our

615
00:20:22,380 --> 00:20:20,620
eyes but also ultraviolet that are bluer

616
00:20:24,330 --> 00:20:22,390
than what we can see and then the

617
00:20:26,520 --> 00:20:24,340
infrared stuff which is redder that we

618
00:20:27,750 --> 00:20:26,530
can see now this is powerful for a

619
00:20:29,460 --> 00:20:27,760
number of reasons but probably the most

620
00:20:31,980 --> 00:20:29,470
important of which is certain molecules

621
00:20:34,380 --> 00:20:31,990
absorb absorb certain wavelengths of

622
00:20:36,420 --> 00:20:34,390
light and because of that if we see dips

623
00:20:38,460 --> 00:20:36,430
in a spectrum we know that there's that

624
00:20:40,050 --> 00:20:38,470
molecule in that atmosphere absorbing

625
00:20:43,350 --> 00:20:40,060
those wavelengths of light so we can see

626
00:20:45,630 --> 00:20:43,360
if there's co or co2 or ch4

627
00:20:47,160 --> 00:20:45,640
I like the carbon species you can tell

628
00:20:48,690 --> 00:20:47,170
you can see if there's water in a

629
00:20:50,790 --> 00:20:48,700
planetary atmosphere with this with this

630
00:20:52,740 --> 00:20:50,800
technique and see if and that's both

631
00:20:55,080 --> 00:20:52,750
important for the habitable and the non

632
00:20:56,460 --> 00:20:55,090
habitable worlds and when you put that

633
00:20:58,230 --> 00:20:56,470
stuff together you can start to get a

634
00:21:00,630 --> 00:20:58,240
bigger picture questions than just what

635
00:21:03,480 --> 00:21:00,640
are the planets made of for example

636
00:21:04,560 --> 00:21:03,490
we've got this theory of sort of we're

637
00:21:06,600 --> 00:21:04,570
starting to build what's called like a

638
00:21:08,790 --> 00:21:06,610

family portrait of exoplanets with like

639
00:21:10,320 --> 00:21:08,800
different classes of planet and one of

640
00:21:13,140 --> 00:21:10,330
the things that we think happens is as

641
00:21:15,780 --> 00:21:13,150
you get to larger mass the composition

642
00:21:17,490 --> 00:21:15,790
shifts so this is metallicity as an

643
00:21:19,470 --> 00:21:17,500
astronomer would define it so this is

644
00:21:21,330 --> 00:21:19,480
like the stuff heavier than hydrogen and

645
00:21:23,340 --> 00:21:21,340
helium with regards to the host star

646
00:21:25,560 --> 00:21:23,350
like so how enriched is this in carbon

647
00:21:27,300 --> 00:21:25,570
and oxygen and everything else that's on

648
00:21:27,630 --> 00:21:27,310
the second row or below on the periodic

649
00:21:29,850 --> 00:21:27,640
table

650
00:21:31,950 --> 00:21:29,860
how enriched is the planet compared to

651
00:21:33,330 --> 00:21:31,960
the star as a function of planet mass

652
00:21:36,060 --> 00:21:33,340
and there's this theory out there that

653
00:21:37,680 --> 00:21:36,070
looks at these sort of like really these

654
00:21:39,510 --> 00:21:37,690
data points with really big error bars

655
00:21:41,220 --> 00:21:39,520
that's saying that there's a trend here

656
00:21:44,670 --> 00:21:41,230
now I don't know if you believe that

657
00:21:45,840 --> 00:21:44,680
trend or not I can squint and see it but

658
00:21:47,670 --> 00:21:45,850
what would be better is if we can make

659
00:21:49,770 --> 00:21:47,680
more measurements which Lavar will do

660
00:21:52,200 --> 00:21:49,780
and if we could have a smaller error

661
00:21:53,910 --> 00:21:52,210
Parrs which blue bar will get for us so

662
00:21:55,380 --> 00:21:53,920
if we were able to make measurements for

663
00:21:57,210 --> 00:21:55,390

a number of data points with this

664
00:21:59,070 --> 00:21:57,220
tighter error bar we would be able to

665
00:22:01,380 --> 00:21:59,080
actually see if this was you know some

666
00:22:02,670 --> 00:22:01,390
byproduct of squinting and drawing a

667
00:22:04,620 --> 00:22:02,680
line through through points with large

668
00:22:05,940 --> 00:22:04,630
error bars or whether or not it was

669
00:22:06,350 --> 00:22:05,950
something that was really happening in

670
00:22:07,970 --> 00:22:06,360
the unit

671
00:22:10,250 --> 00:22:07,980
and by the way there are a few small

672
00:22:11,899 --> 00:22:10,260
error bars on here those are the planets

673
00:22:15,740 --> 00:22:11,909
in our solar system that's why the harem

674
00:22:17,480 --> 00:22:15,750
parts are tight and we will tie it back

675
00:22:18,740 --> 00:22:17,490
to the solar system as well I love this

676
00:22:20,450 --> 00:22:18,750
image so this is from the Juno

677
00:22:25,310 --> 00:22:20,460
spacecraft which is around Jupiter right

678
00:22:27,889 --> 00:22:25,320
now this is a picture both of Jupiter

679
00:22:30,230 --> 00:22:27,899
from Juno and sort of not institute but

680
00:22:31,789 --> 00:22:30,240
in orbit around Jupiter it's also the

681
00:22:33,950 --> 00:22:31,799
same pixel resolution that leVoir would

682
00:22:35,690 --> 00:22:33,960
get from Jupiter so we wouldn't get

683
00:22:37,279 --> 00:22:35,700
exactly this sort of angle on the poles

684
00:22:38,899 --> 00:22:37,289
that you know is getting for us which is

685
00:22:40,490 --> 00:22:38,909
one of the reasons Juno's there but we

686
00:22:43,100 --> 00:22:40,500
could get this these kind of beautiful

687
00:22:44,509 --> 00:22:43,110
images of Jupiter basically anytime we

688
00:22:46,580 --> 00:22:44,519

want whenever it's like in our field of

689
00:22:48,409 --> 00:22:46,590
view which is cool because it makes

690
00:22:50,299 --> 00:22:48,419
awesome pictures that we can share with

691
00:22:51,860 --> 00:22:50,309
the public but it's also important

692
00:22:53,690 --> 00:22:51,870
because we'll be able to probe dynamical

693
00:22:56,029 --> 00:22:53,700
process using Jupiter's atmosphere and

694
00:22:57,529 --> 00:22:56,039
and not just over the course of like you

695
00:22:59,480 --> 00:22:57,539
know weeks or a year or two like our

696
00:23:01,279 --> 00:22:59,490
spacecraft normally last for when when

697
00:23:03,500 --> 00:23:01,289
they're at Jupiter but maybe over

698
00:23:04,970 --> 00:23:03,510
multiple years and if flew before lasts

699
00:23:06,620 --> 00:23:04,980
long enough has Hubble has maybe over

700
00:23:10,370 --> 00:23:06,630
decades and seasons which would be

701
00:23:11,779 --> 00:23:10,380
really neat okay so this is this is now

702
00:23:13,549 --> 00:23:11,789
getting close to my wheelhouse is there

703
00:23:17,320 --> 00:23:13,559
life beyond Earth how long have I been

704
00:23:21,200 --> 00:23:17,330
up here I'm gonna get the time check

705
00:23:22,879 --> 00:23:21,210
okay great so is there life beyond Earth

706
00:23:24,590 --> 00:23:22,889
this is the question that is most

707
00:23:25,970 --> 00:23:24,600
classically astrobiology but I would

708
00:23:27,379 --> 00:23:25,980
argue all the stuff we heard this

709
00:23:29,480 --> 00:23:27,389
morning in this afternoon and all the

710
00:23:33,740 --> 00:23:29,490
stuff I've talked about so far is also

711
00:23:34,039 --> 00:23:33,750
astrobiology so here's our life beyond

712
00:23:36,289 --> 00:23:34,049
Earth

713
00:23:37,549 --> 00:23:36,299

what's the bargain of you there actually

714
00:23:39,740 --> 00:23:37,559
this is the main thing leVoir was

715
00:23:41,360 --> 00:23:39,750
designed to to address at least it's the

716
00:23:43,009 --> 00:23:41,370
the toughest technical problem the

717
00:23:46,250 --> 00:23:43,019
engineers are dealing with I'll get to

718
00:23:47,629 --> 00:23:46,260
that at the end I love this quote so if

719
00:23:49,639 --> 00:23:47,639
people don't know who Nancy Grace Roman

720
00:23:51,080 --> 00:23:49,649
is she was kind of like one of the

721
00:23:53,840 --> 00:23:51,090
pioneers that actually made Hubble a

722
00:23:55,220 --> 00:23:53,850
thing and she's just in especially in

723
00:23:57,919 --> 00:23:55,230
engineering and in space astronomy

724
00:23:59,690 --> 00:23:57,929
circles she's like just universally

725
00:24:01,759 --> 00:23:59,700
regarded with just tremendous esteem and

726
00:24:03,529 --> 00:24:01,769
I love this because I think this is so

727
00:24:05,060 --> 00:24:03,539
true for the field of astrobiology and I

728
00:24:07,009 --> 00:24:05,070
think it's true for basically everything

729
00:24:08,570 --> 00:24:07,019
I'm about to talk about which in our

730
00:24:11,029 --> 00:24:08,580
lifetime is going to move from the realm

731
00:24:13,730 --> 00:24:11,039
of modelers like myself to observational

732
00:24:15,590 --> 00:24:13,740
astronomy or observational astronomer

733
00:24:17,510 --> 00:24:15,600
z-- I like to tell students that the

734
00:24:19,250 --> 00:24:17,520
jobs I took after my PhD were not in

735
00:24:19,730 --> 00:24:19,260
existence only a few years before and

736
00:24:22,010 --> 00:24:19,740
for the kids

737
00:24:23,480 --> 00:24:22,020
here you could do your PhD on the data

738
00:24:25,250 --> 00:24:23,490

we're talking about and get a job that

739
00:24:29,720 --> 00:24:25,260
doesn't exist today when you finish

740
00:24:31,130 --> 00:24:29,730
school that's pretty cool okay so what

741
00:24:32,180 --> 00:24:31,140
lavars gonna do here is it's going to do

742
00:24:34,400 --> 00:24:32,190
two things one it's going to use that

743
00:24:37,100 --> 00:24:34,410
chemical composition to look for signs

744
00:24:39,169 --> 00:24:37,110
of life but it's also going to do that

745
00:24:41,210 --> 00:24:39,179
in a survey sense you know we could

746
00:24:42,940 --> 00:24:41,220
there's there's ideas out there and I'll

747
00:24:46,040 --> 00:24:42,950
talk about this briefly at the end for

748
00:24:47,720 --> 00:24:46,050
telescopes that would assess the

749
00:24:49,370 --> 00:24:47,730
chemical composition of planets in the

750
00:24:52,669 --> 00:24:49,380
habitable zone but only do that maybe

751
00:24:54,590 --> 00:24:52,679
one or a handful of times lavars D being

752
00:24:57,169 --> 00:24:54,600
designed literally with the goal of

753
00:24:58,640 --> 00:24:57,179
doing this for at least thirty rocky

754
00:25:00,860 --> 00:24:58,650
planets in the habitable zones of other

755
00:25:01,820 --> 00:25:00,870
stars now the reason we want to get to

756
00:25:03,500 --> 00:25:01,830
the number thirty we're actually

757
00:25:07,070 --> 00:25:03,510
designing the telescope to get to that

758
00:25:09,650 --> 00:25:07,080
goal is if you if you do the statistics

759
00:25:12,220 --> 00:25:09,660
once you get to thirty you can assess

760
00:25:15,620 --> 00:25:12,230
the presence or absence of a particular

761
00:25:17,450 --> 00:25:15,630
property to within ten percent and that

762
00:25:18,860 --> 00:25:17,460
you can you get an almost as long as

763
00:25:21,110 --> 00:25:18,870

that property is something the telescope

764
00:25:22,370 --> 00:25:21,120
can observe and measure it's any of the

765
00:25:25,280 --> 00:25:22,380
properties and all the properties so I

766
00:25:26,690 --> 00:25:25,290
could say I want to know whether rocky

767
00:25:28,400 --> 00:25:26,700
planets in the habitable zone which is

768
00:25:30,500 --> 00:25:28,410
defined around this concept of having

769
00:25:33,500 --> 00:25:30,510
the possibility to harbor global water

770
00:25:34,970 --> 00:25:33,510
oceans I want to know what percentage of

771
00:25:36,770 --> 00:25:34,980
planets in the habitable zone on rocky

772
00:25:38,600 --> 00:25:36,780
planets in the habitable zone actually

773
00:25:40,400 --> 00:25:38,610
have water and actually have oceans

774
00:25:42,620 --> 00:25:40,410
right is it a hundred percent

775
00:25:44,780 --> 00:25:42,630
is it zero percent is it fifty percent I

776
00:25:47,840 --> 00:25:44,790
don't know the error bars right now are

777
00:25:48,200 --> 00:25:47,850
zero to one hundred percent right after

778
00:25:50,150 --> 00:25:48,210
Louvois

779
00:25:52,220 --> 00:25:50,160
it'll be some number plus or minus ten

780
00:25:54,290 --> 00:25:52,230
percent you could ask the same question

781
00:25:57,200 --> 00:25:54,300
about oxygen potential bio signature or

782
00:25:59,510 --> 00:25:57,210
methane or organic haze I mean you could

783
00:26:02,060 --> 00:25:59,520
anything move our can observe you can

784
00:26:03,799 --> 00:26:02,070
say how abundant is that on planets

785
00:26:05,750 --> 00:26:03,809
inside the habitable zone and if you

786
00:26:07,160 --> 00:26:05,760
believe we can look for life you can not

787
00:26:09,140 --> 00:26:07,170
just look for life but try to put an

788
00:26:11,360 --> 00:26:09,150

estimate on what ATIS of life is how

789
00:26:15,350 --> 00:26:11,370
common is life on these planets that

790
00:26:17,810 --> 00:26:15,360
have global liquid water oceans now how

791
00:26:20,270 --> 00:26:17,820
do we do that we again do it through

792
00:26:22,580 --> 00:26:20,280
spectroscopy and actually we in many

793
00:26:25,220 --> 00:26:22,590
ways leverage things we've learned from

794
00:26:27,500 --> 00:26:25,230
here on earth this is a seasonal map

795
00:26:28,090 --> 00:26:27,510
from space of growth both on the

796
00:26:30,610 --> 00:26:28,100
continents

797
00:26:33,070 --> 00:26:30,620
shown here with force kind of growing

798
00:26:35,110 --> 00:26:33,080
and shrinking seasonally and algal

799
00:26:36,460 --> 00:26:35,120
blooms in the ocean we can observe this

800
00:26:38,350 --> 00:26:36,470
from space because there are certain

801
00:26:40,480 --> 00:26:38,360
pigments that observes absorbs certain

802
00:26:42,100 --> 00:26:40,490
wavelengths of light and because leaves

803
00:26:44,380 --> 00:26:42,110
also have sort of a reflective feature

804
00:26:46,419 --> 00:26:44,390
that is also a wavelength dependent we

805
00:26:48,159 --> 00:26:46,429
can observe from space so not only can

806
00:26:50,650 --> 00:26:48,169
we probe chemical composition remotely

807
00:26:52,630 --> 00:26:50,660
but we can also probe the stuff that

808
00:26:56,020 --> 00:26:52,640
life is made of and especially the stuff

809
00:26:58,600 --> 00:26:56,030
related to photosynthesis and I love

810
00:27:00,520 --> 00:26:58,610
this this is the carbon dioxide in our

811
00:27:02,560 --> 00:27:00,530
atmosphere as observed by the O Co the

812
00:27:04,659 --> 00:27:02,570
observing carbon the orbiting carbon

813
00:27:09,730 --> 00:27:04,669

Observatory which by the way if you draw

814
00:27:11,529 --> 00:27:09,740
that out it's a co2 molecule awesome so

815
00:27:13,510 --> 00:27:11,539
this is co2 coming out from various

816
00:27:15,430 --> 00:27:13,520
places on earth and like there's again

817
00:27:17,409 --> 00:27:15,440
like a whole talk on this one slide if

818
00:27:19,270 --> 00:27:17,419
we wanted to stare at it for a while but

819
00:27:21,130 --> 00:27:19,280
the point here is we can probe carbon

820
00:27:23,200 --> 00:27:21,140
dioxide remotely we know how to do it on

821
00:27:25,510 --> 00:27:23,210
earth the challenge is both with the

822
00:27:27,250 --> 00:27:25,520
carbon dioxide and oxygen and water and

823
00:27:29,560 --> 00:27:27,260
methane and also that the pigment stuff

824
00:27:31,120 --> 00:27:29,570
I was showing before is how can you

825
00:27:33,039 --> 00:27:31,130
assess carbon dioxide when you don't get

826
00:27:34,720 --> 00:27:33,049
this spatial information but you're just

827
00:27:37,000 --> 00:27:34,730
getting a single pixel of light from

828
00:27:39,669 --> 00:27:37,010
that that planet that's that's one of

829
00:27:41,500 --> 00:27:39,679
the big challenges we have because that

830
00:27:43,180 --> 00:27:41,510
you know Carl Sagan was really poetic

831
00:27:44,680 --> 00:27:43,190
about this right you talked about like

832
00:27:46,690 --> 00:27:44,690
you know all of human history is

833
00:27:48,880 --> 00:27:46,700
happened on this one pale blue dot like

834
00:27:50,320 --> 00:27:48,890
and that's awesome unless you're a

835
00:27:51,490 --> 00:27:50,330
scientist trying to figure out and prove

836
00:27:53,470 --> 00:27:51,500
to your colleagues whether or not that

837
00:27:55,840 --> 00:27:53,480
pale blue dot has life or not right

838
00:27:57,159 --> 00:27:55,850

that's hard and again I mentioned this

839
00:27:58,480 --> 00:27:57,169
before we're gonna do this with spectra

840
00:28:00,760 --> 00:27:58,490
we're gonna look for oxygen and ozone

841
00:28:02,409 --> 00:28:00,770
and methane and water we're gonna look

842
00:28:03,789 --> 00:28:02,419
for co2 all those heads gonna be frankly

843
00:28:07,299 --> 00:28:03,799
kind of hard and we're gonna look for

844
00:28:08,500 --> 00:28:07,309
like things like the red edge I would be

845
00:28:10,149 --> 00:28:08,510
willing to put my name on a paper that

846
00:28:11,560 --> 00:28:10,159
said we found evidence of life on a

847
00:28:13,810 --> 00:28:11,570
planet around another star if we had

848
00:28:16,029 --> 00:28:13,820
this whole suite of gases the hard thing

849
00:28:18,159 --> 00:28:16,039
becomes when you don't have the full

850
00:28:19,690 --> 00:28:18,169
suite that Earth has today or if you

851
00:28:21,430 --> 00:28:19,700
start to think about looking for kinds

852
00:28:23,200 --> 00:28:21,440
of life that don't exist on earth today

853
00:28:24,399 --> 00:28:23,210
I mean one of the questions I get from

854
00:28:26,020 --> 00:28:24,409
public art I got actually got this for

855
00:28:28,210 --> 00:28:26,030
my mother-in-law I've got it from fellow

856
00:28:30,399 --> 00:28:28,220
scientists I've gotten from from kids

857
00:28:31,659 --> 00:28:30,409
though there's a common question I get

858
00:28:33,430 --> 00:28:31,669
when we talk about searching for life

859
00:28:34,990 --> 00:28:33,440
beyond Earth it's like well you're

860
00:28:36,789 --> 00:28:35,000
talking about aliens right have you

861
00:28:41,409 --> 00:28:36,799
thought outside the box and are you

862
00:28:45,169 --> 00:28:41,419
ready for the weird stuff right so yeah

863
00:28:51,590 --> 00:28:45,179

you can ask go ahead okay okay keep

864
00:28:53,710 --> 00:28:51,600
going yeah so that's the red edge so

865
00:28:57,380 --> 00:28:53,720
basically if you look at the color of

866
00:28:59,150 --> 00:28:57,390
Leafs you see a big spike and I think it

867
00:29:01,340 --> 00:28:59,160
is associated right around the color red

868
00:29:03,590 --> 00:29:01,350
and that's something that is indicative

869
00:29:05,630 --> 00:29:03,600
of plant life at the surface now there

870
00:29:07,279 --> 00:29:05,640
are potential false positives like

871
00:29:11,510 --> 00:29:07,289
minerals that could give a similar kind

872
00:29:13,700 --> 00:29:11,520
of feature but if you sigh I want to be

873
00:29:15,350 --> 00:29:13,710
careful here I wouldn't count on a lot

874
00:29:17,419 --> 00:29:15,360
of the red edge type stuff to be a

875
00:29:19,039 --> 00:29:17,429
primary bio signature but if I saw that

876
00:29:21,590 --> 00:29:19,049
red edge in the context of a planet that

877
00:29:23,240 --> 00:29:21,600
also had oxygen and methane and water it

878
00:29:24,740 --> 00:29:23,250
would increase my confidence that there

879
00:29:26,630 --> 00:29:24,750
was life on the planet because it also

880
00:29:27,919 --> 00:29:26,640
sees some photos well something that was

881
00:29:30,980 --> 00:29:27,929
consistent with photosynthetic activity

882
00:29:32,690 --> 00:29:30,990
at the surface inside the context of a

883
00:29:34,940 --> 00:29:32,700
planet for which I saw the byproducts of

884
00:29:37,100 --> 00:29:34,950
oxygen photosynthesis in the same planet

885
00:29:38,600 --> 00:29:37,110
at the same time so again looking at

886
00:29:41,270 --> 00:29:38,610
Earth history gives us a guide on how to

887
00:29:42,710 --> 00:29:41,280
start thinking outside the box if you if

888
00:29:45,169 --> 00:29:42,720

you think about the amount of oxygen we

889
00:29:47,270 --> 00:29:45,179
have on earth today it's a lot and it's

890
00:29:49,039 --> 00:29:47,280
detectable but if you go backwards in

891
00:29:50,890 --> 00:29:49,049
time even 500 million years the amount

892
00:29:52,909 --> 00:29:50,900
of oxygen may have been undetectable

893
00:29:54,890 --> 00:29:52,919
fortunately ozone which is a

894
00:29:56,630 --> 00:29:54,900
photochemical byproduct of oxygen in the

895
00:29:59,299 --> 00:29:56,640
atmosphere would have been detectable

896
00:30:00,980 --> 00:29:59,309
for that that that time period all the

897
00:30:03,080 --> 00:30:00,990
way back to about two and a half billion

898
00:30:04,549 --> 00:30:03,090
years ago past that you get into the

899
00:30:07,010 --> 00:30:04,559
Archaean and oxygen levels were so low

900
00:30:08,539 --> 00:30:07,020
that ozone and oxygen both would have

901
00:30:10,220 --> 00:30:08,549
been undetectable which which begs a

902
00:30:11,870 --> 00:30:10,230
question right later and we were talking

903
00:30:13,039 --> 00:30:11,880
about this earlier today the origin of

904
00:30:14,990 --> 00:30:13,049
life wasn't two and a half million years

905
00:30:17,419 --> 00:30:15,000
ago right it was at least a billion

906
00:30:18,980 --> 00:30:17,429
years before that if not longer before

907
00:30:20,630 --> 00:30:18,990
that in Earth's history so if we're

908
00:30:23,120 --> 00:30:20,640
missing a billion years out of Earth's

909
00:30:24,500 --> 00:30:23,130
history of life how you know what are we

910
00:30:25,970 --> 00:30:24,510
doing here right like we're gonna build

911
00:30:27,440 --> 00:30:25,980
an expensive telescope and this a third

912
00:30:29,899 --> 00:30:27,450
of the history of life on Earth if we

913
00:30:32,580 --> 00:30:29,909

were we were staring back at home that

914
00:30:36,070 --> 00:30:32,590
I'm not comfortable with that

915
00:30:37,750 --> 00:30:36,080
so what we well and this is this is part

916
00:30:39,700 --> 00:30:37,760
of what is important about astrobiology

917
00:30:41,260 --> 00:30:39,710
not just thinking about the instruments

918
00:30:42,940 --> 00:30:41,270
and the missions but also thinking about

919
00:30:45,310 --> 00:30:42,950
the fundamental science that goes into

920
00:30:46,720 --> 00:30:45,320
what is a bio signature and what are the

921
00:30:49,060 --> 00:30:46,730
the full range of bio signatures we

922
00:30:50,950 --> 00:30:49,070
might expect so this is work that mostly

923
00:30:52,419 --> 00:30:50,960
follows from my colleague and officemate

924
00:30:54,460 --> 00:30:52,429
Chadha arne who's been thinking about

925
00:30:56,169 --> 00:30:54,470
what signatures that an toxic that

926
00:30:58,240 --> 00:30:56,179
oxygen-free atmosphere would would

927
00:30:59,290 --> 00:30:58,250
present and what she's found is a couple

928
00:31:01,210 --> 00:30:59,300
things one is there was a lot more

929
00:31:02,860 --> 00:31:01,220
methane so as those oxygen and ozone

930
00:31:04,450 --> 00:31:02,870
features are getting less strong the

931
00:31:06,010 --> 00:31:04,460
methane features are getting more strong

932
00:31:07,570 --> 00:31:06,020
which means you can see the methane

933
00:31:10,270 --> 00:31:07,580
which is good the problem is that

934
00:31:12,970 --> 00:31:10,280
methane has a lot of ways to be produced

935
00:31:15,790 --> 00:31:12,980
without biology and that's that's Pat

936
00:31:17,140 --> 00:31:15,800
for example Titan and our own solar

937
00:31:17,730 --> 00:31:17,150
system has plenty of methane in its

938
00:31:20,169 --> 00:31:17,740

atmosphere

939
00:31:21,880 --> 00:31:20,179
now what jawed is proposed in the

940
00:31:23,860 --> 00:31:21,890
literature and I think she's onto

941
00:31:27,190 --> 00:31:23,870
something here is that if you have a

942
00:31:29,650 --> 00:31:27,200
haze and you see that methane you might

943
00:31:31,090 --> 00:31:29,660
you might have a bio signature now the

944
00:31:33,160 --> 00:31:31,100
problem with that is Titan also has a

945
00:31:34,840 --> 00:31:33,170
haze so how do you distinguish between a

946
00:31:36,640 --> 00:31:34,850
biological planet that has a haze and

947
00:31:37,960 --> 00:31:36,650
methane and something like Titan where

948
00:31:40,480 --> 00:31:37,970
there's a haze of methane but no life

949
00:31:42,220 --> 00:31:40,490
and the key is is not just looking at

950
00:31:44,020 --> 00:31:42,230
the one thing that's a bio signature

951
00:31:46,780 --> 00:31:44,030
right like the haze and the methane on

952
00:31:48,430 --> 00:31:46,790
their own are not pile signatures what

953
00:31:50,950 --> 00:31:48,440
is the bio signature is the haze and the

954
00:31:52,570 --> 00:31:50,960
methane in the environmental context of

955
00:31:54,520 --> 00:31:52,580
a planet that is a in the habitable zone

956
00:31:56,680 --> 00:31:54,530
and is bombarded with light and UV

957
00:31:58,900 --> 00:31:56,690
radiation all the time and has lots of

958
00:32:00,700 --> 00:31:58,910
oxygen atoms in its atmosphere in the

959
00:32:02,770 --> 00:32:00,710
form of carbon dioxide and critically of

960
00:32:04,630 --> 00:32:02,780
water because if you've got co2 and

961
00:32:06,310 --> 00:32:04,640
water in the atmosphere there's gonna be

962
00:32:07,840 --> 00:32:06,320
a photochemical Network that works to

963
00:32:09,549 --> 00:32:07,850

destroy the haze and the methane and the

964
00:32:10,840 --> 00:32:09,559
only way you keep the methane and the

965
00:32:13,030 --> 00:32:10,850
haze on the atmosphere is if you're

966
00:32:15,520 --> 00:32:13,040
making the methane at the surface super

967
00:32:17,650 --> 00:32:15,530
rapidly and orders of magnitude more

968
00:32:19,000 --> 00:32:17,660
rapidly than non-biological we think

969
00:32:21,250 --> 00:32:19,010
than we think non-biological processes

970
00:32:23,200 --> 00:32:21,260
can bruise methane right so this isn't a

971
00:32:25,060 --> 00:32:23,210
factor to problem it's not even a factor

972
00:32:26,980 --> 00:32:25,070
a ten problem this is like a three to

973
00:32:29,320 --> 00:32:26,990
four orders of magnitude problem between

974
00:32:30,730 --> 00:32:29,330
the two abiotic production rates of

975
00:32:32,710 --> 00:32:30,740
methane we think you can have on a

976
00:32:35,230 --> 00:32:32,720
planet versus what it takes to maintain

977
00:32:36,940 --> 00:32:35,240
a a x' and methane in an atmosphere

978
00:32:39,850 --> 00:32:36,950
where you've got carbon dioxide and

979
00:32:42,400 --> 00:32:39,860
water and UV light now what's important

980
00:32:43,540 --> 00:32:42,410
about that is that you that means you

981
00:32:45,490 --> 00:32:43,550
can't just look for the haze in the

982
00:32:46,090 --> 00:32:45,500
methane your mission has to be able to

983
00:32:47,350 --> 00:32:46,100
detect that

984
00:32:48,880 --> 00:32:47,360
other stuff too you have to see the

985
00:32:50,470 --> 00:32:48,890
water you have to see the carbon dioxide

986
00:32:52,090 --> 00:32:50,480
and you have to see the UV light from

987
00:32:53,860 --> 00:32:52,100
the hosts Ark and all that has to be

988
00:32:56,140 --> 00:32:53,870

well characterized before you can even

989
00:32:57,760 --> 00:32:56,150
start to talk about a bio signature now

990
00:32:59,860 --> 00:32:57,770
it's what's interesting is as we have

991
00:33:01,390 --> 00:32:59,870
thought about our our modern earth and

992
00:33:03,460 --> 00:33:01,400
proterozoic earth which which we be

993
00:33:06,419 --> 00:33:03,470
looking for oxygen in we're starting to

994
00:33:09,580 --> 00:33:06,429
tell a similar story because in the last

995
00:33:11,950 --> 00:33:09,590
eight years we've started to think about

996
00:33:15,430 --> 00:33:11,960
ways that non-biological processes could

997
00:33:17,500 --> 00:33:15,440
also make oxygen at I shouldn't say make

998
00:33:19,600 --> 00:33:17,510
oxygen I should say accumulate oxygen in

999
00:33:21,399 --> 00:33:19,610
a planetary atmosphere and the way you

1000
00:33:22,960 --> 00:33:21,409
do that is you like I use a bathtub

1001
00:33:24,820 --> 00:33:22,970
analogy like this is kind of gross but

1002
00:33:27,190 --> 00:33:24,830
like it's true if you never clean your

1003
00:33:28,510 --> 00:33:27,200
bathtub right eventually like the dreams

1004
00:33:29,830 --> 00:33:28,520
gonna get clogged and then like you're

1005
00:33:31,210 --> 00:33:29,840
gonna take a shower one day and like the

1006
00:33:32,529 --> 00:33:31,220
water is gonna like start coming up like

1007
00:33:34,330 --> 00:33:32,539
your ankles and it's gonna be a gross

1008
00:33:36,010 --> 00:33:34,340
and then you like you clear the Train

1009
00:33:37,840 --> 00:33:36,020
and then like the water drains out and

1010
00:33:40,149 --> 00:33:37,850
you're good right what's happening there

1011
00:33:41,710 --> 00:33:40,159
is whatever's in blocking the drain is

1012
00:33:43,720 --> 00:33:41,720
slowing the rate at which water leaves

1013
00:33:45,520 --> 00:33:43,730

the bathtub and so if you've got the

1014
00:33:47,380 --> 00:33:45,530
sort of the same input of water but a

1015
00:33:48,970 --> 00:33:47,390
slower output it's gonna come to like a

1016
00:33:49,390 --> 00:33:48,980
greater concentration or level in the

1017
00:33:52,390 --> 00:33:49,400
bathtub

1018
00:33:54,250 --> 00:33:52,400
at steady state we found ways to

1019
00:33:55,480 --> 00:33:54,260
basically do the same thing for abiotic

1020
00:33:57,549 --> 00:33:55,490
planets we found ways to basically

1021
00:33:59,529 --> 00:33:57,559
really slow down the destruction of

1022
00:34:02,080 --> 00:33:59,539
oxygen and so even if you're making it

1023
00:34:03,640 --> 00:34:02,090
slowly with non-biological processes you

1024
00:34:05,710 --> 00:34:03,650
can accumulate it in an atmosphere just

1025
00:34:09,099 --> 00:34:05,720
like water accumulating in a clogged up

1026
00:34:10,780 --> 00:34:09,109
tub so and the important thing about

1027
00:34:12,010 --> 00:34:10,790
that it's just like the arkanar story

1028
00:34:13,480 --> 00:34:12,020
what you want to look for are the

1029
00:34:15,250 --> 00:34:13,490
telltale signs that the oxygen

1030
00:34:17,349 --> 00:34:15,260
destruction is slow and that comes in

1031
00:34:18,700 --> 00:34:17,359
the form of chemical context and we've

1032
00:34:22,000 --> 00:34:18,710
been worried about this because we don't

1033
00:34:23,770 --> 00:34:22,010
what I don't want to do I don't want to

1034
00:34:25,030 --> 00:34:23,780
spend because this telescope by the way

1035
00:34:28,109 --> 00:34:25,040
it's not going to launch till at the

1036
00:34:31,300 --> 00:34:28,119
earliest 2035 and more likely 2040 I

1037
00:34:33,159 --> 00:34:31,310
want to be on that team that's a long

1038
00:34:35,859 --> 00:34:33,169

time from now and I want to retire

1039
00:34:37,780 --> 00:34:35,869
someday I don't want to spend my whole

1040
00:34:40,419 --> 00:34:37,790
career and lots of taxpayer money to

1041
00:34:42,070 --> 00:34:40,429
find evidence of life and call the

1042
00:34:43,540 --> 00:34:42,080
president and tell her we found it and

1043
00:34:45,820 --> 00:34:43,550
then be wrong in the literature like a

1044
00:34:47,320 --> 00:34:45,830
year later okay like that's not there's

1045
00:34:49,629 --> 00:34:47,330
parts of that world that that sound good

1046
00:34:51,070 --> 00:34:49,639
to me but the part where we're wrong

1047
00:34:52,840 --> 00:34:51,080
after spending my life in a lot of other

1048
00:34:55,810 --> 00:34:52,850
people's lives on the mission I don't

1049
00:34:57,430 --> 00:34:55,820
like and so we've been thinking about

1050
00:34:58,940 --> 00:34:57,440
this a lot what we've been doing is

1051
00:35:00,740 --> 00:34:58,950
actually cataloging all the way

1052
00:35:03,650 --> 00:35:00,750
you can make oxygen in a planetary

1053
00:35:06,500 --> 00:35:03,660
atmosphere that don't involve production

1054
00:35:08,060 --> 00:35:06,510
of oxygen at the surface by biology and

1055
00:35:09,170 --> 00:35:08,070
we've been thinking that one step past

1056
00:35:11,120 --> 00:35:09,180
that which are what are the

1057
00:35:13,040 --> 00:35:11,130
observational features that those

1058
00:35:14,750 --> 00:35:13,050
abiotic production mechanisms would have

1059
00:35:16,700 --> 00:35:14,760
and what are the features that are

1060
00:35:18,440 --> 00:35:16,710
unique to the but to the planets for

1061
00:35:21,620 --> 00:35:18,450
which the oxygen is coming from

1062
00:35:23,480 --> 00:35:21,630
biological processes and and the moral

1063
00:35:25,130 --> 00:35:23,490

of this story is basically you want the

1064
00:35:27,230 --> 00:35:25,140
same thing you want to get it how fast

1065
00:35:29,390 --> 00:35:27,240
is the oxygen being destroyed and if you

1066
00:35:31,730 --> 00:35:29,400
see things like methane and water in the

1067
00:35:33,290 --> 00:35:31,740
in the planetary atmosphere you know the

1068
00:35:35,450 --> 00:35:33,300
oxygens going to be destroyed rapidly

1069
00:35:37,250 --> 00:35:35,460
and that you need to replenish it

1070
00:35:39,589 --> 00:35:37,260
rapidly to keep it in the planetary

1071
00:35:41,720 --> 00:35:39,599
atmosphere and again this is an orders

1072
00:35:43,339 --> 00:35:41,730
of magnitude problem the oxygen

1073
00:35:45,920 --> 00:35:43,349
production rates that we can accumulate

1074
00:35:47,780 --> 00:35:45,930
oxygen with here are orders of magnitude

1075
00:35:50,870 --> 00:35:47,790
slower than modern-day oxygen production

1076
00:35:53,240 --> 00:35:50,880
rates right not 10 like not a factor 10

1077
00:35:56,329 --> 00:35:53,250
not a factor to multiple orders of

1078
00:35:57,440 --> 00:35:56,339
magnitude okay now all this leads to

1079
00:35:59,870 --> 00:35:57,450
something that you don't have to read

1080
00:36:01,280 --> 00:35:59,880
but basically all that science I was

1081
00:36:04,430 --> 00:36:01,290
just talking about actually gets fold

1082
00:36:05,809 --> 00:36:04,440
this is a this is a figure from our from

1083
00:36:06,920 --> 00:36:05,819
the loo floor intern report which is

1084
00:36:08,930 --> 00:36:06,930
going to get released to the public in

1085
00:36:10,670 --> 00:36:08,940
about a month we have we have thought

1086
00:36:12,740 --> 00:36:10,680
carefully about a series of observations

1087
00:36:14,870 --> 00:36:12,750
we would make that would both optimize

1088
00:36:17,540 --> 00:36:14,880

our telescope time but also rigorously

1089
00:36:19,010 --> 00:36:17,550
assess the chemical context of a planet

1090
00:36:20,450 --> 00:36:19,020
and its stellar context in terms of the

1091
00:36:20,980 --> 00:36:20,460
UV radiation hitting the top of the

1092
00:36:23,510 --> 00:36:20,990
atmosphere

1093
00:36:24,890 --> 00:36:23,520
okay now levar wouldn't just stop there

1094
00:36:26,720 --> 00:36:24,900
just like with the diversity of worlds

1095
00:36:29,089 --> 00:36:26,730
we're gonna do this this kind of science

1096
00:36:30,770 --> 00:36:29,099
in our solar system as well okay so our

1097
00:36:33,050 --> 00:36:30,780
nearest one of our nearest neighbors

1098
00:36:34,849 --> 00:36:33,060
whenever two nearest neighbors Mars has

1099
00:36:37,280 --> 00:36:34,859
a controversial detection of methane

1100
00:36:39,170 --> 00:36:37,290
that that some say very on seasonal and

1101
00:36:41,510 --> 00:36:39,180
spacial timescales we're measuring it at

1102
00:36:42,680 --> 00:36:41,520
the surface with a rover there's two

1103
00:36:44,510 --> 00:36:42,690
different orbiters from two different

1104
00:36:45,800 --> 00:36:44,520
countries of one from you so one from

1105
00:36:48,050 --> 00:36:45,810
India that are looking at methane from

1106
00:36:49,220 --> 00:36:48,060
orbit and we're looking for an methane

1107
00:36:51,260 --> 00:36:49,230
with ground-based telescopes

1108
00:36:52,849 --> 00:36:51,270
Lavar would help tell that story because

1109
00:36:54,650 --> 00:36:52,859
it's going to be able to get global

1110
00:36:57,290 --> 00:36:54,660
images of the methane on Mars this is

1111
00:36:59,329 --> 00:36:57,300
just a model of like methane diffusing

1112
00:37:01,520 --> 00:36:59,339
from a point source or a plume on the

1113
00:37:03,440 --> 00:37:01,530

surface but if there was a plume of

1114
00:37:05,390 --> 00:37:03,450
methane on the surface imagine you have

1115
00:37:06,890 --> 00:37:05,400
a Rover there you've got an orbiter

1116
00:37:09,580 --> 00:37:06,900
passing overhead that's getting a really

1117
00:37:11,650 --> 00:37:09,590
detailed look across one swath of

1118
00:37:13,240 --> 00:37:11,660
of you know that the of the plume and

1119
00:37:14,650 --> 00:37:13,250
you're able to put that plume in a

1120
00:37:16,060 --> 00:37:14,660
global context because leVoir would be

1121
00:37:17,710 --> 00:37:16,070
able to not just make global

1122
00:37:19,750 --> 00:37:17,720
high-resolution maps of the Martian

1123
00:37:21,490 --> 00:37:19,760
surface but also map out things like

1124
00:37:22,720 --> 00:37:21,500
methane and carbon monoxide and other

1125
00:37:26,590 --> 00:37:22,730
trace gases in the Martian atmosphere

1126
00:37:28,510 --> 00:37:26,600
and our friends on Europa so habitable

1127
00:37:30,610 --> 00:37:28,520
zone is a is a term that exoplanet folks

1128
00:37:31,930 --> 00:37:30,620
throw around loosely and probably

1129
00:37:33,820 --> 00:37:31,940
inaccurately but it's the term we're

1130
00:37:36,250 --> 00:37:33,830
dealt with we don't think Europe is dead

1131
00:37:37,480 --> 00:37:36,260
we actually think it quite has quite a

1132
00:37:38,920 --> 00:37:37,490
lot of potential for life and we

1133
00:37:41,320 --> 00:37:38,930
actually want to be a part of the story

1134
00:37:44,860 --> 00:37:41,330
of what we might be doing in and around

1135
00:37:46,000 --> 00:37:44,870
Europa in a few ways for one there's a

1136
00:37:48,160 --> 00:37:46,010
Europa clipper mission that's being

1137
00:37:50,080 --> 00:37:48,170
planned and also potential Europa Lander

1138
00:37:51,910 --> 00:37:50,090

we want to help sort of serve as like a

1139
00:37:53,890 --> 00:37:51,920
long-term reconnaissance for those

1140
00:37:56,140 --> 00:37:53,900
missions imagine the Clippers like

1141
00:37:57,700 --> 00:37:56,150
flying around Europa and it wants to fly

1142
00:37:58,960 --> 00:37:57,710
into a plume that's coming that's like

1143
00:38:01,570 --> 00:37:58,970
kind of spilling water from the

1144
00:38:02,830 --> 00:38:01,580
subsurface of Europa out into space well

1145
00:38:04,840 --> 00:38:02,840
what levar can do is the same thing

1146
00:38:06,670 --> 00:38:04,850
Hubble did Hubble found those plumes

1147
00:38:08,320 --> 00:38:06,680
right with UV observations that saw the

1148
00:38:10,720 --> 00:38:08,330
hydrogen and oxygen coming up from the

1149
00:38:12,730 --> 00:38:10,730
surface we could do that but we could do

1150
00:38:15,940 --> 00:38:12,740
it at much higher resolution and we can

1151
00:38:17,350 --> 00:38:15,950
tell the Clipper hey the plumes there if

1152
00:38:18,820 --> 00:38:17,360
you want to fly through it and catch a

1153
00:38:21,010 --> 00:38:18,830
little bit a little bit of that plume

1154
00:38:23,140 --> 00:38:21,020
that's where you want to fly we can tell

1155
00:38:24,970 --> 00:38:23,150
we can do long-term observations and see

1156
00:38:26,500 --> 00:38:24,980
if the if these plumes repeatedly crop

1157
00:38:27,880 --> 00:38:26,510
up at the same point on the surface

1158
00:38:31,720 --> 00:38:27,890
which might help with landing site

1159
00:38:35,110 --> 00:38:31,730
selection for a Europa Lander okay so

1160
00:38:36,850 --> 00:38:35,120
that's everything we did everything I

1161
00:38:38,800 --> 00:38:36,860
just talked about is kind of like where

1162
00:38:40,570 --> 00:38:38,810
we start when we think about spaceflight

1163
00:38:42,820 --> 00:38:40,580

missions at NASA we start with the

1164
00:38:45,130 --> 00:38:42,830
science we start with goals of that we

1165
00:38:46,810 --> 00:38:45,140
want to achieve and realize and then we

1166
00:38:48,430 --> 00:38:46,820
get with the engineers and we find out

1167
00:38:50,500 --> 00:38:48,440
what is it going to take to make this

1168
00:38:51,580 --> 00:38:50,510
all possible okay so the rest of this is

1169
00:38:52,840 --> 00:38:51,590
going to be sort of like what is it

1170
00:38:56,680 --> 00:38:52,850
going to take to do all that science I

1171
00:38:59,410 --> 00:38:56,690
just talked about and the the quote here

1172
00:39:01,240 --> 00:38:59,420
that I think is most relevant is one

1173
00:39:02,800 --> 00:39:01,250
from Amelia Earhart which is the most

1174
00:39:03,930 --> 00:39:02,810
effective way to do it is to do it and

1175
00:39:06,430 --> 00:39:03,940
this is important in two ways one

1176
00:39:08,140 --> 00:39:06,440
sometimes you just have to decide that

1177
00:39:10,090 --> 00:39:08,150
you're going to be ambitious enough to

1178
00:39:15,700 --> 00:39:10,100
try something really hard even if it's

1179
00:39:17,410 --> 00:39:15,710
really hard the second is the things

1180
00:39:18,640 --> 00:39:17,420
that we are most capable of doing are

1181
00:39:20,500 --> 00:39:18,650
the things that we already know how to

1182
00:39:22,289 --> 00:39:20,510
do because we've done them before and

1183
00:39:24,299 --> 00:39:22,299
it's important that when we're doing

1184
00:39:26,459 --> 00:39:24,309
really hard things we leverage as much

1185
00:39:30,179 --> 00:39:26,469
of our what we call heritage but our

1186
00:39:32,759 --> 00:39:30,189
expertise and history as possible okay

1187
00:39:34,380 --> 00:39:32,769
so this is not a mistake there's a pale

1188
00:39:36,150 --> 00:39:34,390

blue dot on the screen and it's on here

1189
00:39:38,029 --> 00:39:36,160
to show you the most difficult technical

1190
00:39:41,189 --> 00:39:38,039
problem our engineers have to deal with

1191
00:39:45,150 --> 00:39:41,199
can anyone see it I'd be shocked if you

1192
00:39:46,259 --> 00:39:45,160
could actually I'm wearing glasses and

1193
00:39:47,669 --> 00:39:46,269
I'm right next to the screen like I

1194
00:39:51,229 --> 00:39:47,679
literally can't see it but I promise you

1195
00:39:53,069 --> 00:39:51,239
it's on there now can anyone see it now

1196
00:39:55,439 --> 00:39:53,079
and the back can you see it on the back

1197
00:39:56,939 --> 00:39:55,449
PI nog sir you can't okay so it's right

1198
00:40:00,059 --> 00:39:56,949
if you can't see it it's right there and

1199
00:40:01,859 --> 00:40:00,069
it was right there all along okay now

1200
00:40:03,479 --> 00:40:01,869
there's two problems that I just

1201
00:40:05,249 --> 00:40:03,489
demonstrated right it went from like

1202
00:40:08,929 --> 00:40:05,259
impossible to see it or really hard to

1203
00:40:12,870 --> 00:40:08,939
see the impossible to see part of it

1204
00:40:14,669 --> 00:40:12,880
back here is that little pale blue dot

1205
00:40:15,749 --> 00:40:14,679
even though it's there you can't detect

1206
00:40:17,189 --> 00:40:15,759
it with your eyes because they're

1207
00:40:18,689 --> 00:40:17,199
literally kind of like flooded and

1208
00:40:20,880 --> 00:40:18,699
overwhelmed with light from the rest of

1209
00:40:23,459 --> 00:40:20,890
the screen and that light is running up

1210
00:40:24,689 --> 00:40:23,469
right next to that pale blue dot it's

1211
00:40:26,249 --> 00:40:24,699
kind of like if you're trying to track a

1212
00:40:27,599 --> 00:40:26,259
ball or a plane in the sky and it's

1213
00:40:31,140 --> 00:40:27,609

crossing right over the Sun if you keep

1214
00:40:33,109 --> 00:40:31,150
watching it you'll go blind don't do

1215
00:40:35,549 --> 00:40:33,119
that or at least you'll you'll you'll

1216
00:40:37,769 --> 00:40:35,559
suffer some pain in your eyeballs for a

1217
00:40:39,269 --> 00:40:37,779
little bit and the reason is that the

1218
00:40:40,739 --> 00:40:39,279
sunlight is overwhelming your detectors

1219
00:40:42,209 --> 00:40:40,749
and the same things happening here the

1220
00:40:43,620 --> 00:40:42,219
light from the screen is overwhelming

1221
00:40:45,779 --> 00:40:43,630
your detectors to the point where they

1222
00:40:47,429 --> 00:40:45,789
can't detect the pale blue dot somewhere

1223
00:40:49,679 --> 00:40:47,439
in this field the second problem is the

1224
00:40:51,989 --> 00:40:49,689
pale blue dot is pale it's really dim

1225
00:40:53,640 --> 00:40:51,999
and so you need you need to be able to

1226
00:40:56,009 --> 00:40:53,650
collect photons from that really dim

1227
00:40:57,959 --> 00:40:56,019
thing to be able to analyze it

1228
00:40:59,839 --> 00:40:57,969
especially if you want to not just see

1229
00:41:01,979 --> 00:40:59,849
the pale blue dot but see how blue it is

1230
00:41:03,630 --> 00:41:01,989
which means you have to not just collect

1231
00:41:05,219 --> 00:41:03,640
light from it but collect enough light

1232
00:41:06,569 --> 00:41:05,229
to spread that light out into those

1233
00:41:08,339 --> 00:41:06,579
different color buckets that give you

1234
00:41:10,799 --> 00:41:08,349
the spectrum and do that with enough

1235
00:41:13,229 --> 00:41:10,809
signal-to-noise to make some scientific

1236
00:41:15,979 --> 00:41:13,239
measurements and assessments that's all

1237
00:41:19,019 --> 00:41:15,989
of that is hard it's really hard

1238
00:41:20,429 --> 00:41:19,029

fortunately it's not a unicorn it's not

1239
00:41:22,469 --> 00:41:20,439
something we've never done before

1240
00:41:24,120 --> 00:41:22,479
in fact we're doing it right now just

1241
00:41:26,489 --> 00:41:24,130
not quite at the level we need to do it

1242
00:41:28,799 --> 00:41:26,499
for how rocky planets and the habitable

1243
00:41:31,229 --> 00:41:28,809
zones of other stars all right so these

1244
00:41:32,549 --> 00:41:31,239
are this is real imagery that's been

1245
00:41:34,829 --> 00:41:32,559
stitched together to make a movie this

1246
00:41:36,150 --> 00:41:34,839
is from ground-based observations I want

1247
00:41:37,319 --> 00:41:36,160
to say calamar but I can't remember

1248
00:41:39,750 --> 00:41:37,329
for sure which ground-based telescope

1249
00:41:41,460 --> 00:41:39,760
it's from this is not a potentially

1250
00:41:43,740 --> 00:41:41,470
earth-like worlds this is of like really

1251
00:41:47,130 --> 00:41:43,750
hot Jupiter like things that are far out

1252
00:41:49,109 --> 00:41:47,140
from from their host star but it's using

1253
00:41:51,720 --> 00:41:49,119
the same technology that we need to use

1254
00:41:53,279 --> 00:41:51,730
to find rocky planets closer to the star

1255
00:41:55,140 --> 00:41:53,289
that could have life okay

1256
00:41:56,940 --> 00:41:55,150
the difference is twofold one this is

1257
00:41:58,799 --> 00:41:56,950
being done from the ground so you're

1258
00:42:00,329 --> 00:41:58,809
you're kind of staring through the the

1259
00:42:02,670 --> 00:42:00,339
same atmosphere that make makes the

1260
00:42:04,890 --> 00:42:02,680
stars twinkle at night and screws with

1261
00:42:06,569 --> 00:42:04,900
our astronomical observations and the

1262
00:42:08,039 --> 00:42:06,579
second is it's just not at the level of

1263
00:42:09,569 --> 00:42:08,049

technology we need it to be yet in terms

1264
00:42:10,859 --> 00:42:09,579
of how effective it is at blocking out

1265
00:42:12,900 --> 00:42:10,869
that central starlight and the way this

1266
00:42:14,339 --> 00:42:12,910
works is like you know it's like is

1267
00:42:15,779 --> 00:42:14,349
almost as dumb as you might think like

1268
00:42:17,609 --> 00:42:15,789
if you were tracking a ball in the sky

1269
00:42:18,599 --> 00:42:17,619
playing on the sky you put your hand

1270
00:42:20,700 --> 00:42:18,609
over the Sun that's kind of what it's

1271
00:42:24,450 --> 00:42:20,710
doing it just in like no way more

1272
00:42:26,069 --> 00:42:24,460
complicated way than that okay so that's

1273
00:42:28,049 --> 00:42:26,079
one challenge keep that in mind

1274
00:42:30,299 --> 00:42:28,059
we're developing technologies that will

1275
00:42:32,250 --> 00:42:30,309
help us solve it one of the things we

1276
00:42:33,779 --> 00:42:32,260
need to do is we need a big build the

1277
00:42:35,010 --> 00:42:33,789
larger telescopes that's and I talked

1278
00:42:36,750 --> 00:42:35,020
about this at the outset that's going to

1279
00:42:38,700 --> 00:42:36,760
give us better angular resolution more

1280
00:42:40,470 --> 00:42:38,710
spatial pixels it's gonna let us see

1281
00:42:42,269 --> 00:42:40,480
those pale blue dots and see enough

1282
00:42:45,089 --> 00:42:42,279
light from them just to get spectra on

1283
00:42:46,620 --> 00:42:45,099
them and it turns out that it's easier

1284
00:42:48,299 --> 00:42:46,630
to block out the starlight with a larger

1285
00:42:49,620 --> 00:42:48,309
telescope as well for reasons that have

1286
00:42:51,690 --> 00:42:49,630
to do with the physics of how you how

1287
00:42:53,490 --> 00:42:51,700
you block that central starlight so for

1288
00:42:54,920 --> 00:42:53,500

I'm just gonna put this down well let's

1289
00:42:58,319 --> 00:42:54,930
see I know I can do this

1290
00:43:00,450 --> 00:42:58,329
so for example Hubble is 2.4 meters

1291
00:43:03,420 --> 00:43:00,460
across it's like probably a little bit

1292
00:43:05,160 --> 00:43:03,430
bigger than my wingspan okay so Hubble's

1293
00:43:08,730 --> 00:43:05,170
got a mirror that's about yay big around

1294
00:43:10,260 --> 00:43:08,740
okay Jenni BST Mike I'm gonna walk so my

1295
00:43:12,359 --> 00:43:10,270
levels might spike for a second I

1296
00:43:16,799 --> 00:43:12,369
apologize is six and a half meters

1297
00:43:18,779 --> 00:43:16,809
across so it's probably about the

1298
00:43:20,130 --> 00:43:18,789
probably out the width of this stage is

1299
00:43:22,440 --> 00:43:20,140
six and a half meters across the net

1300
00:43:24,329 --> 00:43:22,450
that's the difference between what JWST

1301
00:43:25,769 --> 00:43:24,339
is gonna see in the universe and Hubble

1302
00:43:27,539 --> 00:43:25,779
it's it's gonna have much better spatial

1303
00:43:28,829 --> 00:43:27,549
resolution it's also looking in the

1304
00:43:30,539 --> 00:43:28,839
infrared and it's gonna be able to see

1305
00:43:32,190 --> 00:43:30,549
really faint stuff that's that's

1306
00:43:34,650 --> 00:43:32,200
redshifted so far we have to look in the

1307
00:43:37,079 --> 00:43:34,660
infrared to see that stuff louvre juarez

1308
00:43:38,970 --> 00:43:37,089
is a factor over to again bigger than

1309
00:43:41,010 --> 00:43:38,980
that so I couldn't even block this out

1310
00:43:42,660 --> 00:43:41,020
it's probably about from here to the

1311
00:43:44,309 --> 00:43:42,670
edge of that room the edge of the room

1312
00:43:46,890 --> 00:43:44,319
is about how big across the Louvre our

1313
00:43:47,990 --> 00:43:46,900

primary Mir would be now not bring and

1314
00:43:49,280 --> 00:43:48,000
by the way

1315
00:43:51,560 --> 00:43:49,290
isn't something we assemble in space

1316
00:43:53,810 --> 00:43:51,570
just like JWST we would fold this up in

1317
00:43:56,690 --> 00:43:53,820
a rocket and by the way yes every time

1318
00:43:58,700 --> 00:43:56,700
SpaceX or Blue Origin or NASA launches a

1319
00:43:59,930 --> 00:43:58,710
new powerful rocket like the scientists

1320
00:44:01,520 --> 00:43:59,940
are cheering because that means like

1321
00:44:04,400 --> 00:44:01,530
more mass and more volume of space we

1322
00:44:06,080 --> 00:44:04,410
get like super excited about it so we

1323
00:44:08,600 --> 00:44:06,090
could we've found out we can fold this

1324
00:44:10,100 --> 00:44:08,610
thing up into SLS which is basically

1325
00:44:11,780 --> 00:44:10,110
like NASA's version of the Falcon Heavy

1326
00:44:13,580 --> 00:44:11,790
it's the next generation rocket NASA's

1327
00:44:15,590 --> 00:44:13,590
building to send humans to Mars and

1328
00:44:19,040 --> 00:44:15,600
other locations for us it's the thing we

1329
00:44:20,480 --> 00:44:19,050
stuff giant space telescopes into now

1330
00:44:21,740 --> 00:44:20,490
not only does it Mir have to be big

1331
00:44:23,780 --> 00:44:21,750
the other challenge with it is it has to

1332
00:44:26,750 --> 00:44:23,790
be super stable it has to be stable on a

1333
00:44:28,490 --> 00:44:26,760
level of like tens of Pico meters and be

1334
00:44:29,660 --> 00:44:28,500
that large and we're developing the

1335
00:44:32,560 --> 00:44:29,670
technologies for that too and I'll show

1336
00:44:34,970 --> 00:44:32,570
a picture or two of that at the end and

1337
00:44:38,210 --> 00:44:34,980
it's going to stow in the rocket and

1338
00:44:39,350 --> 00:44:38,220

then unfold in space this is not the

1339
00:44:40,850 --> 00:44:39,360
current design we've actually changed

1340
00:44:42,770 --> 00:44:40,860
our mirror design it's closer to the one

1341
00:44:44,420 --> 00:44:42,780
I showed on the last image it's going to

1342
00:44:45,950 --> 00:44:44,430
have two folds on either side on like

1343
00:44:47,810 --> 00:44:45,960
web which has one on either side and

1344
00:44:49,280 --> 00:44:47,820
it's got this central baffle to prevent

1345
00:44:51,170 --> 00:44:49,290
stray light from getting in from other

1346
00:44:52,790 --> 00:44:51,180
targets like the moon or other stars

1347
00:44:54,110 --> 00:44:52,800
that we're not looking out it's going to

1348
00:44:56,180 --> 00:44:54,120
have a Sun shield we've had problems

1349
00:44:57,560 --> 00:44:56,190
with the Sun shield on JWST this one's

1350
00:44:59,630 --> 00:44:57,570
the size of a football field yes it

1351
00:45:01,850 --> 00:44:59,640
makes me nervous and it's going to have

1352
00:45:03,050 --> 00:45:01,860
below the telescope or behind it it's

1353
00:45:05,060 --> 00:45:03,060
going to have instruments it'll have

1354
00:45:07,730 --> 00:45:05,070
four instrument bays one difference

1355
00:45:08,660 --> 00:45:07,740
between leVoir and JWST that's important

1356
00:45:10,940 --> 00:45:08,670
other than the differences I've

1357
00:45:12,380 --> 00:45:10,950
mentioned so far is our loop our

1358
00:45:14,180 --> 00:45:12,390
instrument base for loop war will be

1359
00:45:15,890 --> 00:45:14,190
serviceable so they're gonna have all

1360
00:45:18,800 --> 00:45:15,900
the knobs at astronauts or robots need

1361
00:45:20,870 --> 00:45:18,810
to grab onto them swap them out and put

1362
00:45:22,190 --> 00:45:20,880
a next generation instrument in or if we

1363
00:45:23,420 --> 00:45:22,200

mess something up at the telescope put

1364
00:45:27,710 --> 00:45:23,430
in an instrument that has corrective

1365
00:45:29,000 --> 00:45:27,720
optics which is how he fixed Hubble now

1366
00:45:30,980 --> 00:45:29,010
all this and this goes back to the quote

1367
00:45:32,750 --> 00:45:30,990
from Amelia Earhart all of this

1368
00:45:33,980 --> 00:45:32,760
leverages the stuff we've already done

1369
00:45:35,390 --> 00:45:33,990
right we know how to build these

1370
00:45:36,770 --> 00:45:35,400
segments to telescopes we're about to

1371
00:45:40,250 --> 00:45:36,780
launch one I promise we're gonna launch

1372
00:45:41,990 --> 00:45:40,260
it soon with JD BST and that's a huge

1373
00:45:44,180 --> 00:45:42,000
technology that's going into levar but

1374
00:45:46,160 --> 00:45:44,190
it's not the only one w first which is

1375
00:45:47,390 --> 00:45:46,170
the next flagship mission after JD BST

1376
00:45:49,760 --> 00:45:47,400
is helping develop the coronagraph

1377
00:45:51,980 --> 00:45:49,770
technology and demonstrate how it would

1378
00:45:53,840 --> 00:45:51,990
work in space almost to the level we

1379
00:45:55,310 --> 00:45:53,850
need it to work for levar we're learning

1380
00:45:56,990 --> 00:45:55,320
a lot of science from Kepler about these

1381
00:45:58,370 --> 00:45:57,000
exoplanets I talked about before and

1382
00:45:59,780 --> 00:45:58,380
we're going to learn that from tests

1383
00:46:00,620 --> 00:45:59,790
which is also launching later this year

1384
00:46:01,140 --> 00:46:00,630
that's going to be kind of like a

1385
00:46:03,329 --> 00:46:01,150
coupler

1386
00:46:05,579 --> 00:46:03,339
steroids and from Hubble we've learned

1387
00:46:07,710 --> 00:46:05,589
first of all just a tremendous amount

1388
00:46:10,019 --> 00:46:07,720

about the universe but secondly how to

1389
00:46:12,029 --> 00:46:10,029
operate UV optical infrared telescopes

1390
00:46:14,789 --> 00:46:12,039
like Louvre are and operate them for

1391
00:46:15,960 --> 00:46:14,799
many decades a lot of people have said

1392
00:46:18,299 --> 00:46:15,970
like if you really want to know what

1393
00:46:20,190 --> 00:46:18,309
Louvre art is it's the super duper duper

1394
00:46:21,809 --> 00:46:20,200
hubble right like it's Hubble but like

1395
00:46:25,130 --> 00:46:21,819
souped-up in like a thousand different

1396
00:46:27,299 --> 00:46:25,140
ways I should mention before I close

1397
00:46:28,650 --> 00:46:27,309
there's there's one other telescope

1398
00:46:30,839 --> 00:46:28,660
that's being concept that's being

1399
00:46:32,039 --> 00:46:30,849
studied alongside Lubar solovar and by

1400
00:46:33,269 --> 00:46:32,049
the way levar is not like for sure

1401
00:46:34,769 --> 00:46:33,279
happening I don't want to give that

1402
00:46:37,260 --> 00:46:34,779
impression to this audience

1403
00:46:39,180 --> 00:46:37,270
levar is a concept mission that's

1404
00:46:40,740 --> 00:46:39,190
basically me being pitched to the the

1405
00:46:43,049 --> 00:46:40,750
National Academies astrophysics

1406
00:46:44,519 --> 00:46:43,059
decadence survey for sciences right and

1407
00:46:46,349 --> 00:46:44,529
the cantle survey will make a

1408
00:46:48,240 --> 00:46:46,359
prioritization as to whether levar or

1409
00:46:50,130 --> 00:46:48,250
something else should go forward is like

1410
00:46:51,660 --> 00:46:50,140
the next flagship mission for NASA but

1411
00:46:54,299 --> 00:46:51,670
it's one of four concepts that are being

1412
00:46:55,529 --> 00:46:54,309
pitched levar the Origin Space Telescope

1413
00:46:58,890 --> 00:46:55,539

which is going to do science similar to

1414
00:46:59,940 --> 00:46:58,900
web but with a more sensitive set of

1415
00:47:02,730 --> 00:46:59,950
instruments because it's going to be

1416
00:47:04,140 --> 00:47:02,740
even colder than than JWST is Lynx which

1417
00:47:05,730 --> 00:47:04,150
is an x-ray telescope that'll look at

1418
00:47:07,980 --> 00:47:05,740
high-energy processes in the universe

1419
00:47:10,170 --> 00:47:07,990
and have X is the fourth and this is an

1420
00:47:12,269 --> 00:47:10,180
artist's rendering of Havoc's how Beck's

1421
00:47:14,250 --> 00:47:12,279
is a lot like loot floor but on a less

1422
00:47:15,960 --> 00:47:14,260
ambitious scale but with maybe like some

1423
00:47:19,109 --> 00:47:15,970
smaller technological challenges right

1424
00:47:21,690 --> 00:47:19,119
and and this is important because what's

1425
00:47:23,970 --> 00:47:21,700
the quote like the future is is hard to

1426
00:47:26,609 --> 00:47:23,980
predict right especially because it

1427
00:47:29,180 --> 00:47:26,619
hasn't happened yet we don't know what

1428
00:47:30,930 --> 00:47:29,190
our budgets are gonna be like next year

1429
00:47:32,220 --> 00:47:30,940
we definitely don't know what our

1430
00:47:33,569 --> 00:47:32,230
budgets are gonna be in five or ten

1431
00:47:35,279 --> 00:47:33,579
years we don't know what technologies

1432
00:47:37,200 --> 00:47:35,289
that we're trying to develop develop now

1433
00:47:39,120 --> 00:47:37,210
are actually going to be ready when this

1434
00:47:41,160 --> 00:47:39,130
new mission starts in five years it's

1435
00:47:43,470 --> 00:47:41,170
important for us to like study an array

1436
00:47:44,940 --> 00:47:43,480
of different options because we want to

1437
00:47:47,250 --> 00:47:44,950
be ready for that sort of diversity of

1438
00:47:48,779 --> 00:47:47,260

future possibilities and half x is a

1439
00:47:50,190 --> 00:47:48,789
huge part of that so like there's have X

1440
00:47:52,109 --> 00:47:50,200
there's levar they're doing the same

1441
00:47:53,460 --> 00:47:52,119
kind of science on different scales with

1442
00:47:55,010 --> 00:47:53,470
different levels of challenge in front

1443
00:47:57,180 --> 00:47:55,020
of them in terms of technology and cost

1444
00:47:58,529 --> 00:47:57,190
and we've even talked like joked

1445
00:48:00,559 --> 00:47:58,539
internally about like a Louvre X which

1446
00:48:02,609 --> 00:48:00,569
is like maybe a sweet spot in between

1447
00:48:05,099 --> 00:48:02,619
okay so lastly what are our hurdles

1448
00:48:07,680 --> 00:48:05,109
beyond like the technical challenges so

1449
00:48:09,150 --> 00:48:07,690
I love this quote from the senior

1450
00:48:11,160 --> 00:48:09,160
scientist for astrobiology and I think

1451
00:48:12,480 --> 00:48:11,170
that's on display today everyone's an

1452
00:48:13,829 --> 00:48:12,490
astrobiologist they just don't know it

1453
00:48:14,720 --> 00:48:13,839
yet right because this is an

1454
00:48:17,450 --> 00:48:14,730
all-hands-on-deck

1455
00:48:18,920 --> 00:48:17,460
and every way and imaginable we need

1456
00:48:20,150 --> 00:48:18,930
instrument designers and engineers to

1457
00:48:21,950 --> 00:48:20,160
figure out how to block the central

1458
00:48:23,450 --> 00:48:21,960
starlight this is some maps of what that

1459
00:48:25,640 --> 00:48:23,460
looks like as the sort of as the

1460
00:48:27,349 --> 00:48:25,650
telescope instrumentation sees it this

1461
00:48:28,460 --> 00:48:27,359
is actually pictures of the technology

1462
00:48:30,230 --> 00:48:28,470
that would give us that picometer

1463
00:48:31,790 --> 00:48:30,240

stability so and that's like a whole

1464
00:48:33,109 --> 00:48:31,800
different kind of engineering than like

1465
00:48:34,910 --> 00:48:33,119
the because this is like a systems

1466
00:48:36,349 --> 00:48:34,920
engineering promises you need all

1467
00:48:39,349 --> 00:48:36,359
different kinds of engineers like

1468
00:48:41,420 --> 00:48:39,359
mechanical optical thermal electrical

1469
00:48:42,920 --> 00:48:41,430
all onboard this problem then that that

1470
00:48:45,500 --> 00:48:42,930
in and of itself is an interdisciplinary

1471
00:48:47,180 --> 00:48:45,510
problem but we also need to think as

1472
00:48:48,980 --> 00:48:47,190
scientists about the diversity of ways

1473
00:48:50,180 --> 00:48:48,990
that we could assess the data that we're

1474
00:48:52,310 --> 00:48:50,190
gonna get and actually I think the

1475
00:48:53,930 --> 00:48:52,320
person that's pushed this stuff forward

1476
00:48:56,030 --> 00:48:53,940
is someone that debts spent some time

1477
00:48:57,320 --> 00:48:56,040
here which is Sarah Walker who's been

1478
00:48:59,630 --> 00:48:57,330
talking a lot about agnostic

1479
00:49:01,300 --> 00:48:59,640
biosignatures and networks of chemicals

1480
00:49:03,380 --> 00:49:01,310
is biosignature on Europa and Enceladus

1481
00:49:04,970 --> 00:49:03,390
but she's also started to think about

1482
00:49:06,050 --> 00:49:04,980
the same thing for exoplanets right so

1483
00:49:08,540 --> 00:49:06,060
instead of looking at just like the

1484
00:49:10,609 --> 00:49:08,550
oxygen methane water trio maybe using

1485
00:49:12,620 --> 00:49:10,619
what we can see to infer the chemical

1486
00:49:14,390 --> 00:49:12,630
the the complexity of the chemical

1487
00:49:16,250 --> 00:49:14,400
Network that's underneath in that

1488
00:49:18,530 --> 00:49:16,260

planetary atmosphere and trying to use

1489
00:49:19,849 --> 00:49:18,540
that as sort of art our assessment of

1490
00:49:22,580 --> 00:49:19,859
whether or not there's there's life on a

1491
00:49:24,260 --> 00:49:22,590
particular planet which I think there's

1492
00:49:25,580 --> 00:49:24,270
a tremendous amount of Merit here but

1493
00:49:29,030 --> 00:49:25,590
there's a lot of research that has yet

1494
00:49:30,380 --> 00:49:29,040
to be done so but the point here is we

1495
00:49:32,000 --> 00:49:30,390
need all hands on deck we need people

1496
00:49:33,320 --> 00:49:32,010
like Sarah Walker we need people like in

1497
00:49:36,170 --> 00:49:33,330
this room that have thought a lot about

1498
00:49:37,700 --> 00:49:36,180
chemical networks to start thinking

1499
00:49:39,620 --> 00:49:37,710
about what what a bio signature look

1500
00:49:40,940 --> 00:49:39,630
like from a chemical Network perspective

1501
00:49:42,200 --> 00:49:40,950
instead of the perspective I

1502
00:49:43,970 --> 00:49:42,210
traditionally look at it which is like

1503
00:49:45,530 --> 00:49:43,980
two or three individual molecules which

1504
00:49:47,720 --> 00:49:45,540
together are hard to keep in malice fear

1505
00:49:49,220 --> 00:49:47,730
that the network approach is a more

1506
00:49:53,599 --> 00:49:49,230
quantifiable way to say what I just said

1507
00:49:54,980 --> 00:49:53,609
okay and then lastly we need diversity

1508
00:49:56,480 --> 00:49:54,990
in terms of the disciplines we bring to

1509
00:49:58,190 --> 00:49:56,490
bear but like there's a lot of research

1510
00:49:59,599 --> 00:49:58,200
that's shown that like more diverse

1511
00:50:01,430 --> 00:49:59,609
teams not just in terms of discipline

1512
00:50:02,780 --> 00:50:01,440
but in terms of race and gender and just

1513
00:50:04,040 --> 00:50:02,790

socioeconomic background like when

1514
00:50:06,530 --> 00:50:04,050
you've got more diverse teams you get

1515
00:50:08,240 --> 00:50:06,540
two better answers faster and to be

1516
00:50:10,430 --> 00:50:08,250
frank we just we don't have a diverse

1517
00:50:11,930 --> 00:50:10,440
enough community to from me to be

1518
00:50:14,300 --> 00:50:11,940
comfortable to say like we were really

1519
00:50:15,320 --> 00:50:14,310
optimized in that sense and so this is

1520
00:50:17,030 --> 00:50:15,330
the last quote and that's the one I'm

1521
00:50:18,170 --> 00:50:17,040
gonna leave you all with which is it's

1522
00:50:20,330 --> 00:50:18,180
time for parents to teach young people

1523
00:50:21,320 --> 00:50:20,340
early on that in diversity there is

1524
00:50:22,940 --> 00:50:21,330
beauty and there is strength I think

1525
00:50:25,190 --> 00:50:22,950
that's true about the universe I think

1526
00:50:28,130 --> 00:50:25,200
that's true about teams that try to

1527
00:50:28,590 --> 00:50:28,140
tackle hard problems and I thank you for

1528
00:50:30,360 --> 00:50:28,600
your time

1529
00:50:41,859 --> 00:50:30,370
look for deer questions

1530
00:50:50,150 --> 00:50:44,870
so other your risk ended you wanna do

1531
00:50:58,160 --> 00:50:50,160
questions Kenda where is coming yeah

1532
00:51:00,170 --> 00:50:58,170
sure yeah what kind of resolution are

1533
00:51:09,950 --> 00:51:00,180
you getting with the spectrometers on

1534
00:51:12,710 --> 00:51:09,960
the fly yeah well I didn't go into the

1535
00:51:14,180 --> 00:51:12,720
instruments in detail I'm gonna try to

1536
00:51:15,770 --> 00:51:14,190
do this from a memory but I'm probably

1537
00:51:17,089 --> 00:51:15,780
not gonna hit it all are you are you

1538
00:51:18,650 --> 00:51:17,099

asked can I ask what target you're

1539
00:51:24,680 --> 00:51:18,660
asking about is it an exoplanet or a

1540
00:51:26,630 --> 00:51:24,690
solar system target for the exoplanets

1541
00:51:28,160 --> 00:51:26,640
spectra that I was showing okay for the

1542
00:51:31,609 --> 00:51:28,170
exoplanet spectra we're looking at a

1543
00:51:33,920 --> 00:51:31,619
target resolution of 150 because that's

1544
00:51:37,190 --> 00:51:33,930
what we need to see the oxygen a band

1545
00:51:38,900 --> 00:51:37,200
really really well there are all right

1546
00:51:40,579 --> 00:51:38,910
ideas and concepts to go super high

1547
00:51:43,339 --> 00:51:40,589
resolution like into the hundreds or the

1548
00:51:45,490 --> 00:51:43,349
thousands the problem with that is

1549
00:51:48,020 --> 00:51:45,500
unless we have super low noise detectors

1550
00:51:49,599 --> 00:51:48,030
we're breaking up the photons into so

1551
00:51:52,880 --> 00:51:49,609
many bins we're getting hit by the

1552
00:51:55,250 --> 00:51:52,890
detector noise so we the the game we

1553
00:51:56,690 --> 00:51:55,260
want to play is we want to go high

1554
00:51:58,160 --> 00:51:56,700
enough resolution to observe the bands

1555
00:52:00,170 --> 00:51:58,170
we're looking for from oxygen but not

1556
00:52:02,599 --> 00:52:00,180
the molecular lines the the the band

1557
00:52:05,390 --> 00:52:02,609
structure but not so high that we're

1558
00:52:07,910 --> 00:52:05,400
losing to the noise of the of the from

1559
00:52:09,620 --> 00:52:07,920
the binning I mean 150 looks like a

1560
00:52:12,920 --> 00:52:09,630
sweet spot in terms of optimizing your

1561
00:52:14,300 --> 00:52:12,930
observation time for oxygen so and

1562
00:52:15,800 --> 00:52:14,310
because that's so central to a lot of

1563
00:52:18,109 --> 00:52:15,810

what we're doing we've kind of hit it

1564
00:52:19,849 --> 00:52:18,119
there at that resolution we also see

1565
00:52:21,829 --> 00:52:19,859
water and methane and other things in

1566
00:52:23,839 --> 00:52:21,839
that wavelength range we have a higher

1567
00:52:25,900 --> 00:52:23,849
resolution motive I think 200 in the

1568
00:52:29,960 --> 00:52:25,910
concept instrument out in the infrared

1569
00:52:32,780 --> 00:52:29,970
not specifically to see carbon dioxide

1570
00:52:33,950 --> 00:52:32,790
in very co2 rich atmospheres and the

1571
00:52:35,540 --> 00:52:33,960
reason for that is that's one of the

1572
00:52:37,099 --> 00:52:35,550
false positive mechanisms I mentioned

1573
00:52:38,780 --> 00:52:37,109
before if you've got a lot of co2 you

1574
00:52:41,450 --> 00:52:38,790
can fertilize it and make o2 and o3

1575
00:52:43,010 --> 00:52:41,460
without life and so but you can only do

1576
00:52:44,300 --> 00:52:43,020
it if there's a ton of co2 so if you've

1577
00:52:46,099 --> 00:52:44,310
got like three percent of your

1578
00:52:49,220 --> 00:52:46,109
atmosphere co2 which is way more than we

1579
00:52:50,960 --> 00:52:49,230
have then you'd be able to see co2 in

1580
00:52:53,089 --> 00:52:50,970
the infrared but only at a special

1581
00:52:53,730 --> 00:52:53,099
resolution of 200 and that's we've got

1582
00:52:55,920 --> 00:52:53,740
in the infrared

1583
00:52:57,510 --> 00:52:55,930
one mode that's it that high that is

1584
00:52:59,339 --> 00:52:57,520
your question and we've got like three

1585
00:53:00,990 --> 00:52:59,349
or four others spectra spectrographs on

1586
00:53:02,700 --> 00:53:01,000
board like the high-definition

1587
00:53:04,140 --> 00:53:02,710
high-definition imagers got like a wide

1588
00:53:06,540 --> 00:53:04,150

field camera with a spectrograph I

1589
00:53:07,920 --> 00:53:06,550
honestly don't remember what the

1590
00:53:09,530 --> 00:53:07,930
spectral resolution is but if anyone

1591
00:53:14,730 --> 00:53:09,540
wants to know I can show details on

1592
00:53:15,180 --> 00:53:14,740
those concepts later that was a hard

1593
00:53:27,690 --> 00:53:15,190
question

1594
00:53:33,450 --> 00:53:27,700
you ready I've been having bad luck with

1595
00:53:36,599 --> 00:53:33,460
this I had a question about well you

1596
00:53:38,849 --> 00:53:36,609
mentioned four concepts but you chose to

1597
00:53:40,800 --> 00:53:38,859
speak to us about luke war and i was

1598
00:53:47,030 --> 00:53:40,810
just wondering why that was like what

1599
00:54:02,700 --> 00:53:59,280
okay so I'm on two of the 14 so I'm on

1600
00:54:04,530 --> 00:54:02,710
the leVoir team I'm on the hex team it's

1601
00:54:06,780 --> 00:54:04,540
hard to explain this right and not and

1602
00:54:08,670 --> 00:54:06,790
not like shorts I'll have X right so how

1603
00:54:11,070 --> 00:54:08,680
Beck's is literally the mission it's

1604
00:54:12,089 --> 00:54:11,080
like a different brand and an update to

1605
00:54:14,040 --> 00:54:12,099
a mission that when I was a graduate

1606
00:54:16,320 --> 00:54:14,050
student it was like my life's ambition

1607
00:54:18,500 --> 00:54:16,330
to be a part of like that mission and

1608
00:54:20,490 --> 00:54:18,510
that point is called T PFC the

1609
00:54:23,460 --> 00:54:20,500
terrestrial planet finder coronagraph

1610
00:54:25,530 --> 00:54:23,470
mission how X is basically that right so

1611
00:54:27,510 --> 00:54:25,540
had X happen like and I was part of that

1612
00:54:29,910 --> 00:54:27,520
I would be fulfilling my like grad

1613
00:54:33,060 --> 00:54:29,920

student dream at that point

1614
00:54:34,589 --> 00:54:33,070
levar is like that but like x 10

1615
00:54:36,870 --> 00:54:34,599
literally like we'd get like 10 times

1616
00:54:39,140 --> 00:54:36,880
more planets ten times more spectra and

1617
00:54:41,010 --> 00:54:39,150
an important part to this is the

1618
00:54:42,780 --> 00:54:41,020
astronomer community like the general

1619
00:54:44,760 --> 00:54:42,790
astrophysics community they really want

1620
00:54:47,220 --> 00:54:44,770
the big telescope so as an exoplanet

1621
00:54:48,540 --> 00:54:47,230
person we haven't had like Hubble class

1622
00:54:50,550 --> 00:54:48,550
science like a mission that could

1623
00:54:52,470 --> 00:54:50,560
directly imaged exoplanets from space we

1624
00:54:53,700 --> 00:54:52,480
we haven't had that yet the astronomers

1625
00:54:56,490 --> 00:54:53,710
have had Hubble which does a lot of

1626
00:54:58,470 --> 00:54:56,500
great space astronomy already so for

1627
00:55:00,480 --> 00:54:58,480
them going a little bit beyond Hubble

1628
00:55:02,940 --> 00:55:00,490
isn't as worth it as it would be for me

1629
00:55:04,380 --> 00:55:02,950
like in terms of telescope size so the

1630
00:55:05,730 --> 00:55:04,390
the general astrophysics community the

1631
00:55:07,260 --> 00:55:05,740
first third of that talk

1632
00:55:08,910 --> 00:55:07,270
really want to get to a telescope that's

1633
00:55:12,359 --> 00:55:08,920
like eight meters or bigger that's kind

1634
00:55:13,680 --> 00:55:12,369
of their their benchmark and the other

1635
00:55:14,520 --> 00:55:13,690
two missions they would do some

1636
00:55:16,200 --> 00:55:14,530
exoplanet stuff

1637
00:55:17,880 --> 00:55:16,210
OST would do some bio signature stuff

1638
00:55:20,070 --> 00:55:17,890

Lynx would look at like atmospheric

1639
00:55:21,660 --> 00:55:20,080
escape but near the one would do the bio

1640
00:55:29,520 --> 00:55:21,670
signature job that Lubar or Havoc's

1641
00:55:31,980 --> 00:55:29,530
would you questions good and I'll be Oh

1642
00:55:40,470 --> 00:55:31,990
in the back I need a short stop I need a

1643
00:55:42,420 --> 00:55:40,480
relay person all right what's the idea

1644
00:55:44,010 --> 00:55:42,430
behind the choice obviously gasses at

1645
00:55:45,420 --> 00:55:44,020
the monitor for example you exclude

1646
00:55:47,070 --> 00:55:45,430
sulfur compounds which will be

1647
00:55:55,859 --> 00:55:47,080
transitory but they give you a lot of

1648
00:55:57,240 --> 00:55:55,869
information about you know it's hard is

1649
00:55:58,410 --> 00:55:57,250
like I'm literate like I was talking

1650
00:56:00,150 --> 00:55:58,420
about like getting blinded by the Sun

1651
00:56:01,859 --> 00:56:00,160
it's like hard catching this because

1652
00:56:05,190 --> 00:56:01,869
like the floodlights are like right in

1653
00:56:06,420 --> 00:56:05,200
our eyes so the question was about like

1654
00:56:11,930 --> 00:56:06,430
what about sulfur gases

1655
00:56:14,790 --> 00:56:11,940
I love sulfur gases well I'm a modeler I

1656
00:56:16,440 --> 00:56:14,800
don't when I was a grad student the lab

1657
00:56:18,180 --> 00:56:16,450
next to me like was growing microbes

1658
00:56:20,730 --> 00:56:18,190
that make sulfur gases and I didn't love

1659
00:56:21,960 --> 00:56:20,740
sulfur gases though I would just like

1660
00:56:23,250 --> 00:56:21,970
take off for the afternoon when they

1661
00:56:25,170 --> 00:56:23,260
were like doing their experiments cuz

1662
00:56:26,220 --> 00:56:25,180
they for those that like are on the

1663
00:56:28,170 --> 00:56:26,230

internet and aren't scientists like they

1664
00:56:31,380 --> 00:56:28,180
smell horrible most horrible smells are

1665
00:56:33,270 --> 00:56:31,390
like the sulfur gases but they're made

1666
00:56:34,650 --> 00:56:33,280
my life right so why should we look at

1667
00:56:36,450 --> 00:56:34,660
the sulfur gases as well we actually

1668
00:56:37,620 --> 00:56:36,460
looked at this it was back for a

1669
00:56:39,560 --> 00:56:37,630
different telescope called

1670
00:56:42,630 --> 00:56:39,570
TP fi the terrestrial planet finder

1671
00:56:44,520 --> 00:56:42,640
interferometer we ran our model where we

1672
00:56:47,490 --> 00:56:44,530
basically took the modern-day production

1673
00:56:49,230 --> 00:56:47,500
rates of organic sulfur gases like metal

1674
00:56:52,230 --> 00:56:49,240
sulphide and dimethyl sulfide and

1675
00:56:53,790 --> 00:56:52,240
dimethyl disulfide and carbonyl sulfide

1676
00:56:56,030 --> 00:56:53,800
I think I can remember the full list of

1677
00:56:59,040 --> 00:56:56,040
that but we had like five or six

1678
00:57:00,630 --> 00:56:59,050
biologically produced sulfur gases most

1679
00:57:04,050 --> 00:57:00,640
of them had a methyl group and a sulfur

1680
00:57:05,310 --> 00:57:04,060
in some combination and we try to see if

1681
00:57:06,599 --> 00:57:05,320
we could at what rates we'd have to

1682
00:57:08,640 --> 00:57:06,609
produce them in order for them to be

1683
00:57:10,830 --> 00:57:08,650
detectable it turns out that you have to

1684
00:57:12,840 --> 00:57:10,840
get like orders of more orders more

1685
00:57:15,030 --> 00:57:12,850
production out of the biosphere than we

1686
00:57:17,700 --> 00:57:15,040
have a modern-day earth before they grow

1687
00:57:19,490 --> 00:57:17,710
up to detectable levels themselves now

1688
00:57:21,320 --> 00:57:19,500

that could have

1689
00:57:23,300 --> 00:57:21,330
like you know like if you go on the lab

1690
00:57:24,770 --> 00:57:23,310
and you give some methanogens h2s from

1691
00:57:26,780 --> 00:57:24,780
the headspace instead of a ch2 they can

1692
00:57:30,020 --> 00:57:26,790
actually make ch3 SH instead of methane

1693
00:57:32,090 --> 00:57:30,030
so I could imagine as a model or an

1694
00:57:33,680 --> 00:57:32,100
atmosphere that might induce some

1695
00:57:36,530 --> 00:57:33,690
microbes to like make a lot of methyl

1696
00:57:38,060 --> 00:57:36,540
sulfide for example however if you don't

1697
00:57:40,850 --> 00:57:38,070
want to count on that kind of specific

1698
00:57:43,580 --> 00:57:40,860
like fine-tuned answer what you do get

1699
00:57:46,370 --> 00:57:43,590
is even in the cases where you are not

1700
00:57:47,960 --> 00:57:46,380
seeing the ch3 SH or the other organic

1701
00:57:51,020 --> 00:57:47,970
sulfur gases the reason you're not

1702
00:57:53,810 --> 00:57:51,030
seeing them is the the methyl sulfonyl

1703
00:57:57,680 --> 00:57:53,820
for Bob is actually much easier to break

1704
00:58:00,590 --> 00:57:57,690
then the the methyl hydrogen bond and

1705
00:58:04,670 --> 00:58:00,600
methane and as a result if you put the

1706
00:58:08,210 --> 00:58:04,680
same amount of methyl of ch3 into the

1707
00:58:10,520 --> 00:58:08,220
atmosphere with a biosphere verses from

1708
00:58:12,110 --> 00:58:10,530
non-biological processes because the

1709
00:58:13,820 --> 00:58:12,120
organic sulfur gases which are easier to

1710
00:58:15,830 --> 00:58:13,830
break up and turn into ch3 radicals

1711
00:58:17,690 --> 00:58:15,840
because because they're easier to do

1712
00:58:19,490 --> 00:58:17,700
that with you end up making more ethane

1713
00:58:21,320 --> 00:58:19,500

in the atmosphere than you do for the

1714
00:58:22,880 --> 00:58:21,330
non-biological case and so what ended up

1715
00:58:24,770 --> 00:58:22,890
happening is if we put the same amount

1716
00:58:26,810 --> 00:58:24,780
of ch3 in but it was distributed between

1717
00:58:28,730 --> 00:58:26,820
methane and these organic sulfur gases

1718
00:58:30,950 --> 00:58:28,740
we got a much higher ethane and methane

1719
00:58:32,870 --> 00:58:30,960
ratio in the atmosphere and that work I

1720
00:58:34,130 --> 00:58:32,880
showed for the organic haze when we went

1721
00:58:35,720 --> 00:58:34,140
back and looked at the haze the haze

1722
00:58:37,160 --> 00:58:35,730
also got thicker because that's that's a

1723
00:58:39,770 --> 00:58:37,170
long-chain organic carbon and that was

1724
00:58:41,600 --> 00:58:39,780
easier to build up once you're you're

1725
00:58:45,440 --> 00:58:41,610
sort of liberating the ch3 from the

1726
00:58:47,090 --> 00:58:45,450
sulfur so we have looked at it it's

1727
00:58:48,770 --> 00:58:47,100
really hard for those to be directly

1728
00:58:50,690 --> 00:58:48,780
detectable but they may have sort of a

1729
00:58:55,240 --> 00:58:50,700
secondary influence on some of the other

1730
00:59:07,670 --> 00:59:06,410
okay question okay all right so if we do

1731
00:59:18,049 --> 00:59:07,680
find life in the suite of things we

1732
00:59:23,640 --> 00:59:21,569
so seriously I you know I think one of

1733
00:59:24,989 --> 00:59:23,650
the things that would happen is and I

1734
00:59:27,329 --> 00:59:24,999
think back like to the Allen Hills

1735
00:59:29,279 --> 00:59:27,339
meteorite or any-any detection of life

1736
00:59:31,170 --> 00:59:29,289
beyond Earth what's gonna happen is a

1737
00:59:32,969 --> 00:59:31,180
whole bunch of smart people are gonna

1738
00:59:35,219 --> 00:59:32,979

find a way to make the signal we find

1739
00:59:37,109 --> 00:59:35,229
without life like it's not that I don't

1740
00:59:38,759 --> 00:59:37,119
think that aren't like stories like

1741
00:59:40,679 --> 00:59:38,769
locks all like I really believe in our

1742
00:59:42,569 --> 00:59:40,689
story but some genius is gonna like

1743
00:59:44,309 --> 00:59:42,579
figure out some corner case pathological

1744
00:59:46,170 --> 00:59:44,319
way to like reproduce the data without

1745
00:59:48,569 --> 00:59:46,180
biology making it like it's just gonna

1746
00:59:50,009 --> 00:59:48,579
happen but we'll we have I mean but this

1747
00:59:51,269 --> 00:59:50,019
is what the scientific method is about

1748
00:59:53,459 --> 00:59:51,279
what we have to do is make sure that

1749
00:59:55,199 --> 00:59:53,469
that method that makes the signal

1750
00:59:57,329 --> 00:59:55,209
without life has a predictable

1751
00:59:59,400 --> 00:59:57,339
observable feature right and there's

1752
01:00:01,529 --> 00:59:59,410
follow-up missions we could do one of

1753
01:00:02,759 --> 01:00:01,539
them is is to do an interferometer which

1754
01:00:03,269 --> 01:00:02,769
would also get the pictures of the

1755
01:00:04,589 --> 01:00:03,279
planet

1756
01:00:06,329 --> 01:00:04,599
he would get spectra in the infrared

1757
01:00:08,130 --> 01:00:06,339
which would get a complementary set of

1758
01:00:10,589 --> 01:00:08,140
gases including a lot of the sulfur

1759
01:00:12,029 --> 01:00:10,599
gases that all could just asked about it

1760
01:00:13,529 --> 01:00:12,039
would also get information on the

1761
01:00:14,789 --> 01:00:13,539
thermal properties of the planet and its

1762
01:00:17,390 --> 01:00:14,799
climate and stuff like that you get

1763
01:00:19,829 --> 01:00:17,400

complementary information another idea

1764
01:00:22,289 --> 01:00:19,839
as you keep build an interferometer of

1765
01:00:23,729 --> 01:00:22,299
visible of basically a fleet of lavars

1766
01:00:25,589 --> 01:00:23,739
acting as an interferometer would be

1767
01:00:28,019 --> 01:00:25,599
able to let you like map out the surface

1768
01:00:29,999 --> 01:00:28,029
and like maybe even see like when I say

1769
01:00:31,650 --> 01:00:30,009
map out like get pixels across the

1770
01:00:35,189 --> 01:00:31,660
surface and maybe like see a like a

1771
01:00:37,410 --> 01:00:35,199
rainforest or an algal bloom that would

1772
01:00:39,209 --> 01:00:37,420
be pretty hard to explain if you had

1773
01:00:45,089 --> 01:00:39,219
oxygen and methane and you saw like

1774
01:00:53,669 --> 01:00:45,099
seasonal blooms of like chlorophyll then

1775
01:00:55,049 --> 01:00:53,679
then my kid retires I mean for me what

1776
01:00:56,189 --> 01:00:55,059
makes it this actually goes back to the

1777
01:00:57,599 --> 01:00:56,199
first question what makes this so

1778
01:00:59,669 --> 01:00:57,609
exciting is there's two things that

1779
01:01:02,339 --> 01:00:59,679
Lavar in particular get me really like

1780
01:01:03,689 --> 01:01:02,349
jazzed up about well even with regards

1781
01:01:06,269 --> 01:01:03,699
to have X which I like love would be

1782
01:01:09,390 --> 01:01:06,279
like super stoked if it happened one is

1783
01:01:10,739 --> 01:01:09,400
I want to start ask it goes back to like

1784
01:01:13,140 --> 01:01:10,749
the exoplanet stuff I was talking about

1785
01:01:15,059 --> 01:01:13,150
like we've rewritten our models of how

1786
01:01:17,160 --> 01:01:15,069
planets evolve and interact rabbit

1787
01:01:18,959 --> 01:01:17,170
ational II and we know better how our

1788
01:01:21,089 --> 01:01:18,969

home system has evolved as a result I

1789
01:01:22,979 --> 01:01:21,099
want to do the same kind of science for

1790
01:01:24,989 --> 01:01:22,989
how a biosphere interacts with its host

1791
01:01:26,519 --> 01:01:24,999
planet on a number of targets beyond the

1792
01:01:28,349 --> 01:01:26,529
solar system right whether there's life

1793
01:01:30,230 --> 01:01:28,359
there or not even if we find no bio

1794
01:01:32,630 --> 01:01:30,240
signatures or even if we find a

1795
01:01:34,040 --> 01:01:32,640
you biosignatures understanding the

1796
01:01:36,140 --> 01:01:34,050
planetary environments in which we do

1797
01:01:37,460 --> 01:01:36,150
and do not find them in cases where we

1798
01:01:40,070 --> 01:01:37,470
otherwise would expect them to be and

1799
01:01:41,630 --> 01:01:40,080
probing that to greater detail is going

1800
01:01:43,520 --> 01:01:41,640
to teach us a tremendous amount of

1801
01:01:45,140 --> 01:01:43,530
planetary science and earth system

1802
01:01:47,120 --> 01:01:45,150
science and I'm looking forward to that

1803
01:01:50,720 --> 01:01:47,130
like that's that's what I want to see

1804
01:01:52,100 --> 01:01:50,730
right and then the other aspect to it is

1805
01:01:54,770 --> 01:01:52,110
and this is like where the retirement

1806
01:01:55,790 --> 01:01:54,780
joke comes in like my gender I don't

1807
01:01:58,160 --> 01:01:55,800
know how many people in the room like

1808
01:02:00,620 --> 01:01:58,170
remember Apollo like like like like I

1809
01:02:03,260 --> 01:02:00,630
saw it on TV like I did right like my

1810
01:02:05,240 --> 01:02:03,270
generation we don't have an Apollo like

1811
01:02:07,220 --> 01:02:05,250
landing moment right and and the reason

1812
01:02:09,020 --> 01:02:07,230
Apollo is it like so amazing is like

1813
01:02:11,180 --> 01:02:09,030

it's the first time that ever happened

1814
01:02:13,010 --> 01:02:11,190
right and whether it's exoplanets or

1815
01:02:14,870 --> 01:02:13,020
whether it's Europa or Mars or Enceladus

1816
01:02:16,910 --> 01:02:14,880
or Titan or some other target or you

1817
01:02:19,910 --> 01:02:16,920
know some say Venus although I'm not too

1818
01:02:21,320 --> 01:02:19,920
optimistic they're the first time we

1819
01:02:23,600 --> 01:02:21,330
fight like there's only one time in

1820
01:02:25,280 --> 01:02:23,610
human history that we find life beyond

1821
01:02:26,870 --> 01:02:25,290
Earth for the first time right like that

1822
01:02:28,340 --> 01:02:26,880
that's gonna happen once and that's

1823
01:02:30,500 --> 01:02:28,350
gonna be it and we'll all remember it

1824
01:02:31,940 --> 01:02:30,510
right so in some sense like after like

1825
01:02:33,260 --> 01:02:31,950
that's where the retirement joke comes

1826
01:02:35,090 --> 01:02:33,270
in right because then I'm good like

1827
01:02:41,660 --> 01:02:35,100
we've made history I'm good like

1828
01:02:42,560 --> 01:02:41,670
chilling out after that that it all

1829
01:02:43,940 --> 01:02:42,570
right I'm gonna hang out so other

1830
01:02:51,160 --> 01:02:43,950
questions come up to me with the beer or

1831
01:02:57,430 --> 01:02:55,700
[Music]