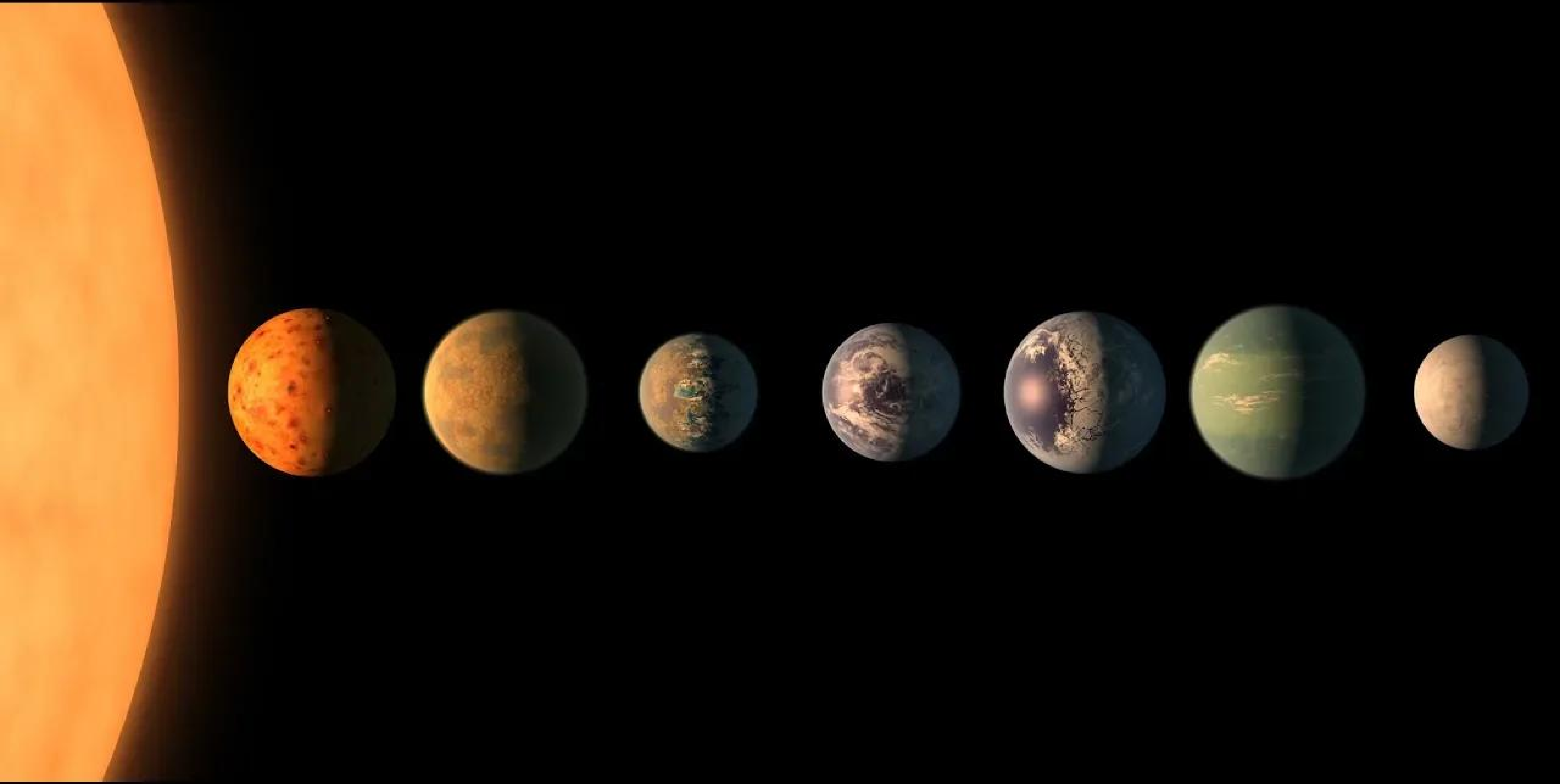

1
00:00:06,590 --> 00:00:05,329
hello and welcome to NASA's Jet

2
00:00:08,870 --> 00:00:06,600
Propulsion Laboratory in Pasadena

3
00:00:12,080 --> 00:00:08,880
California for our monthly public

4
00:00:14,770 --> 00:00:12,090
lecture the von Karman series the title

5
00:00:17,570 --> 00:00:14,780
of our show this month the golden age of

6
00:00:20,179 --> 00:00:17,580
exoplanet exploration as we'll discuss

7
00:00:22,279 --> 00:00:20,189
with our speakers later on there's some

8
00:00:24,019 --> 00:00:22,289
room for debate whether that's golden

9
00:00:26,540 --> 00:00:24,029
ages upon us right now or whether it's

10
00:00:28,160 --> 00:00:26,550
still to come and don't worry if you are

11
00:00:30,980 --> 00:00:28,170
scratching your head out there wondering

12
00:00:32,299 --> 00:00:30,990
just what the heck is an exoplanet we've

13
00:00:33,740 --> 00:00:32,309

got you covered

14
00:00:35,720 --> 00:00:33,750
we'll hear from two speakers this

15
00:00:36,709 --> 00:00:35,730
evening followed by some discussion with

16
00:00:38,690 --> 00:00:36,719
them and then we'll take your questions

17
00:00:40,910 --> 00:00:38,700
and if you're watching our live webcast

18
00:00:43,610 --> 00:00:40,920
you can submit questions via the YouTube

19
00:00:46,130 --> 00:00:43,620
chat and we'll take some of those later

20
00:00:47,990 --> 00:00:46,140
on and so to start us off our first

21
00:00:50,209 --> 00:00:48,000
speaker is a research scientist at the

22
00:00:52,850 --> 00:00:50,219
NASA exoplanet science Institute at

23
00:00:55,970 --> 00:00:52,860
Caltech where she searches for discovers

24
00:00:57,500 --> 00:00:55,980
and characterizes extrasolar planets she

25
00:00:59,330 --> 00:00:57,510
also keeps track of all the known

26
00:01:02,360 --> 00:00:59,340
exoplanets and their properties in

27
00:01:11,760 --> 00:01:02,370
nasa's exoplanet archive please welcome

28
00:01:15,130 --> 00:01:13,539
hi everybody

29
00:01:17,170 --> 00:01:15,140
I'm very excited to be here tonight to

30
00:01:19,480 --> 00:01:17,180
talk with you about the Golden Age of

31
00:01:21,100 --> 00:01:19,490
exoplanet exploration and not just

32
00:01:23,649 --> 00:01:21,110
because I believe it's the Golden Age of

33
00:01:25,120 --> 00:01:23,659
exoplanet exploration for everybody but

34
00:01:28,440 --> 00:01:25,130
that it really is genuinely for me

35
00:01:30,460 --> 00:01:28,450
personally let me tell you a story

36
00:01:32,740 --> 00:01:30,470
fifteen years ago when I was a

37
00:01:35,109 --> 00:01:32,750
fresh-faced young grad student looking

38
00:01:36,520 --> 00:01:35,119

for a research project exoplanets had

39
00:01:39,639 --> 00:01:36,530
just started to capture the public

40
00:01:42,450 --> 00:01:39,649
imagination and I thought now there's an

41
00:01:45,279 --> 00:01:42,460
exciting idea I could hunt for planets

42
00:01:47,950 --> 00:01:45,289
so I set out on a quest I would find an

43
00:01:49,570 --> 00:01:47,960
exoplanet the first two years of my

44
00:01:53,230 --> 00:01:49,580
thesis I did a survey from the South

45
00:01:54,790 --> 00:01:53,240
Pole in Antarctica no exoplanets the

46
00:01:56,380 --> 00:01:54,800
second two years of my thesis I did a

47
00:01:57,160 --> 00:01:56,390
survey from the countryside in New South

48
00:02:00,279 --> 00:01:57,170
Wales Australia

49
00:02:03,910 --> 00:02:00,289
no exoplanets I got a thesis but no

50
00:02:05,919 --> 00:02:03,920
exoplanets I moved to the US and did a

51
00:02:08,199 --> 00:02:05,929
research position at Harvard University

52
00:02:10,540 --> 00:02:08,209
I spent two years using the nasa EPOXI

53
00:02:13,270 --> 00:02:10,550
mission to look for exoplanets no

54
00:02:14,920 --> 00:02:13,280
exoplanets so at this point I had looked

55
00:02:17,380 --> 00:02:14,930
at literally hundreds of thousands of

56
00:02:18,690 --> 00:02:17,390
stars looking for exoplanets and I was

57
00:02:21,310 --> 00:02:18,700
starting to feel a little discouraged

58
00:02:23,289 --> 00:02:21,320
but then I got the email that would

59
00:02:25,569 --> 00:02:23,299
change my life which was an invitation

60
00:02:28,390 --> 00:02:25,579
to join NASA's spectacularly successful

61
00:02:30,940 --> 00:02:28,400
and sadly very recently departed Kepler

62
00:02:32,680 --> 00:02:30,950
mission now with Kepler I was lucky

63
00:02:35,229 --> 00:02:32,690

enough to find thousands of exoplanets

64
00:02:36,970 --> 00:02:35,239
so for me the quest was finally realized

65
00:02:38,770 --> 00:02:36,980
and it truly is the golden age of

66
00:02:40,870 --> 00:02:38,780
exoplanet exploration because those

67
00:02:43,030 --> 00:02:40,880
thousands of exoplanets have turned out

68
00:02:44,560 --> 00:02:43,040
to be so much more incredibly diverse

69
00:02:47,400 --> 00:02:44,570
and interesting than we even could have

70
00:02:50,949 --> 00:02:47,410
imagined so let's go on that journey

71
00:02:55,479 --> 00:02:50,959
okay so let's start a step back for a

72
00:02:57,250 --> 00:02:55,489
second what is an exoplanet okay this is

73
00:02:59,699 --> 00:02:57,260
a graphic of our solar system not to

74
00:03:05,880 --> 00:03:02,910
we have one star in our solar system the

75
00:03:09,869 --> 00:03:05,890
Sun our Sun is a star we have eight

76
00:03:11,610 --> 00:03:09,879
planets boo hiss Shh I know I know

77
00:03:13,020 --> 00:03:11,620
tomorrow night Mike Brown is talking all

78
00:03:15,569 --> 00:03:13,030
about why he killed a Pluto down at

79
00:03:19,080 --> 00:03:15,579
Caltech so go see that talk okay we have

80
00:03:20,819 --> 00:03:19,090
eight planets we also have dwarf planets

81
00:03:22,649 --> 00:03:20,829
which is this new bucket that Pluto and

82
00:03:24,300 --> 00:03:22,659
his friends all fell into place Edna

83
00:03:27,899 --> 00:03:24,310
Makemake Eris and Sarah's they're all

84
00:03:29,879 --> 00:03:27,909
dwarf planets we also have minor planets

85
00:03:31,020 --> 00:03:29,889
which is basically everything in the

86
00:03:32,520 --> 00:03:31,030
solar system that's bigger than a grain

87
00:03:36,509 --> 00:03:32,530
of dust that we've managed to catalog

88
00:03:40,559 --> 00:03:36,519

and we have found over 700,000 of those

89
00:03:43,259 --> 00:03:40,569
the solar system is a dusty place but

90
00:03:46,470 --> 00:03:43,269
what our exoplanets exoplanets are

91
00:03:48,569 --> 00:03:46,480
planets around other stars for thousands

92
00:03:51,420 --> 00:03:48,579
of years people had thought about the

93
00:03:53,729 --> 00:03:51,430
idea of exoplanets our Sun is a star our

94
00:03:58,740 --> 00:03:53,739
sky is full of stars do those stars have

95
00:04:00,089 --> 00:03:58,750
planets around them too so over 2,000

96
00:04:01,050 --> 00:04:00,099
years ago the Greek philosophers were

97
00:04:03,059 --> 00:04:01,060
talking about this

98
00:04:04,530 --> 00:04:03,069
they were theorizing whether earth was

99
00:04:06,839 --> 00:04:04,540
singular or plural were there other

100
00:04:08,580 --> 00:04:06,849
Earth's out there and they were talking

101
00:04:09,750 --> 00:04:08,590
about it in a very hypothetical sense

102
00:04:11,849 --> 00:04:09,760
kind of the way we think about

103
00:04:13,710 --> 00:04:11,859
multiverses today like a really cool

104
00:04:15,960 --> 00:04:13,720
thought experiment but like no chance of

105
00:04:17,099 --> 00:04:15,970
ever really testing it but they thought

106
00:04:18,390 --> 00:04:17,109
it was fun to talk about they did the

107
00:04:19,140 --> 00:04:18,400
Greek philosopher thing of just sitting

108
00:04:20,789 --> 00:04:19,150
around and chatting

109
00:04:24,270 --> 00:04:20,799
do you think that there's one earth or

110
00:04:27,089 --> 00:04:24,280
multiple earths so a few thousand years

111
00:04:29,339 --> 00:04:27,099
go by and we come up to the Renaissance

112
00:04:31,170 --> 00:04:29,349
the Renaissance was a good time to be a

113
00:04:33,980 --> 00:04:31,180

scientist was a bad time to be a

114
00:04:36,290 --> 00:04:33,990
scientist who said this

115
00:04:38,150 --> 00:04:36,300
there are countless sons and countless

116
00:04:40,010 --> 00:04:38,160
Earth's all rotating around to their

117
00:04:41,659 --> 00:04:40,020
sons in exactly the same way as the

118
00:04:43,279 --> 00:04:41,669
seven planets of our solar system this

119
00:04:44,420 --> 00:04:43,289
was before Neptune and then Pluto and

120
00:04:46,909 --> 00:04:44,430
they're not Pluto again so they were

121
00:04:48,710 --> 00:04:46,919
seven so this was Jay Don Oh Bruno who

122
00:04:50,930 --> 00:04:48,720
was an Italian mathematician who was

123
00:04:52,219 --> 00:04:50,940
burned at the stake for saying this

124
00:04:53,480 --> 00:04:52,229
amongst other things he said a lot of

125
00:04:54,379 --> 00:04:53,490
very silly things about the church at

126
00:04:55,730 --> 00:04:54,389
the time when you shouldn't have said

127
00:04:56,870 --> 00:04:55,740
silly things about the church but this

128
00:04:58,580 --> 00:04:56,880
is one of the things he said that got

129
00:05:01,010 --> 00:04:58,590
him in hot water that there were planets

130
00:05:02,480 --> 00:05:01,020
going around other stars so one of the

131
00:05:05,059 --> 00:05:02,490
reasons I particularly want to bring up

132
00:05:07,879 --> 00:05:05,069
Bruno is he really articulated for the

133
00:05:08,839 --> 00:05:07,889
first time that we know of why we

134
00:05:10,279 --> 00:05:08,849
haven't found them yet we've been

135
00:05:12,020 --> 00:05:10,289
imagining them for thousands of years

136
00:05:14,180 --> 00:05:12,030
why haven't we found them yet because

137
00:05:15,950 --> 00:05:14,190
stars are really big and really bright

138
00:05:18,140 --> 00:05:15,960

and planets are really small and really

139
00:05:22,490 --> 00:05:18,150
dark it's incredibly hard to solve that

140
00:05:25,760 --> 00:05:22,500
problem so let's go forward another 400

141
00:05:28,279 --> 00:05:25,770
years or so and we get to 1950 52 - a

142
00:05:29,810 --> 00:05:28,289
man called Otto Struve and he comes up

143
00:05:33,080 --> 00:05:29,820
with an idea of how we might do this how

144
00:05:35,629 --> 00:05:33,090
we might detect these exit weapons so in

145
00:05:37,760 --> 00:05:35,639
1952 we already knew about binary stars

146
00:05:39,379 --> 00:05:37,770
so two stars going around each other

147
00:05:40,909 --> 00:05:39,389
orbiting each other and they can all be

148
00:05:42,140 --> 00:05:40,919
very close to each other binary stars

149
00:05:45,020 --> 00:05:42,150
can orbit each other in just a few hours

150
00:05:46,969 --> 00:05:45,030
or a few days if you look at the stars

151
00:05:48,320 --> 00:05:46,979
in the sky you can see them doing this

152
00:05:49,550 --> 00:05:48,330
they move towards you and move away they

153
00:05:50,839 --> 00:05:49,560
move toward you they move away as

154
00:05:54,709 --> 00:05:50,849
they're dancing around each other we

155
00:05:56,749 --> 00:05:54,719
knew that already and Otto said what if

156
00:05:58,700 --> 00:05:56,759
we take one of those stars out and put a

157
00:06:00,589 --> 00:05:58,710
planet there instead it would have to be

158
00:06:02,870 --> 00:06:00,599
a really big planet and we'd have to be

159
00:06:05,330 --> 00:06:02,880
very close to the star orbiting the star

160
00:06:06,320 --> 00:06:05,340
in only a few days but maybe if the

161
00:06:08,060 --> 00:06:06,330
planet was big enough and close enough

162
00:06:11,089 --> 00:06:08,070
we'd be able to see the motion of That

163
00:06:12,589 --> 00:06:11,099

star what he was proposing is the radial

164
00:06:15,469 --> 00:06:12,599
velocity method this is one of the ways

165
00:06:17,749 --> 00:06:15,479
we used to detect planets so here's this

166
00:06:20,089 --> 00:06:17,759
star in the middle of this exoplanet

167
00:06:21,860 --> 00:06:20,099
system and here is I'm still just

168
00:06:24,830 --> 00:06:21,870
getting used to this here is the planet

169
00:06:26,570 --> 00:06:24,840
going around so the star moves towards

170
00:06:28,189 --> 00:06:26,580
us at the moment and then wait a little

171
00:06:29,689 --> 00:06:28,199
bit and the Stars moving away from us

172
00:06:30,980 --> 00:06:29,699
again we can see this in the light curve

173
00:06:33,969 --> 00:06:30,990
of the star that the Stars moving

174
00:06:36,020 --> 00:06:33,979
towards us in away from us the thing is

175
00:06:38,570 --> 00:06:36,030
everybody at the time I can only imagine

176
00:06:40,850 --> 00:06:38,580
was like Auto that's crazy I assume his

177
00:06:42,769 --> 00:06:40,860
friends called him Auto the reason

178
00:06:45,230 --> 00:06:42,779
that's crazy is because until that point

179
00:06:46,700 --> 00:06:45,240
we only had one planetary system which

180
00:06:48,710 --> 00:06:46,710
was our solar system and I

181
00:06:50,720 --> 00:06:48,720
showed it to you we have rocky planets

182
00:06:52,670 --> 00:06:50,730
small rocky planets close to the Sun and

183
00:06:54,260 --> 00:06:52,680
big gas giants and ice giants further

184
00:06:56,270 --> 00:06:54,270
out that's what our solar system looks

185
00:06:58,160 --> 00:06:56,280
like so all our theories about how

186
00:07:00,110 --> 00:06:58,170
planet systems form and evolve and

187
00:07:02,300 --> 00:07:00,120
migrate we're geared towards reproducing

188
00:07:04,130 --> 00:07:02,310

our solar system if your simulation

189
00:07:06,560 --> 00:07:04,140
created a giant planet like Jupiter and

190
00:07:08,270 --> 00:07:06,570
then moved it right next to the Sun well

191
00:07:09,440 --> 00:07:08,280
you'd be like okay I've got a I've got

192
00:07:11,510 --> 00:07:09,450
something wrong I've got to go back to

193
00:07:12,890 --> 00:07:11,520
my calculation to try again so this idea

194
00:07:14,600 --> 00:07:12,900
that he had that we could detect these

195
00:07:20,290 --> 00:07:14,610
planets the idea that these planets

196
00:07:26,510 --> 00:07:24,470
let's fast forward 40 more years 1995

197
00:07:28,910 --> 00:07:26,520
the first exoplanet was finally found

198
00:07:29,930 --> 00:07:28,920
after thousands of years of wondering

199
00:07:31,700 --> 00:07:29,940
whether there were planets around other

200
00:07:34,400 --> 00:07:31,710
stars the first planet orbiting a star

201
00:07:36,410 --> 00:07:34,410
like our Sun was found and it was found

202
00:07:38,690 --> 00:07:36,420
using the radial velocity method which

203
00:07:40,340 --> 00:07:38,700
is an amazing thing so for 40 years this

204
00:07:42,440 --> 00:07:40,350
paper had like seven citations

205
00:07:45,370 --> 00:07:42,450
now it's had 700 because everyone's like

206
00:07:47,600 --> 00:07:45,380
oh he was right that's cool

207
00:07:49,520 --> 00:07:47,610
the other method I want to talk about

208
00:07:53,030 --> 00:07:49,530
because it's important for the rest of

209
00:07:55,040 --> 00:07:53,040
our talks is the transit method this is

210
00:07:56,540 --> 00:07:55,050
another way we use to define to find

211
00:07:58,820 --> 00:07:56,550
planets and it's the most successful one

212
00:08:00,590 --> 00:07:58,830
we've used so far so the transit method

213
00:08:03,230 --> 00:08:00,600

relies on the fact that if your planet

214
00:08:04,580 --> 00:08:03,240
system is lined up just right then the

215
00:08:06,890 --> 00:08:04,590
planet will go in front of the star that

216
00:08:08,540 --> 00:08:06,900
you're observing now we can't resolve

217
00:08:10,430 --> 00:08:08,550
this with our eyes we can't see your

218
00:08:11,810 --> 00:08:10,440
planet going in front of a star but if

219
00:08:13,660 --> 00:08:11,820
we're just measuring the brightness of

220
00:08:15,770 --> 00:08:13,670
That star over and over and over again

221
00:08:17,210 --> 00:08:15,780
occasionally when the planet comes in

222
00:08:18,830 --> 00:08:17,220
front there'll be a dip the star will

223
00:08:20,300 --> 00:08:18,840
look like it gets dimmer just for a

224
00:08:22,430 --> 00:08:20,310
little little while and then it'll get

225
00:08:24,440 --> 00:08:22,440
bright again and then sometime later

226
00:08:26,210 --> 00:08:24,450
it'll get dimmer again so if you were an

227
00:08:27,920 --> 00:08:26,220
alien civilization looking at our Sun

228
00:08:30,920 --> 00:08:27,930
and you were lined up just the right way

229
00:08:32,210 --> 00:08:30,930
every 365 days you would see a little

230
00:08:34,040 --> 00:08:32,220
dip and that would be Earth going in

231
00:08:35,750 --> 00:08:34,050
front of the Sun so this is the transit

232
00:08:37,310 --> 00:08:35,760
method so what we do is monitor the

233
00:08:38,780 --> 00:08:37,320
brightness of tens or hundreds of

234
00:08:41,440 --> 00:08:38,790
thousands of stars which is what I did

235
00:08:45,230 --> 00:08:41,450
during my thesis and look for these dips

236
00:08:47,980 --> 00:08:45,240
and with this transit method we've

237
00:08:50,450 --> 00:08:47,990
managed to find thousands of planets and

238
00:08:51,980 --> 00:08:50,460

they were nothing like we expected so as

239
00:08:53,840 --> 00:08:51,990
I said we were expecting to find our

240
00:08:55,570 --> 00:08:53,850
solar system that's all we knew and we

241
00:08:58,640 --> 00:08:55,580
went out there and we found anything but

242
00:08:59,199 --> 00:08:58,650
so what did we find the first kind of

243
00:09:00,790 --> 00:08:59,209
new interesting

244
00:09:02,650 --> 00:09:00,800
we found thing we found because it was

245
00:09:04,540 --> 00:09:02,660
the easiest thing to find with these hot

246
00:09:05,710 --> 00:09:04,550
Jupiters we call them hot Jupiters

247
00:09:07,059 --> 00:09:05,720
because they're jupiter-sized planets

248
00:09:08,980 --> 00:09:07,069
that are thousands of degrees and we

249
00:09:12,069 --> 00:09:08,990
have no imagination so they're called

250
00:09:15,189 --> 00:09:12,079
hot Jupiters and the first one we found

251
00:09:17,169 --> 00:09:15,199
was called 51 peg so what I'm going to

252
00:09:19,540 --> 00:09:17,179
show tonight are a series of the

253
00:09:21,549 --> 00:09:19,550
exoplanet exploration officers travel

254
00:09:22,989 --> 00:09:21,559
Bureau posters and I believe there are a

255
00:09:25,090 --> 00:09:22,999
bunch of these available for people to

256
00:09:26,439 --> 00:09:25,100
take tonight so this is also an

257
00:09:27,970 --> 00:09:26,449
advertisement for the excellent

258
00:09:30,699 --> 00:09:27,980
excellent graphic artists we have here

259
00:09:32,019 --> 00:09:30,709
at JPL so this was the first planet that

260
00:09:33,850 --> 00:09:32,029
was discovered the reason there are

261
00:09:35,889 --> 00:09:33,860
several other planets on this posters

262
00:09:37,449 --> 00:09:35,899
there's some debate over which planet

263
00:09:39,400 --> 00:09:37,459

was found first and by whom and when it

264
00:09:41,590 --> 00:09:39,410
was confirmed always the way everyone's

265
00:09:44,439 --> 00:09:41,600
racing but here's our first exoplanet

266
00:09:46,540 --> 00:09:44,449
and it was a hot Jupiter and so we found

267
00:09:48,340 --> 00:09:46,550
many more of these now and as I said

268
00:09:50,169 --> 00:09:48,350
they completely trashed our previous

269
00:09:52,199 --> 00:09:50,179
theories of how planets formed now we

270
00:09:54,609 --> 00:09:52,209
have to somehow form a giant planet

271
00:09:55,840 --> 00:09:54,619
probably far away from the star although

272
00:09:58,179 --> 00:09:55,850
there's a few theories that they might

273
00:10:00,340 --> 00:09:58,189
form right next to the star then we have

274
00:10:02,379 --> 00:10:00,350
to migrate it all the way in but not all

275
00:10:04,329 --> 00:10:02,389
the way into the star has to stop a few

276
00:10:05,919 --> 00:10:04,339
days away from the star and sit there

277
00:10:07,379 --> 00:10:05,929
for a while and there's all these

278
00:10:13,569 --> 00:10:07,389
interesting properties of these planets

279
00:10:15,220 --> 00:10:13,579
my favorite hd1 8 973 3 B is a is a

280
00:10:17,199 --> 00:10:15,230
really well study it's a really real

281
00:10:18,819 --> 00:10:17,209
really well study planet we've been able

282
00:10:20,590 --> 00:10:18,829
to measure the composition of its

283
00:10:22,660 --> 00:10:20,600
atmosphere and Carl will talk a little

284
00:10:24,369 --> 00:10:22,670
bit about how we do this we've been able

285
00:10:25,840 --> 00:10:24,379
to measure the wind speed in the

286
00:10:27,009 --> 00:10:25,850
atmosphere and we've been able to

287
00:10:29,559 --> 00:10:27,019
measure the temperature of the

288
00:10:31,389 --> 00:10:29,569

atmosphere so for this planet HD one

289
00:10:33,939 --> 00:10:31,399
eight nine seven three three B when I

290
00:10:36,639 --> 00:10:33,949
say it's hot it is so hot it is raining

291
00:10:39,369 --> 00:10:36,649
liquid glass sideways in the atmosphere

292
00:10:40,689 --> 00:10:39,379
of this planet so yes we're we're

293
00:10:44,949 --> 00:10:40,699
waiting for spring to come back to LA

294
00:10:47,470 --> 00:10:44,959
there they're already deep in summer all

295
00:10:49,359 --> 00:10:47,480
right we didn't just find big hot

296
00:10:51,309 --> 00:10:49,369
planets we found small hot planets as

297
00:10:53,169 --> 00:10:51,319
well this new class of planets that we

298
00:10:56,350 --> 00:10:53,179
call larval worlds these are planets

299
00:10:58,090 --> 00:10:56,360
which are rock little rocks but they're

300
00:10:59,439 --> 00:10:58,100
so close to their star again like these

301
00:11:01,239 --> 00:10:59,449
hot Jupiters that there are thousands of

302
00:11:04,780 --> 00:11:01,249
degrees so they're so hot that their

303
00:11:07,840 --> 00:11:04,790
surface is a molten lava world's the

304
00:11:09,819 --> 00:11:07,850
first one we found was kepler-10c and

305
00:11:12,470 --> 00:11:09,829
now I want to say it was B I want to say

306
00:11:15,230 --> 00:11:12,480
C kepler-10c and which was the first

307
00:11:17,569 --> 00:11:15,240
sighs planet we found so this one 55

308
00:11:20,449 --> 00:11:17,579
Cancri E is actually twice the size of

309
00:11:21,650 --> 00:11:20,459
Earth which leads me to my second big

310
00:11:25,879 --> 00:11:21,660
class of interesting planets that we

311
00:11:27,379 --> 00:11:25,889
found which is super Earths because we

312
00:11:31,370 --> 00:11:27,389
want to get funding so we call them

313
00:11:32,750 --> 00:11:31,380

super whatsit super earth so here I'm

314
00:11:34,970 --> 00:11:32,760
going to show all the planets in our

315
00:11:39,110 --> 00:11:34,980
solar system to scale so we've got

316
00:11:41,660 --> 00:11:39,120
Jupiter Saturn Uranus Neptune then we

317
00:11:44,030 --> 00:11:41,670
have the inner planets Venus Mars

318
00:11:45,590 --> 00:11:44,040
Mercury okay so you can see already

319
00:11:47,240 --> 00:11:45,600
there's an interesting structure just in

320
00:11:49,250 --> 00:11:47,250
our solar system we have these four

321
00:11:50,540 --> 00:11:49,260
small planets and we have a big jump to

322
00:11:53,930 --> 00:11:50,550
the ice giants and then we have another

323
00:11:56,240 --> 00:11:53,940
big jump to the gas giants this is where

324
00:11:58,579 --> 00:11:56,250
55 Cancri EU eyes it's two times the

325
00:12:00,500 --> 00:11:58,589
size of the earth and actually when we

326
00:12:02,389 --> 00:12:00,510
look with the Kepler telescope these

327
00:12:03,939 --> 00:12:02,399
super Earths or sub Neptune's depending

328
00:12:07,129 --> 00:12:03,949
on who you're trying to get funding from

329
00:12:09,139 --> 00:12:07,139
are the most common kind of planet we

330
00:12:10,670 --> 00:12:09,149
found they seem to be everywhere and

331
00:12:11,870 --> 00:12:10,680
that's a mystery because in our solar

332
00:12:13,639 --> 00:12:11,880
system we have eight planets we have

333
00:12:15,939 --> 00:12:13,649
nothing in the size range but these seem

334
00:12:18,680 --> 00:12:15,949
to be the most common planets out there

335
00:12:21,290 --> 00:12:18,690
now the reason it's a fun mystery for

336
00:12:25,100 --> 00:12:21,300
the rest of us is what are they made of

337
00:12:27,590 --> 00:12:25,110
are they rocks that got big are they ice

338
00:12:29,180 --> 00:12:27,600

giants that got small are they something

339
00:12:30,920 --> 00:12:29,190
we don't have in our solar system like

340
00:12:32,689 --> 00:12:30,930
Waterworld some of them seem to have the

341
00:12:34,460 --> 00:12:32,699
density of the same density as water is

342
00:12:37,340 --> 00:12:34,470
it just a big glob of water really hot

343
00:12:39,230 --> 00:12:37,350
water so it's a mystery and it's really

344
00:12:40,490 --> 00:12:39,240
exciting because we love mysteries so we

345
00:12:45,110 --> 00:12:40,500
have this whole new class of planets we

346
00:12:46,759 --> 00:12:45,120
found called super Earths okay so we

347
00:12:48,650 --> 00:12:46,769
haven't just found diverse kinds of

348
00:12:51,379 --> 00:12:48,660
planets we've also found them in very

349
00:12:53,439 --> 00:12:51,389
diverse situations so I stressed at the

350
00:12:56,030 --> 00:12:53,449
start that our solar system has one star

351
00:12:59,960 --> 00:12:56,040
now who here has seen the original Star

352
00:13:04,009 --> 00:12:59,970
Wars yeah yeah it seems like that kind

353
00:13:05,900 --> 00:13:04,019
of crowd so in in in a new hope you have

354
00:13:09,019 --> 00:13:05,910
Luke standing on the surface of Tatooine

355
00:13:11,809 --> 00:13:09,029
watching the Sun set how many stars are

356
00:13:14,090 --> 00:13:11,819
there two so George Lucas had this

357
00:13:15,470 --> 00:13:14,100
vision like 40 years ago that there

358
00:13:17,030 --> 00:13:15,480
could be planets around binary stars

359
00:13:19,490 --> 00:13:17,040
this was before we even knew there were

360
00:13:22,660 --> 00:13:19,500
planets and we found it we found

361
00:13:24,550 --> 00:13:22,670
Tatooine we call it kepler 16b but

362
00:13:26,590 --> 00:13:24,560
it's a planet that orbits two stars and

363
00:13:27,790 --> 00:13:26,600

actually if you do the correction if you

364
00:13:29,530 --> 00:13:27,800
do the color correction right they're

365
00:13:31,810 --> 00:13:29,540
the same color is the two stars in

366
00:13:33,490 --> 00:13:31,820
George Lucas's imagining of this the

367
00:13:34,810 --> 00:13:33,500
sizes aren't quite right relative to

368
00:13:38,620 --> 00:13:34,820
each other but the colors are right so

369
00:13:39,910 --> 00:13:38,630
then he did really well and so far we

370
00:13:42,400 --> 00:13:39,920
found really a dozen of these

371
00:13:44,290 --> 00:13:42,410
circumbinary planets which is really

372
00:13:46,330 --> 00:13:44,300
interesting because half the stars we

373
00:13:47,770 --> 00:13:46,340
see in the sky are binary systems so

374
00:13:49,300 --> 00:13:47,780
knowing that they can have planets

375
00:13:51,010 --> 00:13:49,310
around them that you can have stable

376
00:13:52,870 --> 00:13:51,020
planetary orbits around binary systems

377
00:13:54,250 --> 00:13:52,880
really opens up the possibilities of

378
00:13:57,790 --> 00:13:54,260
where we might be finding these planets

379
00:13:59,560 --> 00:13:57,800
so that was really exciting another

380
00:14:01,810 --> 00:13:59,570
thing we found that's really different

381
00:14:04,450 --> 00:14:01,820
from our solar system is really crowded

382
00:14:06,340 --> 00:14:04,460
planetary systems so in our solar system

383
00:14:09,310 --> 00:14:06,350
mercury is the closest planet to our Sun

384
00:14:10,900 --> 00:14:09,320
it has a period or a year of 88 days it

385
00:14:13,330 --> 00:14:10,910
takes 88 days for Makery to go all the

386
00:14:14,800 --> 00:14:13,340
way around and come back this what I'm

387
00:14:17,140 --> 00:14:14,810
about to show you is a system called k2

388
00:14:19,060 --> 00:14:17,150

138 which was found by citizen

389
00:14:22,480 --> 00:14:19,070
scientists in a project that I helped to

390
00:14:25,960 --> 00:14:22,490
start it has six planets that all have

391
00:14:27,940 --> 00:14:25,970
periods of 42 days or shorter so mercury

392
00:14:29,920 --> 00:14:27,950
is out here 88 there are six planets

393
00:14:33,840 --> 00:14:29,930
halfway between that distance and that

394
00:14:37,420 --> 00:14:33,850
star that's really incredible ecosystem

395
00:14:38,980 --> 00:14:37,430
is stable is really fascinating all the

396
00:14:40,750 --> 00:14:38,990
planets are in resonance with each other

397
00:14:43,120 --> 00:14:40,760
alright the five inter planets are all

398
00:14:44,860 --> 00:14:43,130
in resonance with each other so that

399
00:14:47,470 --> 00:14:44,870
means that their periods are related to

400
00:14:49,570 --> 00:14:47,480
each other by multiple integers so for

401
00:14:50,770 --> 00:14:49,580
every three times the inner planet goes

402
00:14:53,050 --> 00:14:50,780
around to the next planet goes around

403
00:14:54,310 --> 00:14:53,060
twice for every three times that planet

404
00:14:56,950 --> 00:14:54,320
goes around to the next planet goes

405
00:14:59,200 --> 00:14:56,960
around twice and so on 3 2 2 3 2 2 3 2 2

406
00:15:00,970 --> 00:14:59,210
all the way out through that system what

407
00:15:03,280 --> 00:15:00,980
that means is the system is musical

408
00:15:04,630 --> 00:15:03,290
because because resonances are musical

409
00:15:12,900 --> 00:15:04,640
intervals so let's listen to what the

410
00:15:17,410 --> 00:15:14,980
so every time one of the planets

411
00:15:18,940 --> 00:15:17,420
transits it makes a bawling sound and

412
00:15:20,319 --> 00:15:18,950
the bong is related to the period the

413
00:15:22,269 --> 00:15:20,329

high-pitched one is the fastest-moving

414
00:15:26,350 --> 00:15:22,279
planet and the low-pitched one is the

415
00:15:28,300 --> 00:15:26,360
slowest moving planet the reason it

416
00:15:30,730 --> 00:15:28,310
sounds good is the three to two ratio is

417
00:15:32,519 --> 00:15:30,740
the perfect fifth interval which if you

418
00:15:35,290 --> 00:15:32,529
if you're into musical theory is a very

419
00:15:37,300 --> 00:15:35,300
standard tonic chord in the western

420
00:15:40,370 --> 00:15:37,310
music theory

421
00:15:42,260 --> 00:15:40,380
[Music]

422
00:15:44,310 --> 00:15:42,270
so this is just your moment of sin in

423
00:15:45,960 --> 00:15:44,320
the middle of my talk

424
00:15:47,759 --> 00:15:45,970
it just relax and listen to the music

425
00:15:50,040 --> 00:15:47,769
and think about the fact that these

426
00:15:52,110 --> 00:15:50,050
planets these planets are actually all

427
00:15:54,480 --> 00:15:52,120
only in less than 13 days the sixth

428
00:15:56,280 --> 00:15:54,490
planet is way out there at 42 days this

429
00:15:58,139 --> 00:15:56,290
is five planets in periods 13 days and

430
00:15:59,850 --> 00:15:58,149
shorter so I want to acknowledge that

431
00:16:02,280 --> 00:15:59,860
this animation was made by Matt Russo of

432
00:16:04,019 --> 00:16:02,290
system sounds he has made a bunch of a

433
00:16:05,550 --> 00:16:04,029
very awesome sonification of other

434
00:16:07,290 --> 00:16:05,560
exoplanet systems and solar system

435
00:16:12,449 --> 00:16:07,300
objects as well so go to system sounds

436
00:16:14,759 --> 00:16:12,459
and check that out okay so some of the

437
00:16:16,439 --> 00:16:14,769
planets in the k2 138 system are

438
00:16:18,329 --> 00:16:16,449

starting to get exciting for another

439
00:16:19,650 --> 00:16:18,339
reason not just because they're in

440
00:16:20,189 --> 00:16:19,660
compact systems and not just because

441
00:16:22,860 --> 00:16:20,199
there isn't it

442
00:16:25,220 --> 00:16:22,870
but because they're small one of our

443
00:16:27,240 --> 00:16:25,230
goals is to find planets like the earth

444
00:16:28,620 --> 00:16:27,250
so what do I mean by planets like the

445
00:16:29,999 --> 00:16:28,630
earth we have to be careful here there's

446
00:16:33,930 --> 00:16:30,009
lots of different ways a planet could be

447
00:16:35,309 --> 00:16:33,940
like the earth one is the size so we

448
00:16:37,710 --> 00:16:35,319
think planets the size of Earth are

449
00:16:39,150 --> 00:16:37,720
probably rocky if they were made of gas

450
00:16:41,160 --> 00:16:39,160
there was not enough matter that's not a

451
00:16:43,680 --> 00:16:41,170
mass to keep them as a ball so they

452
00:16:44,819 --> 00:16:43,690
probably need to be made of rock we need

453
00:16:46,559 --> 00:16:44,829
them to be the right temperature for

454
00:16:48,420 --> 00:16:46,569
liquid water and we could have a whole

455
00:16:50,970 --> 00:16:48,430
nother talk about what we mean by

456
00:16:52,439 --> 00:16:50,980
habitability and where life to be but

457
00:16:54,210 --> 00:16:52,449
the only place we know where life is is

458
00:16:56,100 --> 00:16:54,220
earth and all life on earth needs liquid

459
00:16:57,720 --> 00:16:56,110
water so we make that a criteria the

460
00:17:00,600 --> 00:16:57,730
temperature needs to be right for liquid

461
00:17:02,370 --> 00:17:00,610
water on the surface the other third

462
00:17:03,840 --> 00:17:02,380
criteria is that it's orbiting a star

463
00:17:05,280 --> 00:17:03,850

like the Sun and I'll explain a little

464
00:17:07,919 --> 00:17:05,290
bit more about why that's important in a

465
00:17:10,049 --> 00:17:07,929
minute but we have found another very

466
00:17:11,429 --> 00:17:10,059
interesting compact system of these

467
00:17:12,750 --> 00:17:11,439
small planets called Trappist one

468
00:17:14,939 --> 00:17:12,760
hopefully you've heard of Travis one

469
00:17:16,710 --> 00:17:14,949
it's one of our incredibly exciting rich

470
00:17:18,630 --> 00:17:16,720
planetary systems that we've found it

471
00:17:21,419 --> 00:17:18,640
has three planets that are the right

472
00:17:24,990 --> 00:17:21,429
size and the right temperature so that's

473
00:17:26,669 --> 00:17:25,000
really exciting it's also was discovered

474
00:17:29,010 --> 00:17:26,679
in part by the spectacular NASA

475
00:17:30,780 --> 00:17:29,020
telescope Spitzer and k2 k2 was a

476
00:17:32,549 --> 00:17:30,790
successor to the Kepler mission so we're

477
00:17:34,620 --> 00:17:32,559
particularly proud of it

478
00:17:36,960 --> 00:17:34,630
but this is starting to get towards the

479
00:17:38,549 --> 00:17:36,970
thing we're really asking about the

480
00:17:40,620 --> 00:17:38,559
whole purpose of the NASA Kepler mission

481
00:17:42,810 --> 00:17:40,630
was to measure how common are planets

482
00:17:44,100 --> 00:17:42,820
like the earth the right size the right

483
00:17:47,640 --> 00:17:44,110
temperature around the right kind of

484
00:17:48,990 --> 00:17:47,650
star and what we found is we think we

485
00:17:50,299 --> 00:17:49,000
had to make some guesses but we think

486
00:17:55,370 --> 00:17:50,309
that these planets are incredibly common

487
00:18:02,940 --> 00:18:00,600
look I lost my thing there we go okay so

488
00:18:06,090 --> 00:18:02,950

we have found seven seven planets to the

489
00:18:08,940 --> 00:18:06,100
right size and the right temperature so

490
00:18:10,440 --> 00:18:08,950
they are Proxima Centauri B so hopefully

491
00:18:13,440 --> 00:18:10,450
you've heard of Proxima Centauri it's

492
00:18:15,420 --> 00:18:13,450
the closest star to our solar system so

493
00:18:17,820 --> 00:18:15,430
there's a our closest star system has

494
00:18:19,530 --> 00:18:17,830
three stars in it Alpha Centauri a Alpha

495
00:18:21,930 --> 00:18:19,540
Centauri B and Proxima Centauri

496
00:18:23,280 --> 00:18:21,940
and we found a rocky planet of the right

497
00:18:26,310 --> 00:18:23,290
temperature around Proxima Centauri

498
00:18:27,960 --> 00:18:26,320
that's really exciting that's that's you

499
00:18:32,190 --> 00:18:27,970
know 3.8 light-years away

500
00:18:35,310 --> 00:18:32,200
that's milliseconds or 3.8 is but it's

501
00:18:36,810 --> 00:18:35,320
very small here are the three Trappist

502
00:18:38,370 --> 00:18:36,820
planets that I just talked about trapars

503
00:18:40,620 --> 00:18:38,380
two one eat wrappers on F and strapless

504
00:18:42,300 --> 00:18:40,630
one G or rocky at the right temperature

505
00:18:43,950 --> 00:18:42,310
and then there are three more planets

506
00:18:47,160 --> 00:18:43,960
that we found with radial velocity GJ

507
00:18:49,560 --> 00:18:47,170
667cc or transit Kappa for four to be

508
00:18:51,810 --> 00:18:49,570
and kepler 186f which are also in the

509
00:18:54,180 --> 00:18:51,820
size range in temperature range the

510
00:18:56,310 --> 00:18:54,190
problem with all of these planets is the

511
00:18:58,020 --> 00:18:56,320
kind of star that they orbit so remember

512
00:19:01,260 --> 00:18:58,030
I said they need to orbit stars like the

513
00:19:03,570 --> 00:19:01,270

Sun all seven of these planets orbit are

514
00:19:06,360 --> 00:19:03,580
much smaller much cooler kind of star

515
00:19:08,640 --> 00:19:06,370
called an M dwarf so our Sun is just a

516
00:19:10,170 --> 00:19:08,650
boring middle-aged yellow G star this is

517
00:19:13,590 --> 00:19:10,180
how astronomers classify stars with

518
00:19:15,090 --> 00:19:13,600
letters so these are all M stars so that

519
00:19:18,120 --> 00:19:15,100
most of the stars in the galaxies are

520
00:19:20,310 --> 00:19:18,130
actually M stars 75% of the stars are M

521
00:19:21,300 --> 00:19:20,320
stars or M dwarfs or red dwarfs there's

522
00:19:24,780 --> 00:19:21,310
another thing you might have heard them

523
00:19:26,910 --> 00:19:24,790
called the problem with M dwarfs is that

524
00:19:29,760 --> 00:19:26,920
relative to the Sun they put out much

525
00:19:31,410 --> 00:19:29,770
more of their energy in UV radiation so

526
00:19:33,540 --> 00:19:31,420
UV radiation is the thing that here on

527
00:19:35,760 --> 00:19:33,550
earth will give you sunburn or feel

528
00:19:38,670 --> 00:19:35,770
really unlucky cancer and that's because

529
00:19:42,000 --> 00:19:38,680
the high energy high high frequency

530
00:19:44,760 --> 00:19:42,010
radiation mutates your DNA and in fact

531
00:19:47,040 --> 00:19:44,770
cleanrooms around the world use UV light

532
00:19:49,380 --> 00:19:47,050
to sterilize things to make sure there's

533
00:19:50,820 --> 00:19:49,390
no life so we found all these rocky

534
00:19:52,740 --> 00:19:50,830
planets at the right temperature but we

535
00:19:54,600 --> 00:19:52,750
don't know they could all be completely

536
00:19:57,060 --> 00:19:54,610
sterilized by the radiation from their M

537
00:19:58,740 --> 00:19:57,070
stars so how many planets have we found

538
00:20:00,180 --> 00:19:58,750

that are truly like the earth that are

539
00:20:03,150 --> 00:20:00,190
the right size at the right temperature

540
00:20:05,850 --> 00:20:03,160
around stars like the Sun none yeah

541
00:20:07,770 --> 00:20:05,860
ah but as I said it's not because we

542
00:20:09,300 --> 00:20:07,780
don't think they're common if we make

543
00:20:10,650 --> 00:20:09,310
some extrapolations from the Kepler data

544
00:20:12,780 --> 00:20:10,660
we think that they're actually quite

545
00:20:14,130 --> 00:20:12,790
common and there could be tens or

546
00:20:15,830 --> 00:20:14,140
hundreds of millions of these in the

547
00:20:18,630 --> 00:20:15,840
galaxy

548
00:20:20,460 --> 00:20:18,640
the problem is they're still too small

549
00:20:21,920 --> 00:20:20,470
and too far away from their star and the

550
00:20:24,090 --> 00:20:21,930
stars that they orbit are too far away

551
00:20:26,160 --> 00:20:24,100
so we're kind of stuck at this point

552
00:20:27,510 --> 00:20:26,170
again at this precipice where our

553
00:20:29,130 --> 00:20:27,520
imaginations have gotten ahead of

554
00:20:30,900 --> 00:20:29,140
ourselves we can't we don't have the

555
00:20:32,010 --> 00:20:30,910
technology to realize our dreams and

556
00:20:34,230 --> 00:20:32,020
find these things that we're thinking

557
00:20:35,670 --> 00:20:34,240
about like the same situations the

558
00:20:37,280 --> 00:20:35,680
Greeks are in 2,000 years ago they had

559
00:20:39,510 --> 00:20:37,290
dreams but they didn't know how to do it

560
00:20:41,370 --> 00:20:39,520
but what we want to do is take these

561
00:20:44,010 --> 00:20:41,380
realizations these these illustrations

562
00:20:45,810 --> 00:20:44,020
these artists concepts and turn them

563
00:20:49,800 --> 00:20:45,820

into real observations of real planets

564
00:20:51,900 --> 00:20:49,810
but this time we have a plan so this is

565
00:20:54,210 --> 00:20:51,910
our NASA exoplanet mission roadmap or

566
00:20:58,260 --> 00:20:54,220
our exoplanet missions swoop as we call

567
00:20:59,460 --> 00:20:58,270
it we're about here so we had to say

568
00:21:01,290 --> 00:20:59,470
goodbye to the Kepler mission recently

569
00:21:02,700 --> 00:21:01,300
the test mission which I didn't get a

570
00:21:04,200 --> 00:21:02,710
chance to talk about but is our new

571
00:21:06,120 --> 00:21:04,210
planet finder we launched last year

572
00:21:08,190 --> 00:21:06,130
already finding planets very exciting

573
00:21:10,710 --> 00:21:08,200
the James Webb telescope is just around

574
00:21:12,000 --> 00:21:10,720
the corner and then we have more

575
00:21:14,370 --> 00:21:12,010
technology in the future that we're

576
00:21:16,140 --> 00:21:14,380
building towards now and I'm going to

577
00:21:17,970 --> 00:21:16,150
let my colleague Kyle tell you about how

578
00:21:19,140 --> 00:21:17,980
we're going to turn our dreams into

579
00:21:21,780 --> 00:21:19,150
reality how we're gonna go from

580
00:21:23,050 --> 00:21:21,790
imagination to real observations so

581
00:21:31,780 --> 00:21:23,060
thank you very much

582
00:21:35,500 --> 00:21:31,790
[Applause]

583
00:21:37,990 --> 00:21:35,510
thanks Jesse SETI stuff well now that

584
00:21:39,430 --> 00:21:38,000
you've heard a bit about the kinds of

585
00:21:41,200 --> 00:21:39,440
exoplanets that scientists are

586
00:21:42,550 --> 00:21:41,210
discovering out there our next speaker

587
00:21:45,550 --> 00:21:42,560
as Jesse mentioned will shed some light

588
00:21:47,770 --> 00:21:45,560

on what it takes to actually find and

589
00:21:50,650 --> 00:21:47,780
study them and coming up right after

590
00:21:52,330 --> 00:21:50,660
that my colleague philia will show you a

591
00:21:54,220 --> 00:21:52,340
fun tool that we've developed for

592
00:21:55,720 --> 00:21:54,230
imagining what it might actually look

593
00:21:58,270 --> 00:21:55,730
like if you could stand on the surfaces

594
00:22:00,280 --> 00:21:58,280
of some of these planets but up first

595
00:22:02,800 --> 00:22:00,290
our next speaker is the chief scientist

596
00:22:05,170 --> 00:22:02,810
in nasa's exoplanet exploration program

597
00:22:07,390 --> 00:22:05,180
office here at JPL he acts as a

598
00:22:08,950 --> 00:22:07,400
principal adviser to nasa leadership in

599
00:22:10,810 --> 00:22:08,960
the development and operation of

600
00:22:14,050 --> 00:22:10,820
exoplanet space missions like some of

601
00:22:16,150 --> 00:22:14,060
these he has extensive experience in

602
00:22:18,310 --> 00:22:16,160
studies of exoplanet formation and

603
00:22:21,340 --> 00:22:18,320
concepts for missions that could

604
00:22:23,360 --> 00:22:21,350
directly image some exoplanets so please

605
00:22:30,650 --> 00:22:23,370
welcome dr. Karl staple felt

606
00:22:34,610 --> 00:22:32,900
hey good evening everyone it's really

607
00:22:36,320 --> 00:22:34,620
great to be here because I have been in

608
00:22:38,900 --> 00:22:36,330
this audience so many times it's my

609
00:22:42,380 --> 00:22:38,910
first time up on the stage as part of

610
00:22:45,230 --> 00:22:42,390
the presentation so I've been at JPL for

611
00:22:47,900 --> 00:22:45,240
quite a few years now but I started out

612
00:22:51,740 --> 00:22:47,910
as a grad student down at Cal Tech with

613
00:22:53,570 --> 00:22:51,750

a summer job here in 1985 and that was a

614
00:22:55,130 --> 00:22:53,580
time when we did not have exoplanets I

615
00:22:57,410 --> 00:22:55,140
didn't have the opportunity like Jesse

616
00:22:59,240 --> 00:22:57,420
to not find planets in my thesis because

617
00:23:01,040 --> 00:22:59,250
nobody was finding them we weren't even

618
00:23:03,950 --> 00:23:01,050
looking really but what we did have

619
00:23:05,780 --> 00:23:03,960
happening at that stage of astronomy is

620
00:23:08,450 --> 00:23:05,790
we had found the first evidence for

621
00:23:10,850 --> 00:23:08,460
clouds of dust and gas orbiting young

622
00:23:13,400 --> 00:23:10,860
stars these orbit like in a flat pancake

623
00:23:15,290 --> 00:23:13,410
like shape and theory had told us for a

624
00:23:16,940 --> 00:23:15,300
long time that these would be the likely

625
00:23:19,370 --> 00:23:16,950
environments where a planetary system

626
00:23:21,800 --> 00:23:19,380
could form so we were starting to see

627
00:23:23,660 --> 00:23:21,810
that maybe if the formation of them the

628
00:23:25,430 --> 00:23:23,670
conditions were widespread for that

629
00:23:27,410 --> 00:23:25,440
planets would be widespread too so I

630
00:23:29,540 --> 00:23:27,420
kind of had a feeling that there was

631
00:23:31,550 --> 00:23:29,550
going to be some real mileage in this

632
00:23:34,160 --> 00:23:31,560
field coming up in the future

633
00:23:36,440 --> 00:23:34,170
so fast forward from that grad student

634
00:23:38,390 --> 00:23:36,450
now I've got a chance to really direct

635
00:23:39,860 --> 00:23:38,400
what NASA is doing along with my

636
00:23:42,170 --> 00:23:39,870
colleagues in the exoplanet program

637
00:23:44,720 --> 00:23:42,180
office and that's really exciting

638
00:23:46,580 --> 00:23:44,730

so Jesse's told you about how we've

639
00:23:48,170 --> 00:23:46,590
counted up large numbers of planets

640
00:23:50,110 --> 00:23:48,180
we've been able to measure their sizes

641
00:23:53,900 --> 00:23:50,120
with missions like the Kepler telescope

642
00:23:55,880 --> 00:23:53,910
so the thing that we want to be able to

643
00:23:58,040 --> 00:23:55,890
do next is go to understanding what

644
00:23:59,780 --> 00:23:58,050
these planets are made of how similar

645
00:24:02,360 --> 00:23:59,790
are they to the earth in their

646
00:24:04,430 --> 00:24:02,370
conditions and in terms of their

647
00:24:06,440 --> 00:24:04,440
temperatures and their composition so

648
00:24:08,330 --> 00:24:06,450
I'm here to tell you about what our

649
00:24:10,910 --> 00:24:08,340
plans are for being able to do that and

650
00:24:13,160 --> 00:24:10,920
in particular for small planets like the

651
00:24:14,630 --> 00:24:13,170
size of the earth the hot Jupiters have

652
00:24:16,940 --> 00:24:14,640
been very easy to find they're

653
00:24:18,620 --> 00:24:16,950
fascinating but even more fascinating is

654
00:24:20,960 --> 00:24:18,630
to know how common are planets like the

655
00:24:23,030 --> 00:24:20,970
earth out there so we're headed towards

656
00:24:25,430 --> 00:24:23,040
that goal so I'm going to show you a few

657
00:24:27,920 --> 00:24:25,440
graphs that tell you how astronomers

658
00:24:30,200 --> 00:24:27,930
expect to be able to recognize an

659
00:24:32,390 --> 00:24:30,210
earth-like planet when they see it or at

660
00:24:34,430 --> 00:24:32,400
least start debating seriously if it's

661
00:24:37,310 --> 00:24:34,440
earth-like so let's start here out here

662
00:24:39,440 --> 00:24:37,320
with this graph so I'm showing you here

663
00:24:41,960 --> 00:24:39,450

on the horizontal Direction a color of

664
00:24:43,080 --> 00:24:41,970
light here is a blue light that you can

665
00:24:45,060 --> 00:24:43,090
see when you're

666
00:24:46,620 --> 00:24:45,070
can I here's a red light and if you go

667
00:24:48,510 --> 00:24:46,630
past where your eye can see your

668
00:24:50,790 --> 00:24:48,520
wavelengths we call near-infrared

669
00:24:53,040 --> 00:24:50,800
the brightness here and the blue curve

670
00:24:55,710 --> 00:24:53,050
this is brighter higher up in the graph

671
00:24:58,080 --> 00:24:55,720
fainter going across this shows you the

672
00:24:59,100 --> 00:24:58,090
spectrum of light that is reflected off

673
00:25:01,230 --> 00:24:59,110
of the earth

674
00:25:03,420 --> 00:25:01,240
so all the colors broken down into a

675
00:25:05,760 --> 00:25:03,430
brightness number for every wavelength

676
00:25:07,950 --> 00:25:05,770
of light and what's important about this

677
00:25:10,470 --> 00:25:07,960
graph is that you can see number one in

678
00:25:12,300 --> 00:25:10,480
the blue the earth is brighter in the

679
00:25:14,160 --> 00:25:12,310
red it's fainter that makes you have a

680
00:25:16,710 --> 00:25:14,170
blue planet all right then in addition

681
00:25:18,480 --> 00:25:16,720
we can see that there's this big dip in

682
00:25:20,790 --> 00:25:18,490
the signal over here where water vapor

683
00:25:22,590 --> 00:25:20,800
produces an absorption and we've got

684
00:25:25,080 --> 00:25:22,600
that same thing here and here from water

685
00:25:27,390 --> 00:25:25,090
vapor but most telltale of all of the

686
00:25:30,030 --> 00:25:27,400
earth is this presence of molecular

687
00:25:32,610 --> 00:25:30,040
oxygen in our atmosphere produced by

688
00:25:34,500 --> 00:25:32,620

life which sustains all the animals and

689
00:25:35,760 --> 00:25:34,510
so this is something that we would

690
00:25:38,940 --> 00:25:35,770
really like to be able to see in an

691
00:25:41,190 --> 00:25:38,950
exoplanet now compare this to Mars Mars

692
00:25:43,380 --> 00:25:41,200
has very little light in the blue it has

693
00:25:45,810 --> 00:25:43,390
a lot more light in the red that's a red

694
00:25:48,690 --> 00:25:45,820
planet and so going across here you

695
00:25:50,670 --> 00:25:48,700
notice no oxygen signature no dip in

696
00:25:52,710 --> 00:25:50,680
Mars at the same wavelength of light and

697
00:25:54,690 --> 00:25:52,720
there really are two neat strong water

698
00:25:56,880 --> 00:25:54,700
features from Mars either there is a

699
00:25:58,280 --> 00:25:56,890
little bit of a feature here which when

700
00:26:01,410 --> 00:25:58,290
I go to the next slide you'll see

701
00:26:03,360 --> 00:26:01,420
actually is carbon dioxide because and

702
00:26:05,640 --> 00:26:03,370
this is the atmosphere of Venus shown in

703
00:26:07,860 --> 00:26:05,650
comparison to the earth and all of these

704
00:26:09,870 --> 00:26:07,870
strong dips in the spectrum of Venus are

705
00:26:12,800 --> 00:26:09,880
due to carbon dioxide in its atmosphere

706
00:26:15,120 --> 00:26:12,810
there's a little bit of that for Mars

707
00:26:18,870 --> 00:26:15,130
carbon dioxide you know here and here

708
00:26:21,410 --> 00:26:18,880
and there is a lot for Venus so again no

709
00:26:25,530 --> 00:26:21,420
oxygen and Venus and very little water

710
00:26:26,880 --> 00:26:25,540
so now astronomers have been imaginative

711
00:26:28,800 --> 00:26:26,890
they've made computer models of

712
00:26:30,120 --> 00:26:28,810
theoretically possible planets that

713
00:26:32,130 --> 00:26:30,130

would be rocky like the earth that would

714
00:26:34,860 --> 00:26:32,140
have different atmospheres and so the

715
00:26:36,810 --> 00:26:34,870
orange curve here is showing a planet

716
00:26:38,910 --> 00:26:36,820
that has say no water vapor at all

717
00:26:40,650 --> 00:26:38,920
but has really huge amounts of oxygen

718
00:26:43,500 --> 00:26:40,660
maybe ten times the oxygen that we have

719
00:26:45,900 --> 00:26:43,510
in our own solar system and this is an

720
00:26:48,150 --> 00:26:45,910
example of dozens of possible scenarios

721
00:26:50,340 --> 00:26:48,160
that have been exploring computers so we

722
00:26:52,050 --> 00:26:50,350
have a understanding of planetary

723
00:26:53,790 --> 00:26:52,060
atmospheres predictions about the

724
00:26:55,710 --> 00:26:53,800
possible diversity that would be out

725
00:26:57,220 --> 00:26:55,720
there so what we really want to go is

726
00:27:00,100 --> 00:26:57,230
find and measure

727
00:27:02,620 --> 00:27:00,110
the spectra of lots of small planets see

728
00:27:05,049 --> 00:27:02,630
what the diversity of them is and see

729
00:27:08,350 --> 00:27:05,059
how many match the spectrum of our own

730
00:27:10,870 --> 00:27:08,360
earth so let me talk to you about how we

731
00:27:12,909 --> 00:27:10,880
do that now the most normal thing you

732
00:27:14,470 --> 00:27:12,919
would do is you would just want to be

733
00:27:16,150 --> 00:27:14,480
able to look at the light that reflects

734
00:27:17,590 --> 00:27:16,160
off a planet that's what we do with the

735
00:27:19,960 --> 00:27:17,600
moon at night we see the sun's light

736
00:27:21,490 --> 00:27:19,970
reflecting off of it the way we see Mars

737
00:27:23,680 --> 00:27:21,500
and Jupiter and all the great pictures

738
00:27:26,220 --> 00:27:23,690

is from the light of the Sun reflected

739
00:27:29,140 --> 00:27:26,230
off of it so we'd like to do that with

740
00:27:31,299 --> 00:27:29,150
exoplanets too but the problem is that

741
00:27:32,890 --> 00:27:31,309
glare from the star the star is so close

742
00:27:34,750 --> 00:27:32,900
together to the exoplanet when you look

743
00:27:37,120 --> 00:27:34,760
out at a distance of you know many

744
00:27:38,680 --> 00:27:37,130
light-years it's very hard to separate

745
00:27:40,690 --> 00:27:38,690
the light of the exoplanet from the

746
00:27:42,580 --> 00:27:40,700
light of the star so right now we have

747
00:27:45,100 --> 00:27:42,590
zero exoplanets that we've been able to

748
00:27:47,020 --> 00:27:45,110
measure in the reflected light that you

749
00:27:50,409 --> 00:27:47,030
use your own eyes to see planets in the

750
00:27:52,090 --> 00:27:50,419
night sky here so we actually though

751
00:27:55,120 --> 00:27:52,100
have been able to develop a technique

752
00:27:56,740 --> 00:27:55,130
that can still get you a spectrum in a

753
00:27:59,320 --> 00:27:56,750
totally unexpected way and I want to

754
00:28:00,789 --> 00:27:59,330
talk to you about that here so this is

755
00:28:02,770 --> 00:28:00,799
an example of things that are lit from

756
00:28:04,659 --> 00:28:02,780
the front and the sunlight is reflecting

757
00:28:07,870 --> 00:28:04,669
off like a planet so here's a cloud

758
00:28:10,630 --> 00:28:07,880
here's me at the launch of tests this is

759
00:28:14,020 --> 00:28:10,640
Saturn's moon Titan and this is Venus as

760
00:28:15,760 --> 00:28:14,030
seen from a spacecraft now what if you

761
00:28:17,490 --> 00:28:15,770
give up on trying to separate the light

762
00:28:20,020 --> 00:28:17,500
of the star from the light of the planet

763
00:28:21,880 --> 00:28:20,030

if you are willing to combine them

764
00:28:24,820 --> 00:28:21,890
together you can actually still see a

765
00:28:27,010 --> 00:28:24,830
signal from the planet itself so in that

766
00:28:29,919 --> 00:28:27,020
case what we're doing is we're using the

767
00:28:31,810 --> 00:28:29,929
silver lining of the planet to probe its

768
00:28:34,120 --> 00:28:31,820
atmosphere so here's a cloud silver

769
00:28:35,470 --> 00:28:34,130
lining here's me in the studio back on

770
00:28:37,450 --> 00:28:35,480
Wednesday when you light me up from

771
00:28:39,430 --> 00:28:37,460
behind you can see maybe I've got gray

772
00:28:42,789 --> 00:28:39,440
hair you can see that I believe got some

773
00:28:45,159 --> 00:28:42,799
blood flow in my ears but then this is

774
00:28:47,799 --> 00:28:45,169
the picture of of Titan taken by the

775
00:28:49,810 --> 00:28:47,809
Cassini mission JPL's Cassini mission at

776
00:28:52,299 --> 00:28:49,820
the particular time when the Sun was

777
00:28:54,760 --> 00:28:52,309
directly behind Titan and you can see

778
00:28:56,110 --> 00:28:54,770
the same Silver Lining effect here that

779
00:28:58,480 --> 00:28:56,120
the light of the Sun is passing through

780
00:29:01,210 --> 00:28:58,490
the upper atmosphere here so even if the

781
00:29:04,390 --> 00:29:01,220
Sun is still in the same picture as it

782
00:29:06,250 --> 00:29:04,400
is here back in 2004 when Venus was

783
00:29:08,799 --> 00:29:06,260
crossing the face of the Sun there's

784
00:29:10,480 --> 00:29:08,809
this little thin film on this side which

785
00:29:13,810 --> 00:29:10,490
is light that's transmitted through the

786
00:29:15,400 --> 00:29:13,820
miss fear of Venus so for the time being

787
00:29:17,919 --> 00:29:15,410
we're not separating the light of the

788
00:29:19,750 --> 00:29:17,929

planet from the star in in in most cases

789
00:29:21,370 --> 00:29:19,760
we have only a couple dozen planets

790
00:29:23,740 --> 00:29:21,380
we've been able to get a spectrum this

791
00:29:26,020 --> 00:29:23,750
way out of the thousands that Kepler has

792
00:29:28,060 --> 00:29:26,030
been able to find so far but we can use

793
00:29:31,240 --> 00:29:28,070
this technique to go and find the

794
00:29:32,590 --> 00:29:31,250
spectra of planets around stars Hubble

795
00:29:34,540 --> 00:29:32,600
has been able to do this in some limited

796
00:29:36,100 --> 00:29:34,550
way for hot Jupiters it's been able to

797
00:29:39,549 --> 00:29:36,110
see that yes they have water vapor in

798
00:29:42,910 --> 00:29:39,559
their atmospheres but the big coming

799
00:29:44,440 --> 00:29:42,920
activity in these backlit planets is the

800
00:29:47,350 --> 00:29:44,450
James Webb telescope it's supposed to

801
00:29:49,510 --> 00:29:47,360
launch now in 2021 so right now James

802
00:29:51,490 --> 00:29:49,520
Webb is famous for being late and for

803
00:29:53,140 --> 00:29:51,500
costing more than expected but in like

804
00:29:55,390 --> 00:29:53,150
three years it's going to be famous for

805
00:29:56,650 --> 00:29:55,400
a lot of important discoveries and in

806
00:29:58,600 --> 00:29:56,660
the early universe seeing the first

807
00:30:00,850 --> 00:29:58,610
galaxies and it's going to be famous for

808
00:30:03,100 --> 00:30:00,860
what it does in exoplanets too because

809
00:30:05,260 --> 00:30:03,110
it's going to be much larger mirror than

810
00:30:06,760 --> 00:30:05,270
Hubble almost a factor of three larger

811
00:30:08,380 --> 00:30:06,770
mirror and it's gonna work in the

812
00:30:10,630 --> 00:30:08,390
infrared which is really good for

813
00:30:13,000 --> 00:30:10,640

studying the atmospheres of planets and

814
00:30:15,430 --> 00:30:13,010
so here it is after it's deployed out in

815
00:30:17,890 --> 00:30:15,440
orbit it's got these 18 segments on the

816
00:30:19,780 --> 00:30:17,900
mirror here a sunshade to keep the whole

817
00:30:22,210 --> 00:30:19,790
telescope cold it's operating in the

818
00:30:24,250 --> 00:30:22,220
infrared almost exclusively and so James

819
00:30:26,950 --> 00:30:24,260
Webb is going to be able to do this kind

820
00:30:28,840 --> 00:30:26,960
of result in backlit planets so here's

821
00:30:30,820 --> 00:30:28,850
the Trappist system Jessie mentioned to

822
00:30:32,440 --> 00:30:30,830
you with that fierce little red dwarf

823
00:30:36,040 --> 00:30:32,450
star with all the ultraviolet light and

824
00:30:37,600 --> 00:30:36,050
the three planets here in the middle are

825
00:30:39,370 --> 00:30:37,610
the ones that have the right conditions

826
00:30:41,470 --> 00:30:39,380
apparently for having liquid water on

827
00:30:44,110 --> 00:30:41,480
their surface so the people who are

828
00:30:46,210 --> 00:30:44,120
going to use JWST the James Webb Space

829
00:30:47,650 --> 00:30:46,220
Telescope have simulated what they

830
00:30:50,940 --> 00:30:47,660
believe they'll be able to achieve on

831
00:30:54,580 --> 00:30:50,950
this planet which is planet b c d e f

832
00:30:57,100 --> 00:30:54,590
Trappist 1f and so this is a signal that

833
00:30:59,799 --> 00:30:57,110
they expect to be able to get where the

834
00:31:01,840 --> 00:30:59,809
differences between the planet when it's

835
00:31:03,340 --> 00:31:01,850
crossed in the star when it's crossing

836
00:31:04,810 --> 00:31:03,350
in front of them on the planet crosses

837
00:31:07,090 --> 00:31:04,820
in front of the star you take a spectrum

838
00:31:08,799 --> 00:31:07,100

when the star is there by itself you

839
00:31:10,630 --> 00:31:08,809
take a spectrum you make the difference

840
00:31:12,610 --> 00:31:10,640
between those two so you have a

841
00:31:14,710 --> 00:31:12,620
condition where it's the star plus the

842
00:31:16,600 --> 00:31:14,720
backlit planet signal and the star by

843
00:31:19,060 --> 00:31:16,610
itself take the difference and you can

844
00:31:21,310 --> 00:31:19,070
then get this spectrum the vertical axis

845
00:31:23,650 --> 00:31:21,320
here is parts per million so this is how

846
00:31:25,240 --> 00:31:23,660
much the light is going to change

847
00:31:27,880 --> 00:31:25,250
because of that planet passing in front

848
00:31:29,710 --> 00:31:27,890
and these are water vapor features so we

849
00:31:32,440 --> 00:31:29,720
think that there will be dozens of

850
00:31:35,770 --> 00:31:32,450
planets like the ones Kepler found that

851
00:31:37,600 --> 00:31:35,780
have sizes like twice in three times the

852
00:31:40,330 --> 00:31:37,610
earth that will get spectra from with

853
00:31:41,800 --> 00:31:40,340
JWST we also think there will be a few

854
00:31:43,660 --> 00:31:41,810
around the size of the earth like

855
00:31:47,080 --> 00:31:43,670
Trappist here that we should be able to

856
00:31:49,480 --> 00:31:47,090
characterize so but I want to get back

857
00:31:51,700 --> 00:31:49,490
to that first problem how are you gonna

858
00:31:53,620 --> 00:31:51,710
be able to see the planet the normal way

859
00:31:56,530 --> 00:31:53,630
lit from the front reflecting the light

860
00:31:58,740 --> 00:31:56,540
of its star well it's been reckoned that

861
00:32:01,350 --> 00:31:58,750
it's similar to the problem of seeing a

862
00:32:03,640 --> 00:32:01,360
firefly you know next to a searchlight

863
00:32:05,950 --> 00:32:03,650

when you're all the way across the

864
00:32:07,630 --> 00:32:05,960
country on the East Coast from here okay

865
00:32:09,430 --> 00:32:07,640
so the brightness difference is very

866
00:32:11,350 --> 00:32:09,440
challenging and the tiny separation

867
00:32:13,000 --> 00:32:11,360
between the two is very challenging

868
00:32:15,940 --> 00:32:13,010
think about also like you're driving on

869
00:32:17,530 --> 00:32:15,950
a road at night and you're trying to

870
00:32:18,970 --> 00:32:17,540
make sure you can see the road and the

871
00:32:21,400 --> 00:32:18,980
car is coming at you with with

872
00:32:23,530 --> 00:32:21,410
headlights and there's billions of

873
00:32:24,670 --> 00:32:23,540
headlights in your rear-view mirror that

874
00:32:25,810 --> 00:32:24,680
that's the kind of you're trying to look

875
00:32:27,070 --> 00:32:25,820
out the window at the same time and

876
00:32:29,230 --> 00:32:27,080
you've got all this light shining in you

877
00:32:31,330 --> 00:32:29,240
from the cars behind you it's just very

878
00:32:33,550 --> 00:32:31,340
very difficult to be able to do that but

879
00:32:36,010 --> 00:32:33,560
that's our job and the NASA exoplanet

880
00:32:37,420 --> 00:32:36,020
program is to develop the technology

881
00:32:39,880 --> 00:32:37,430
that will make this brightness

882
00:32:41,950 --> 00:32:39,890
difference problem go away to get the

883
00:32:45,040 --> 00:32:41,960
glare of the star under control to see

884
00:32:47,680 --> 00:32:45,050
those faint planets so now I'm going to

885
00:32:51,250 --> 00:32:47,690
show you another graph this is a showing

886
00:32:52,900 --> 00:32:51,260
two different directions up on this

887
00:32:55,780 --> 00:32:52,910
direction is the brightness difference

888
00:32:57,970 --> 00:32:55,790

so up here are the few planets have been

889
00:33:00,220 --> 00:32:57,980
able to image today using telescopes

890
00:33:02,830 --> 00:33:00,230
like Gemini in Hawaii and in South

891
00:33:05,890 --> 00:33:02,840
America and there's a roughly a dozen or

892
00:33:08,440 --> 00:33:05,900
so of these and these are about 10,000

893
00:33:10,300 --> 00:33:08,450
times fainter than their star and you

894
00:33:12,700 --> 00:33:10,310
can see they're out at this separation

895
00:33:14,140 --> 00:33:12,710
of about one arc seconds so that's easy

896
00:33:16,180 --> 00:33:14,150
that's only one tenth of the way to the

897
00:33:19,090 --> 00:33:16,190
East Coast to be able to see those

898
00:33:20,770 --> 00:33:19,100
planets so but the we've got to go from

899
00:33:23,110 --> 00:33:20,780
a factor of sort of ten thousand to a

900
00:33:25,090 --> 00:33:23,120
million where these are down to where

901
00:33:27,910 --> 00:33:25,100
the earth where it would be as if you

902
00:33:29,500 --> 00:33:27,920
were seen from 30 light-years away this

903
00:33:31,000 --> 00:33:29,510
so you can see Venus is closer and

904
00:33:32,350 --> 00:33:31,010
brighter than the earth Jupiter is

905
00:33:34,420 --> 00:33:32,360
further out because it's such a large

906
00:33:36,640 --> 00:33:34,430
planet it reflects a lot of light and so

907
00:33:37,090 --> 00:33:36,650
it's brighter and that's down here at

908
00:33:43,330 --> 00:33:37,100
one

909
00:33:45,669 --> 00:33:43,340
down here at 10 billion to 1 contrast so

910
00:33:47,830 --> 00:33:45,679
you may be surprised to learn that we

911
00:33:50,320 --> 00:33:47,840
have about two minutes walk from here a

912
00:33:53,110 --> 00:33:50,330
vacuum chamber testing facility where we

913
00:33:55,210 --> 00:33:53,120

have a coronagraph instrument which

914
00:33:56,470 --> 00:33:55,220
blocks the light of the star to let you

915
00:33:59,460 --> 00:33:56,480
see something faint next to it and we

916
00:34:02,860 --> 00:33:59,470
have already achieved 1 billion to 1

917
00:34:05,110 --> 00:34:02,870
contrast that a few beam with separation

918
00:34:06,760 --> 00:34:05,120
from the star it's in the lab it works

919
00:34:09,159 --> 00:34:06,770
we've been developing an instrument

920
00:34:11,050 --> 00:34:09,169
concept based on it and so we think we

921
00:34:13,090 --> 00:34:11,060
have done all gone a lot of the way

922
00:34:14,800 --> 00:34:13,100
toward demonstrating that we can do this

923
00:34:16,750 --> 00:34:14,810
kind of measurement we just want to get

924
00:34:18,669 --> 00:34:16,760
it out of the lab and onto a space

925
00:34:21,550 --> 00:34:18,679
mission and that next space mission for

926
00:34:23,379 --> 00:34:21,560
that is called w first so this is a

927
00:34:26,349 --> 00:34:23,389
telescope that was recommended by the

928
00:34:28,090 --> 00:34:26,359
2010 to Cadle survey of astrophysics its

929
00:34:30,099 --> 00:34:28,100
primary goal is a really wide angle

930
00:34:32,320 --> 00:34:30,109
camera view of the sky for dark energy

931
00:34:34,210 --> 00:34:32,330
extra galactic science and also for

932
00:34:35,590 --> 00:34:34,220
counting planets by the micro lensing

933
00:34:38,230 --> 00:34:35,600
technique I won't go into that but you

934
00:34:40,149 --> 00:34:38,240
could ask me after the talk but W first

935
00:34:41,770 --> 00:34:40,159
has a second instrument in addition to

936
00:34:44,020 --> 00:34:41,780
its wide field camera it has a

937
00:34:45,820 --> 00:34:44,030
coronagraph like the one in our test bed

938
00:34:48,430 --> 00:34:45,830

facility so we're gonna get a first

939
00:34:50,200 --> 00:34:48,440
chance to go and see planets around

940
00:34:52,000 --> 00:34:50,210
other stars that have been found by the

941
00:34:55,659 --> 00:34:52,010
radial velocity wobble technique that

942
00:34:58,210 --> 00:34:55,669
Jesse spoke of so that's the first step

943
00:35:01,120 --> 00:34:58,220
W first will get us to a Jupiter around

944
00:35:03,609 --> 00:35:01,130
another star factor of a billion to one

945
00:35:07,240 --> 00:35:03,619
they won't get us to ten billion to one

946
00:35:09,970 --> 00:35:07,250
which is an earth-like planet so just as

947
00:35:12,970 --> 00:35:09,980
W first was recommended in 2010 we have

948
00:35:14,260 --> 00:35:12,980
in 2020 another time on the National

949
00:35:16,030 --> 00:35:14,270
Academy of Sciences is going to

950
00:35:18,250 --> 00:35:16,040
recommend what should NASA do as this

951
00:35:19,900 --> 00:35:18,260
next large telescope project there are a

952
00:35:21,730 --> 00:35:19,910
lot of ideas some of them are not

953
00:35:23,530 --> 00:35:21,740
exoplanets they all have strong merit

954
00:35:26,050 --> 00:35:23,540
but there are two ideas that our

955
00:35:27,700 --> 00:35:26,060
exoplanet focused the NASA's invested in

956
00:35:29,650 --> 00:35:27,710
the developing the concept I just want

957
00:35:31,510 --> 00:35:29,660
to tell you about them briefly now one

958
00:35:34,060 --> 00:35:31,520
of them is called hey BECs it stands for

959
00:35:36,250 --> 00:35:34,070
the habitable exoplanet Observatory so

960
00:35:38,470 --> 00:35:36,260
it's a telescope about 60 percent larger

961
00:35:40,780 --> 00:35:38,480
than Hubble with one of us coronagraph

962
00:35:42,310 --> 00:35:40,790
instruments put inside tuned up to go to

963
00:35:45,070 --> 00:35:42,320

ten billion to one using the lessons

964
00:35:46,870 --> 00:35:45,080
from the W first coronagraph and then it

965
00:35:49,270 --> 00:35:46,880
also has a separate formation flying

966
00:35:50,910 --> 00:35:49,280
star shade spacecraft which provides an

967
00:35:53,970 --> 00:35:50,920
alternate way of blocking out the

968
00:35:55,470 --> 00:35:53,980
of the star and seeing the planet the

969
00:35:57,660 --> 00:35:55,480
star shade is particularly useful for

970
00:35:59,280 --> 00:35:57,670
letting a smaller sized telescope look

971
00:36:02,039 --> 00:35:59,290
closer in than it otherwise would be

972
00:36:04,530 --> 00:36:02,049
able to do so hey BECs is something that

973
00:36:06,750 --> 00:36:04,540
would probably able to see hundreds of

974
00:36:08,039 --> 00:36:06,760
planets of different types and planets

975
00:36:10,380 --> 00:36:08,049
that are like the Earth's size in the

976
00:36:11,819 --> 00:36:10,390
habitable zone probably about ten is our

977
00:36:13,799 --> 00:36:11,829
current estimate those estimates all

978
00:36:16,230 --> 00:36:13,809
rely on what Kepler told us about the

979
00:36:18,960 --> 00:36:16,240
frequency of planets and so this is one

980
00:36:22,430 --> 00:36:18,970
of the two ideas the next one is called

981
00:36:25,859 --> 00:36:22,440
leVoir so Louvois R stands for large

982
00:36:28,440 --> 00:36:25,869
ultraviolet optical infrared telescope

983
00:36:30,870 --> 00:36:28,450
and so this is much bigger than Havoc's

984
00:36:33,630 --> 00:36:30,880
this is a telescope now that is about a

985
00:36:36,270 --> 00:36:33,640
factor of let's say this is this is also

986
00:36:37,680 --> 00:36:36,280
three times bigger than Hubble for the

987
00:36:40,380 --> 00:36:37,690
eight meter version I'm showing you here

988
00:36:43,049 --> 00:36:40,390

there's also a 15 meter version and so

989
00:36:44,579 --> 00:36:43,059
this is a telescope that because of its

990
00:36:46,380 --> 00:36:44,589
larger size and would have a better

991
00:36:49,770 --> 00:36:46,390
ability to look in close to other stars

992
00:36:52,010 --> 00:36:49,780
this would be able to get 30 or so

993
00:36:54,750 --> 00:36:52,020
earth-like planets we believe for a

994
00:36:56,819 --> 00:36:54,760
rocky planets in a habitable zone for

995
00:36:58,470 --> 00:36:56,829
the small version that you're seeing

996
00:37:00,630 --> 00:36:58,480
here and a larger version not shown

997
00:37:03,539 --> 00:37:00,640
you'll be able to get about 60 of them

998
00:37:06,299 --> 00:37:03,549
so like JWST it has a segmented mirror

999
00:37:07,950 --> 00:37:06,309
that would have to unfold on orbit it

1000
00:37:09,569 --> 00:37:07,960
has a very large sunshade to keep the

1001
00:37:12,059 --> 00:37:09,579
temperature of the telescope regulated

1002
00:37:12,990 --> 00:37:12,069
so these this is a mission concept it's

1003
00:37:15,240 --> 00:37:13,000
not approved

1004
00:37:18,089 --> 00:37:15,250
it's an as a suggestion for what we

1005
00:37:20,160 --> 00:37:18,099
could do as the next major goal so what

1006
00:37:22,620 --> 00:37:20,170
will our de kado Survey coming up decide

1007
00:37:24,120 --> 00:37:22,630
they're just starting to meet now we

1008
00:37:26,309 --> 00:37:24,130
think we are close to being ready to

1009
00:37:27,990 --> 00:37:26,319
build these kind of instruments these

1010
00:37:29,880 --> 00:37:28,000
kind of missions but it's up to our

1011
00:37:31,829 --> 00:37:29,890
peers in the community to trade off this

1012
00:37:34,200 --> 00:37:31,839
possibility versus other things that

1013
00:37:38,940 --> 00:37:34,210

might be done and say whether we get the

1014
00:37:40,970 --> 00:37:38,950
signal for go in 2022 so let me try to

1015
00:37:43,620 --> 00:37:40,980
say where we're gonna end up with this

1016
00:37:45,420 --> 00:37:43,630
Galileo with his first telescope was

1017
00:37:47,190 --> 00:37:45,430
able to look at Jupiter and see the

1018
00:37:48,539 --> 00:37:47,200
moons of Jupiter he took what was a

1019
00:37:50,640 --> 00:37:48,549
point of light in the star and showed

1020
00:37:52,470 --> 00:37:50,650
that it was a system and at that time he

1021
00:37:53,789 --> 00:37:52,480
could only hand draw what he was seeing

1022
00:37:55,559 --> 00:37:53,799
so that's what you have here on the left

1023
00:37:58,500 --> 00:37:55,569
from night tonight the moons moved

1024
00:38:00,390 --> 00:37:58,510
around so it with modern ground-based

1025
00:38:02,309 --> 00:38:00,400
telescopes we've been able to see one

1026
00:38:04,620 --> 00:38:02,319
really fantastic system with four

1027
00:38:07,200 --> 00:38:04,630
planets that actually

1028
00:38:09,480 --> 00:38:07,210
over the past you know ten years or so

1029
00:38:11,910 --> 00:38:09,490
have been shown to orbit around this is

1030
00:38:15,300 --> 00:38:11,920
a time-lapse photo by Jason Wang at

1031
00:38:17,700 --> 00:38:15,310
Caltech and if we're successful both in

1032
00:38:19,500 --> 00:38:17,710
our technical work and in convincing the

1033
00:38:23,160 --> 00:38:19,510
community this is what we hope to be

1034
00:38:25,530 --> 00:38:23,170
able to do around 2035 with a loofah or

1035
00:38:28,560 --> 00:38:25,540
a head next mission see our solar system

1036
00:38:31,290 --> 00:38:28,570
the analog of it around many many other

1037
00:38:32,730 --> 00:38:31,300
stars and tell us if planets were the

1038
00:38:36,510 --> 00:38:32,740

properties like the earth are really

1039
00:38:40,050 --> 00:38:36,520
common or very unusual and so another

1040
00:38:42,000 --> 00:38:40,060
point when I conclude on is that once we

1041
00:38:43,290 --> 00:38:42,010
find out that there is a planet at the

1042
00:38:44,880 --> 00:38:43,300
right distance from its Sun to be the

1043
00:38:47,630 --> 00:38:44,890
right temperature and it has the

1044
00:38:50,070 --> 00:38:47,640
composition of the Earth's atmosphere

1045
00:38:51,870 --> 00:38:50,080
that's going to captivate people if

1046
00:38:53,610 --> 00:38:51,880
you're ever going to go and try to have

1047
00:38:55,170 --> 00:38:53,620
interstellar travel you've got to know

1048
00:38:57,330 --> 00:38:55,180
what the destination is first you have

1049
00:38:58,920 --> 00:38:57,340
to get the map for the travelers well

1050
00:39:01,050 --> 00:38:58,930
this is the kind of way we could get

1051
00:39:03,000 --> 00:39:01,060
started on this in the next decade

1052
00:39:05,160 --> 00:39:03,010
having these missions that can find

1053
00:39:07,200 --> 00:39:05,170
where are the nearest earth-like planets

1054
00:39:08,670 --> 00:39:07,210
so with that I'll turn it back over to

1055
00:39:23,460 --> 00:39:08,680
Preston

1056
00:39:29,530 --> 00:39:25,900
so we will not be turning it over to

1057
00:39:31,290 --> 00:39:29,540
Preston hello my name is Talia Rivera

1058
00:39:34,060 --> 00:39:31,300
and I work for NASA exoplanet

1059
00:39:35,980 --> 00:39:34,070
exploration program I do communications

1060
00:39:38,620 --> 00:39:35,990
and one of the things that was mentioned

1061
00:39:41,230 --> 00:39:38,630
earlier was the exoplanet travel Bureau

1062
00:39:43,030 --> 00:39:41,240
so Jessie in her talk earlier showed you

1063
00:39:45,880 --> 00:39:43,040

the posters that we have created to

1064
00:39:47,530 --> 00:39:45,890
visualize some of these exoplanets but

1065
00:39:51,280 --> 00:39:47,540
what I will be showing you is where they

1066
00:39:52,870 --> 00:39:51,290
live and also a an immersive 360 VR

1067
00:39:57,760 --> 00:39:52,880
experience that you can all enjoy at

1068
00:39:59,590 --> 00:39:57,770
home so let's explore the galaxy so you

1069
00:40:02,140 --> 00:39:59,600
guys will be able to find full

1070
00:40:04,810 --> 00:40:02,150
resolution files of the exoplanet travel

1071
00:40:07,660 --> 00:40:04,820
Bureau posters available at exoplanets

1072
00:40:10,090 --> 00:40:07,670
nasa.gov but you will also be able to

1073
00:40:11,470 --> 00:40:10,100
explore these surfaces of four different

1074
00:40:14,320 --> 00:40:11,480
exoplanets that we've actually

1075
00:40:17,170 --> 00:40:14,330
discovered so this planet right here is

1076
00:40:19,930 --> 00:40:17,180
called 55 Cancri E it is one of the lava

1077
00:40:26,500 --> 00:40:19,940
worlds that Jesse mentioned earlier so

1078
00:40:29,470 --> 00:40:26,510
let's explore the surface so these 360

1079
00:40:32,260 --> 00:40:29,480
VR experiences work on your desktop a

1080
00:40:36,370 --> 00:40:32,270
tablet or your mobile device so you can

1081
00:40:38,260 --> 00:40:36,380
use them as a 360 experience on a

1082
00:40:41,860 --> 00:40:38,270
desktop or tablet but if you have a

1083
00:40:44,650 --> 00:40:41,870
Google cardboard or a similar device you

1084
00:40:46,630 --> 00:40:44,660
can get it on your phone split it into a

1085
00:40:50,830 --> 00:40:46,640
stereoscopic view pop it into your

1086
00:40:53,890 --> 00:40:50,840
device and view it in the or mode so

1087
00:40:55,930 --> 00:40:53,900
some really interesting features here on

1088
00:40:59,440 --> 00:40:55,940

this planet that we've highlighted with

1089
00:41:01,390 --> 00:40:59,450
these text hotspots are the star so if

1090
00:41:02,800 --> 00:41:01,400
you click that text hotspot it actually

1091
00:41:05,470 --> 00:41:02,810
gives you some more information about

1092
00:41:07,150 --> 00:41:05,480
what you're looking at so here it gives

1093
00:41:09,550 --> 00:41:07,160
information about this star which

1094
00:41:12,310 --> 00:41:09,560
appears to be really close it is not a

1095
00:41:15,400 --> 00:41:12,320
fountain of lava but it is the star in

1096
00:41:20,110 --> 00:41:15,410
this system so this star is 65 times

1097
00:41:22,450 --> 00:41:20,120
closer to this planet then our Sun is to

1098
00:41:24,430 --> 00:41:22,460
earth which is why it looks so big and

1099
00:41:27,130 --> 00:41:24,440
one of my favorite features when I was

1100
00:41:29,120 --> 00:41:27,140
working on developing this product is

1101
00:41:32,210 --> 00:41:29,130
right here what appears

1102
00:41:35,390 --> 00:41:32,220
sparkles in the sky the these are

1103
00:41:37,220 --> 00:41:35,400
actually sparkly clouds of silicate in

1104
00:41:39,920 --> 00:41:37,230
this planet as Jessie mentioned earlier

1105
00:41:42,799 --> 00:41:39,930
is so hot that silicate would evaporate

1106
00:41:44,240 --> 00:41:42,809
and create clouds so if you click on

1107
00:41:45,920 --> 00:41:44,250
that it tells you a little bit more and

1108
00:41:48,440 --> 00:41:45,930
these clouds would reflect reflect the

1109
00:41:53,839 --> 00:41:48,450
surface of the lava so they would look

1110
00:41:55,700 --> 00:41:53,849
sparkly so again you guys can find the

1111
00:41:57,680 --> 00:41:55,710
VR and all of the travel posters

1112
00:41:59,809 --> 00:41:57,690
available for download and used at home

1113
00:42:01,670 --> 00:41:59,819

you do not have to download any apps to

1114
00:42:04,730 --> 00:42:01,680
use the VR it runs directly from our

1115
00:42:13,980 --> 00:42:04,740
website and that is all available at

1116
00:42:19,620 --> 00:42:17,130
all right Thank You Philly and if my my

1117
00:42:22,050 --> 00:42:19,630
speakers will join us so over here and

1118
00:42:25,530 --> 00:42:22,060
we'll get started soon with the

1119
00:42:27,030 --> 00:42:25,540
discussion part of our show tonight be

1120
00:42:29,880 --> 00:42:27,040
sure though to check out the exoplanet

1121
00:42:31,320 --> 00:42:29,890
travel Bureau online Philly I don't

1122
00:42:33,060 --> 00:42:31,330
think it was mentioned she's actually

1123
00:42:34,680 --> 00:42:33,070
instrumental in making those

1124
00:42:36,660 --> 00:42:34,690
visualizations and so she's really

1125
00:42:38,099 --> 00:42:36,670
talented and I think it really does a

1126
00:42:40,800 --> 00:42:38,109
nice job of demonstrating how there are

1127
00:42:42,570 --> 00:42:40,810
careers for all kinds of folks at NASA

1128
00:42:44,460 --> 00:42:42,580
working as part of the space Crypt

1129
00:42:46,410 --> 00:42:44,470
program whether you're a scientist an

1130
00:42:47,579 --> 00:42:46,420
engineer or a communicator and all kinds

1131
00:42:49,740 --> 00:42:47,589
of other things so I think it's a great

1132
00:42:51,510 --> 00:42:49,750
way to highlight that so let's move on

1133
00:42:59,060 --> 00:42:51,520
to the discussion part of our show with

1134
00:43:02,820 --> 00:42:59,070
Jessie and Carl hey guys but thank you

1135
00:43:04,320 --> 00:43:02,830
so I wanted to start by asking you a

1136
00:43:06,690 --> 00:43:04,330
question I told you I was going to ask

1137
00:43:08,609 --> 00:43:06,700
which was about the names we wanted to

1138
00:43:12,480 --> 00:43:08,619

talk about the names of the planets and

1139
00:43:14,120 --> 00:43:12,490
why they're so funky yes so I want to

1140
00:43:18,300 --> 00:43:14,130
apologize on behalf of my entire

1141
00:43:20,609 --> 00:43:18,310
profession the names of garbage they're

1142
00:43:22,859 --> 00:43:20,619
almost always either named after the

1143
00:43:25,140 --> 00:43:22,869
star if the star already had a name and

1144
00:43:25,980 --> 00:43:25,150
the star names usually start out as

1145
00:43:28,530 --> 00:43:25,990
garbage

1146
00:43:30,359 --> 00:43:28,540
they're almost all numbered so HD one

1147
00:43:34,470 --> 00:43:30,369
eight nine seven three three was Henry

1148
00:43:37,620 --> 00:43:34,480
Draper's 189733 star that he put in his

1149
00:43:39,150 --> 00:43:37,630
catalog so then we add a little B to the

1150
00:43:40,710 --> 00:43:39,160
end to say that's the first planet we

1151
00:43:41,970 --> 00:43:40,720
found or little C is the second planet

1152
00:43:44,339 --> 00:43:41,980
or little D is the third planet so you

1153
00:43:45,870 --> 00:43:44,349
end up with these big names if the star

1154
00:43:47,310 --> 00:43:45,880
didn't already have a name then it's

1155
00:43:50,490 --> 00:43:47,320
named after the mission that found it so

1156
00:43:52,079 --> 00:43:50,500
Kepler 442 B for instance was a 440

1157
00:43:54,089 --> 00:43:52,089
second planetary system found by Kepler

1158
00:44:03,570 --> 00:43:54,099
That star didn't already have a name

1159
00:44:05,240 --> 00:44:03,580
that was in common use we do give some

1160
00:44:06,870 --> 00:44:05,250
of them names sometimes where there's

1161
00:44:09,240 --> 00:44:06,880
occasionally there will be there will be

1162
00:44:12,030 --> 00:44:09,250
in a kind of an exciting name right and

1163
00:44:14,010 --> 00:44:12,040

they're like a marathon or so I you had

1164
00:44:16,200 --> 00:44:14,020
this name EXO world's competition a few

1165
00:44:18,210 --> 00:44:16,210
years ago where they there were like 50

1166
00:44:19,920 --> 00:44:18,220
planets that they had a basically a vote

1167
00:44:21,750 --> 00:44:19,930
where you could vote for very cool names

1168
00:44:23,880 --> 00:44:21,760
so some some of them do have I a you

1169
00:44:25,680 --> 00:44:23,890
names the professionals never use them

1170
00:44:27,660 --> 00:44:25,690
there will be a second round of I

1171
00:44:31,740 --> 00:44:27,670
you naming coming up I believe this year

1172
00:44:34,890 --> 00:44:31,750
so stay tuned to websites you might be

1173
00:44:37,560 --> 00:44:34,900
able to submit your own suggestions so

1174
00:44:40,620 --> 00:44:37,570
are the title of our show the Golden Age

1175
00:44:42,930 --> 00:44:40,630
of exoplanet exploration I wanted to ask

1176
00:44:45,960 --> 00:44:42,940
you for your take on that

1177
00:44:47,970 --> 00:44:45,970
is this the golden age now and I think

1178
00:44:51,360 --> 00:44:47,980
you mentioned that you sort of had it

1179
00:44:54,180 --> 00:44:51,370
had that opinion is it with us now or is

1180
00:44:56,310 --> 00:44:54,190
it still in the future I'm going to be

1181
00:44:59,220 --> 00:44:56,320
evasive and give two answers I think of

1182
00:45:02,700 --> 00:44:59,230
counting planets it really is the golden

1183
00:45:04,290 --> 00:45:02,710
age finding so many and their sizes and

1184
00:45:06,150 --> 00:45:04,300
you haven't even heard the half of it

1185
00:45:08,370 --> 00:45:06,160
because the test mission that launched

1186
00:45:11,100 --> 00:45:08,380
last April is going to be expected to

1187
00:45:14,100 --> 00:45:11,110
find another 10,000 or so planets above

1188
00:45:16,110 --> 00:45:14,110

the 4,000 we have now and the European

1189
00:45:18,480 --> 00:45:16,120
Space Agency has a mission called Gaia

1190
00:45:21,000 --> 00:45:18,490
which uses another wobble technique to

1191
00:45:23,220 --> 00:45:21,010
measure the stars and we're expecting

1192
00:45:25,610 --> 00:45:23,230
tens of thousands of planets to be found

1193
00:45:28,920 --> 00:45:25,620
through that again indirectly so

1194
00:45:30,270 --> 00:45:28,930
counting it's the golden age in terms of

1195
00:45:32,580 --> 00:45:30,280
characterizing and measuring their

1196
00:45:33,290 --> 00:45:32,590
properties I think that age is still to

1197
00:45:36,890 --> 00:45:33,300
come

1198
00:45:40,830 --> 00:45:36,900
well then so let's talk about that how

1199
00:45:42,690 --> 00:45:40,840
far can we get down this path of

1200
00:45:44,520 --> 00:45:42,700
studying exoplanets and finding them and

1201
00:45:47,850 --> 00:45:44,530
studying them with telescopes alone I

1202
00:45:49,380 --> 00:45:47,860
mean is there a limit to how much we can

1203
00:45:52,020 --> 00:45:49,390
learn about exoplanets without actually

1204
00:45:53,670 --> 00:45:52,030
going to one well we can look at our own

1205
00:45:55,440 --> 00:45:53,680
solar system for the answers to that

1206
00:45:57,510 --> 00:45:55,450
there's a lot of planets that we haven't

1207
00:45:59,760 --> 00:45:57,520
gone and landed on yet we can learn a

1208
00:46:01,440 --> 00:45:59,770
lot by looking at them remotely but we

1209
00:46:03,210 --> 00:46:01,450
always get more answers when we go there

1210
00:46:04,770 --> 00:46:03,220
and land a robot or a person on the

1211
00:46:06,390 --> 00:46:04,780
surface and they can actually bring

1212
00:46:08,160 --> 00:46:06,400
stuff back or take instruments to

1213
00:46:11,220 --> 00:46:08,170

actually measure so we can get very

1214
00:46:13,050 --> 00:46:11,230
exciting and very interesting ways there

1215
00:46:15,510 --> 00:46:13,060
but there's so much more we can get if

1216
00:46:17,250 --> 00:46:15,520
we get there one of the jobs of our

1217
00:46:18,840 --> 00:46:17,260
office is to plan the future of

1218
00:46:20,670 --> 00:46:18,850
exoplanet exploration at least the

1219
00:46:24,240 --> 00:46:20,680
options that can be presented to the

1220
00:46:25,560 --> 00:46:24,250
community to evaluate and so of course

1221
00:46:28,290 --> 00:46:25,570
we've thought about what might happen

1222
00:46:30,270 --> 00:46:28,300
after a have X or a leVoir if they might

1223
00:46:32,130 --> 00:46:30,280
get suggested so keep in mind all those

1224
00:46:34,050 --> 00:46:32,140
future missions would only be able to

1225
00:46:35,910 --> 00:46:34,060
show you a point of light and measure

1226
00:46:38,340 --> 00:46:35,920
its spectrum they wouldn't show you the

1227
00:46:40,050 --> 00:46:38,350
geography or the cloud patterns

1228
00:46:41,490 --> 00:46:40,060
on those planets but you can think about

1229
00:46:43,980 --> 00:46:41,500
what a mission would be like that could

1230
00:46:46,380 --> 00:46:43,990
do that so right now we've only planned

1231
00:46:48,900 --> 00:46:46,390
to make our missions good enough to

1232
00:46:51,270 --> 00:46:48,910
separate the planet from its star well

1233
00:46:54,120 --> 00:46:51,280
it turns out that the Earth's size is

1234
00:46:56,670 --> 00:46:54,130
about 120 thousandth of the separation

1235
00:46:58,940 --> 00:46:56,680
between the Earth and the Sun so if we

1236
00:47:01,650 --> 00:46:58,950
just scale up leVoir by a factor of

1237
00:47:03,930 --> 00:47:01,660
20,000 then we'll be in a position to

1238
00:47:07,050 --> 00:47:03,940

start seeing features on the surface of

1239
00:47:09,140 --> 00:47:07,060
that planet now that's actually too big

1240
00:47:11,550 --> 00:47:09,150
of a telescope to make all in one piece

1241
00:47:13,080 --> 00:47:11,560
but there are techniques in astronomy to

1242
00:47:15,240 --> 00:47:13,090
combine the light of two separated

1243
00:47:17,700 --> 00:47:15,250
telescopes so these would be separated

1244
00:47:20,280 --> 00:47:17,710
by quite a while so take 8 meters for Lu

1245
00:47:22,920 --> 00:47:20,290
4r x 20,000 so you need things that are

1246
00:47:27,390 --> 00:47:22,930
separated by a hundred thousand meters

1247
00:47:29,760 --> 00:47:27,400
or so to be able to do this more than

1248
00:47:31,850 --> 00:47:29,770
that 160,000 but you can think about

1249
00:47:36,450 --> 00:47:31,860
being able to make a mission like that

1250
00:47:39,420 --> 00:47:36,460
physically possible so then what happens

1251
00:47:42,030 --> 00:47:39,430
whether it's soon or much farther down

1252
00:47:45,330 --> 00:47:42,040
the road though what happens when you

1253
00:47:47,610 --> 00:47:45,340
find something that might be an

1254
00:47:50,460 --> 00:47:47,620
earth-like planet what will that do to

1255
00:47:54,030 --> 00:47:50,470
the search and the study of exoplanets

1256
00:47:55,770 --> 00:47:54,040
right well before 1995 there was

1257
00:47:57,660 --> 00:47:55,780
actually a hundred and fifty years of

1258
00:47:59,100 --> 00:47:57,670
claimed exoplanet detection that were

1259
00:48:00,630 --> 00:47:59,110
then retracted and then claimed

1260
00:48:02,040 --> 00:48:00,640
exoplanet detections that were then

1261
00:48:03,630 --> 00:48:02,050
retracted when you're trying to make

1262
00:48:05,430 --> 00:48:03,640
these really difficult measurements

1263
00:48:07,290 --> 00:48:05,440

right at the edge of your ability to do

1264
00:48:10,770 --> 00:48:07,300
it you're going to get it wrong a few

1265
00:48:14,340 --> 00:48:10,780
times so the very first time we think we

1266
00:48:16,170 --> 00:48:14,350
found a black planet it might not stick

1267
00:48:17,490 --> 00:48:16,180
we're gonna have to go and look at it

1268
00:48:19,290 --> 00:48:17,500
with bigger telescopes different

1269
00:48:21,000 --> 00:48:19,300
instruments and then we'll see but

1270
00:48:22,410 --> 00:48:21,010
everybody on earth will throw every

1271
00:48:23,490 --> 00:48:22,420
telescope at it essentially as soon as

1272
00:48:28,280 --> 00:48:23,500
we find one we're just going to

1273
00:48:33,510 --> 00:48:31,770
well for the imaging method that we're

1274
00:48:34,950 --> 00:48:33,520
really focusing on you have to do a

1275
00:48:36,750 --> 00:48:34,960
series of checks you have to make sure

1276
00:48:38,670 --> 00:48:36,760
that something that's really faint next

1277
00:48:40,740 --> 00:48:38,680
to your star actually belongs to that

1278
00:48:42,450 --> 00:48:40,750
star that it's not in the background so

1279
00:48:44,610 --> 00:48:42,460
we have to do a check and wait to see if

1280
00:48:46,800 --> 00:48:44,620
that planet candidate moves with a star

1281
00:48:48,840 --> 00:48:46,810
then if you see that it has that the

1282
00:48:50,820 --> 00:48:48,850
right spectrum to be the earth we have

1283
00:48:51,269 --> 00:48:50,830
to ask well is there life on there or

1284
00:48:53,579 --> 00:48:51,279
not

1285
00:48:55,499 --> 00:48:53,589
clever chemical modelers have figured

1286
00:48:57,239 --> 00:48:55,509
out a way to have oxygen in the

1287
00:48:59,849 --> 00:48:57,249
atmosphere of a planet without life a

1288
00:49:01,140 --> 00:48:59,859

completely abiotic oxygen atmosphere so

1289
00:49:02,789 --> 00:49:01,150
we have some tests that are being flown

1290
00:49:04,979 --> 00:49:02,799
up now about how you might be able to

1291
00:49:07,979 --> 00:49:04,989
tell that kind of oxygen atmosphere from

1292
00:49:09,299 --> 00:49:07,989
a life-bearing oxygen atmosphere so I

1293
00:49:11,249 --> 00:49:09,309
think there will be a lot of discussion

1294
00:49:14,339 --> 00:49:11,259
and debate and just as Jessie says maybe

1295
00:49:16,140 --> 00:49:14,349
some retractions but I'll just spur you

1296
00:49:19,499 --> 00:49:16,150
know further progress towards a really

1297
00:49:21,509 --> 00:49:19,509
solid result ok then and then on that

1298
00:49:23,189 --> 00:49:21,519
thread thinking about looking for

1299
00:49:26,489 --> 00:49:23,199
earth-like planets and considering life

1300
00:49:28,399 --> 00:49:26,499
do you guys have a belief personal or

1301
00:49:33,089 --> 00:49:28,409
professional about the likelihood of

1302
00:49:35,999 --> 00:49:33,099
that there is life beyond Earth well

1303
00:49:37,829 --> 00:49:36,009
it's hard to imagine that that if the

1304
00:49:39,959 --> 00:49:37,839
planets are as numerous as Kepler is

1305
00:49:41,099 --> 00:49:39,969
telling us and the conditions that the

1306
00:49:43,349 --> 00:49:41,109
universe is made of the same substance

1307
00:49:45,509 --> 00:49:43,359
as we have here on earth the conditions

1308
00:49:48,169 --> 00:49:45,519
seem to be possible for life in many

1309
00:49:51,259 --> 00:49:48,179
settings but whether that actually

1310
00:49:54,149 --> 00:49:51,269
progresses the star is quiet enough

1311
00:49:56,249 --> 00:49:54,159
long-lived enough whether it progresses

1312
00:49:58,109 --> 00:49:56,259
to multicellular life and then

1313
00:49:59,999 --> 00:49:58,119

intelligent life is something that's

1314
00:50:02,399 --> 00:50:00,009
still a totally open question and we

1315
00:50:07,249 --> 00:50:02,409
have room for speculation as you see in

1316
00:50:10,829 --> 00:50:07,259
the movies and on TV yeah so on earth

1317
00:50:12,539 --> 00:50:10,839
basically as soon as Earth was able to

1318
00:50:14,729 --> 00:50:12,549
support simple life

1319
00:50:16,829 --> 00:50:14,739
you see simple life start to emerge like

1320
00:50:18,809 --> 00:50:16,839
single celled things but then it's

1321
00:50:20,099 --> 00:50:18,819
millions billions of years before the

1322
00:50:22,049 --> 00:50:20,109
single-celled things turn into

1323
00:50:23,849 --> 00:50:22,059
multi-celled things so like Carl said it

1324
00:50:26,519 --> 00:50:23,859
might be the case that single-celled

1325
00:50:28,380 --> 00:50:26,529
life is easy to make and can be found

1326
00:50:30,659 --> 00:50:28,390
but that the progression to multi cell

1327
00:50:32,630 --> 00:50:30,669
life is very difficult and and maybe not

1328
00:50:37,079 --> 00:50:32,640
driven in some way it's as an accident

1329
00:50:38,489 --> 00:50:37,089
so that not really an answer but we

1330
00:50:42,120 --> 00:50:38,499
don't really have an answer and you're

1331
00:50:43,469 --> 00:50:42,130
not the type to speculate you have an

1332
00:50:45,209 --> 00:50:43,479
angle to get an answer if you can

1333
00:50:47,489 --> 00:50:45,219
measure the atmospheres of enough

1334
00:50:49,559 --> 00:50:47,499
planets and see how common these oxygen

1335
00:50:52,140 --> 00:50:49,569
features really are then maybe you can

1336
00:50:54,749 --> 00:50:52,150
start to say well life could be no more

1337
00:50:56,880 --> 00:50:54,759
common than this or as common as that I

1338
00:50:58,399 --> 00:50:56,890

think a large sample does a lot for

1339
00:51:02,279 --> 00:50:58,409
helping to understand what's happening

1340
00:51:03,930 --> 00:51:02,289
well going back to then how non

1341
00:51:08,789 --> 00:51:03,940
scientists like me

1342
00:51:10,339 --> 00:51:08,799
approach astronomy the idea that you can

1343
00:51:13,410 --> 00:51:10,349
tell what's in a planet's atmosphere

1344
00:51:14,910 --> 00:51:13,420
that that that the light from that

1345
00:51:16,950 --> 00:51:14,920
planet star goes through that atmosphere

1346
00:51:19,140 --> 00:51:16,960
and travels through space to your

1347
00:51:22,730 --> 00:51:19,150
telescope and that there's information

1348
00:51:27,539 --> 00:51:22,740
hidden in the light is just this a

1349
00:51:30,930 --> 00:51:27,549
magical idea right has there been a

1350
00:51:34,740 --> 00:51:30,940
moment where you found yourself stunned

1351
00:51:36,299 --> 00:51:34,750
by a realization like that either as you

1352
00:51:38,519 --> 00:51:36,309
were training to become a researcher or

1353
00:51:41,190 --> 00:51:38,529
since you've started working as a

1354
00:51:44,039 --> 00:51:41,200
professional scientist that just stunned

1355
00:51:45,960 --> 00:51:44,049
you like that I would say the first time

1356
00:51:48,480 --> 00:51:45,970
I looked at Kepler data real Kepler data

1357
00:51:50,190 --> 00:51:48,490
from the spacecraft so I hadn't spent as

1358
00:51:53,309 --> 00:51:50,200
I mentioned a long time looking at

1359
00:51:55,650 --> 00:51:53,319
crappy crappy data from the ground that

1360
00:51:58,859 --> 00:51:55,660
was had weather and gaps because of the

1361
00:52:00,749 --> 00:51:58,869
Sun coming up and telescopes breaking

1362
00:52:02,819 --> 00:52:00,759
and all of these reasons why I didn't

1363
00:52:04,289 --> 00:52:02,829

have good data and then the first and it

1364
00:52:05,730 --> 00:52:04,299
was in the first week after I joined the

1365
00:52:07,680 --> 00:52:05,740
cap of Science office we sat down to

1366
00:52:10,019 --> 00:52:07,690
look at the new batch of data and it was

1367
00:52:11,940 --> 00:52:10,029
just exquisite everything just looked

1368
00:52:13,710 --> 00:52:11,950
like a model like this was exactly what

1369
00:52:15,930 --> 00:52:13,720
they told you a transit would look like

1370
00:52:17,579 --> 00:52:15,940
and it was a real data and so after

1371
00:52:18,900 --> 00:52:17,589
years of not finding planets we

1372
00:52:22,140 --> 00:52:18,910
literally sat there for an hour like

1373
00:52:24,690 --> 00:52:22,150
that's one that's one oh that one's

1374
00:52:26,370 --> 00:52:24,700
interesting this one and I was just

1375
00:52:28,019 --> 00:52:26,380
blown away I was just like this was like

1376
00:52:30,480 --> 00:52:28,029
the culmination of all of those years

1377
00:52:33,120 --> 00:52:30,490
it's just like they're everywhere so it

1378
00:52:35,069 --> 00:52:33,130
was amazing anything like that for you

1379
00:52:36,329 --> 00:52:35,079
call ynv Jesse's experience with the

1380
00:52:39,120 --> 00:52:36,339
Kepler mission this was such a great

1381
00:52:40,799 --> 00:52:39,130
mission the opportunity I had that was

1382
00:52:41,970 --> 00:52:40,809
similar to that was to be involved in

1383
00:52:44,759 --> 00:52:41,980
the repair of the Hubble Space Telescope

1384
00:52:46,440 --> 00:52:44,769
back in 1993 and when it when those

1385
00:52:47,910 --> 00:52:46,450
images came down and showed that finally

1386
00:52:49,980 --> 00:52:47,920
things were in proper focus and we could

1387
00:52:52,230 --> 00:52:49,990
start to see all the things that we had

1388
00:52:54,029 --> 00:52:52,240

expected to see and that that then led

1389
00:52:57,569 --> 00:52:54,039
to this fantastic set of Hubble results

1390
00:52:58,829 --> 00:52:57,579
over the past you know 25 years I'm that

1391
00:53:00,660 --> 00:52:58,839
that was that kind of moment for me that

1392
00:53:04,249 --> 00:53:00,670
I realized I you know hit the big time

1393
00:53:07,740 --> 00:53:04,259
of science what motivates you guys

1394
00:53:10,289 --> 00:53:07,750
personally to study exoplanets what is

1395
00:53:14,430 --> 00:53:10,299
it that makes this particular field of

1396
00:53:16,620 --> 00:53:14,440
science of astronomy so compelling well

1397
00:53:17,760 --> 00:53:16,630
I think it's the opportunity to see the

1398
00:53:19,620 --> 00:53:17,770
diversity of what

1399
00:53:21,540 --> 00:53:19,630
there I enjoy going on travel or hiking

1400
00:53:23,010 --> 00:53:21,550
and seeing the diversity that we have on

1401
00:53:24,480 --> 00:53:23,020
earth all the different environments and

1402
00:53:25,980 --> 00:53:24,490
the earth is so fascinating and

1403
00:53:28,140 --> 00:53:25,990
intricate the idea that there are

1404
00:53:30,630 --> 00:53:28,150
thousands more out there with different

1405
00:53:32,640 --> 00:53:30,640
kinds of life-forms perhaps that that's

1406
00:53:34,470 --> 00:53:32,650
really exciting that that possibility

1407
00:53:36,870 --> 00:53:34,480
and so if we can just take a step toward

1408
00:53:40,350 --> 00:53:36,880
making civilizations discover all that

1409
00:53:42,840 --> 00:53:40,360
extra stuff I would be thrilled for me

1410
00:53:45,270 --> 00:53:42,850
it's really the discovery like the

1411
00:53:48,720 --> 00:53:45,280
exploration the fact that I get to find

1412
00:53:50,670 --> 00:53:48,730
new worlds you know it's one of those

1413
00:53:52,260 --> 00:53:50,680

the this idiom that you hear that you

1414
00:53:53,910 --> 00:53:52,270
know you were born too late to explore

1415
00:53:55,950 --> 00:53:53,920
the earth but born too early to explore

1416
00:53:57,990 --> 00:53:55,960
space I don't feel that way because I'm

1417
00:53:59,310 --> 00:53:58,000
exploring space everyday I'm finding new

1418
00:54:00,720 --> 00:53:59,320
planets all the time and there are new

1419
00:54:02,910 --> 00:54:00,730
worlds and each one is unique and

1420
00:54:04,320 --> 00:54:02,920
interesting so for me it's just it's

1421
00:54:07,109 --> 00:54:04,330
like that hit of dimpling it's like

1422
00:54:11,760 --> 00:54:07,119
another one another one another one so I

1423
00:54:14,760 --> 00:54:11,770
think it's fantastic it's fantastic so

1424
00:54:17,970 --> 00:54:14,770
we wanted to talk a little bit I know

1425
00:54:20,340 --> 00:54:17,980
about about letting how other people can

1426
00:54:21,359 --> 00:54:20,350
be involved in that process of discovery

1427
00:54:23,160 --> 00:54:21,369
even if they're not professional

1428
00:54:25,290 --> 00:54:23,170
scientists the whole idea of citizen

1429
00:54:27,240 --> 00:54:25,300
science and there there are some ways

1430
00:54:29,670 --> 00:54:27,250
that you wanted to talk about about how

1431
00:54:31,349 --> 00:54:29,680
citizen scientists can help with the

1432
00:54:34,349 --> 00:54:31,359
discovery of exoplanets what is what is

1433
00:54:36,720 --> 00:54:34,359
that right so so looking for transits

1434
00:54:39,300 --> 00:54:36,730
around stars I told you you're just

1435
00:54:40,680 --> 00:54:39,310
looking for dips so we have software

1436
00:54:41,880 --> 00:54:40,690
that can do that we have codes that we

1437
00:54:43,380 --> 00:54:41,890
write to look through all these stuff

1438
00:54:46,230 --> 00:54:43,390

that light curves and look for the dips

1439
00:54:49,200 --> 00:54:46,240
but software is not infallible it's not

1440
00:54:51,570 --> 00:54:49,210
perfect what's really good at finding

1441
00:54:53,580 --> 00:54:51,580
dips is the human brain so we're

1442
00:54:54,900 --> 00:54:53,590
excellent at pattern recognition was the

1443
00:54:57,300 --> 00:54:54,910
reason why we knew the difference

1444
00:54:58,560 --> 00:54:57,310
between a tiger and grass right like

1445
00:55:01,109 --> 00:54:58,570
being able to see those stripes was

1446
00:55:02,880 --> 00:55:01,119
important so we're excellent to pattern

1447
00:55:04,770 --> 00:55:02,890
recognition and I can teach you in less

1448
00:55:06,510 --> 00:55:04,780
than five minutes how to find planets

1449
00:55:08,160 --> 00:55:06,520
using the transit method so there's a

1450
00:55:11,490 --> 00:55:08,170
few different websites that you can go

1451
00:55:13,740 --> 00:55:11,500
to launched hosted by the Zooniverse

1452
00:55:16,470 --> 00:55:13,750
platforms universe is a citizen science

1453
00:55:17,970 --> 00:55:16,480
online program where scientists can

1454
00:55:19,349 --> 00:55:17,980
bring their data and then citizen

1455
00:55:20,640 --> 00:55:19,359
scientists can come and help them

1456
00:55:22,859 --> 00:55:20,650
analyze it so there's two different

1457
00:55:24,750 --> 00:55:22,869
exoplanet programs one is called planet

1458
00:55:27,510 --> 00:55:24,760
hunters and one is called exoplanet

1459
00:55:29,700 --> 00:55:27,520
explorers exoplanet explorers was k2

1460
00:55:30,300 --> 00:55:29,710
data planet hunters was kepler daughter

1461
00:55:32,700 --> 00:55:30,310
and

1462
00:55:34,800 --> 00:55:32,710
test data so if you're interested in

1463
00:55:36,720 --> 00:55:34,810

going and looking for these transits so

1464
00:55:38,730 --> 00:55:36,730
the k2 138 system that I showed the

1465
00:55:40,380 --> 00:55:38,740
musical system was discovered by citizen

1466
00:55:42,030 --> 00:55:40,390
scientists they found this amazing

1467
00:55:44,340 --> 00:55:42,040
incredible resonance system which is so

1468
00:55:45,960 --> 00:55:44,350
rich so I encourage you if you're

1469
00:55:47,700 --> 00:55:45,970
interested to go home tonight and go to

1470
00:55:49,320 --> 00:55:47,710
planet hunters org and start looking for

1471
00:55:52,980 --> 00:55:49,330
planets around test data because we need

1472
00:55:54,630 --> 00:55:52,990
your help yeah well there's a 10 million

1473
00:55:57,860 --> 00:55:54,640
stars or so that that test will be

1474
00:56:00,240 --> 00:55:57,870
monitoring over its lifetime yes so

1475
00:56:03,900 --> 00:56:00,250
every one of you could go adopt a star

1476
00:56:05,220 --> 00:56:03,910
and see if it's got a planet or not so

1477
00:56:06,660 --> 00:56:05,230
as you can see as you've heard there are

1478
00:56:08,790 --> 00:56:06,670
all kinds of ways that you can you can

1479
00:56:10,410 --> 00:56:08,800
get involved learn a whole lot more and

1480
00:56:12,330 --> 00:56:10,420
even explore some of these planets and

1481
00:56:14,370 --> 00:56:12,340
and what they might might look like I

1482
00:56:16,530 --> 00:56:14,380
think this is a good place for us to

1483
00:56:20,130 --> 00:56:16,540
hear from you and the audience though

1484
00:56:22,530 --> 00:56:20,140
now and transition to your questions so

1485
00:56:24,660 --> 00:56:22,540
we'll have a microphone down front and

1486
00:56:26,760 --> 00:56:24,670
if you have a question please come on

1487
00:56:28,560 --> 00:56:26,770
down and give us your question and then

1488
00:56:32,520 --> 00:56:28,570

we'll get a few of the questions from

1489
00:56:34,890 --> 00:56:32,530
YouTube in here as well so hi there go

1490
00:56:37,860 --> 00:56:34,900
ahead hi how are you guys tonight

1491
00:56:40,230 --> 00:56:37,870
how do you first I want to thank you

1492
00:56:43,260 --> 00:56:40,240
both for a great lecture not only that

1493
00:56:44,610 --> 00:56:43,270
but also your continued work it gives me

1494
00:56:47,030 --> 00:56:44,620
something to look forward to

1495
00:56:50,070 --> 00:56:47,040
always the data you guys give it back

1496
00:56:52,110 --> 00:56:50,080
but I guess I'd like to combine two

1497
00:56:55,710 --> 00:56:52,120
things you were at the beginning talking

1498
00:56:57,330 --> 00:56:55,720
about how you named stars and planets

1499
00:56:58,380 --> 00:56:57,340
that you find and then you just

1500
00:57:02,010 --> 00:56:58,390
mentioned that I might be able to find

1501
00:57:05,970 --> 00:57:02,020
some I was wondering if I can name one

1502
00:57:07,260 --> 00:57:05,980
Jeff you can give them unofficial names

1503
00:57:09,660 --> 00:57:07,270
and a lot of them actually do have

1504
00:57:11,760 --> 00:57:09,670
unofficial names so the first one that

1505
00:57:14,790 --> 00:57:11,770
we found that has the pure density of

1506
00:57:19,590 --> 00:57:14,800
pure pure water we call it Kevin after

1507
00:57:21,330 --> 00:57:19,600
Kevin Costner Waterworld so some of them

1508
00:57:23,430 --> 00:57:21,340
do have nicknames so I will find one

1509
00:57:26,060 --> 00:57:23,440
where Jeff is appropriate thank you guys

1510
00:57:33,930 --> 00:57:27,990
how's it going thank you for a great

1511
00:57:36,660 --> 00:57:33,940
talk I had two questions the couple

1512
00:57:39,990 --> 00:57:36,670
together given detection from the

1513
00:57:42,330 --> 00:57:40,000

transit method if some other

1514
00:57:43,490 --> 00:57:42,340
civilization somewhere out there is

1515
00:57:45,020 --> 00:57:43,500
looking at

1516
00:57:47,450 --> 00:57:45,030
there would be a good chance that they

1517
00:57:49,820 --> 00:57:47,460
might reciprocally detect us via the

1518
00:57:52,310 --> 00:57:49,830
transit method and so the question I had

1519
00:57:55,280 --> 00:57:52,320
was a test question of the four cameras

1520
00:57:58,430 --> 00:57:55,290
that are displayed on the 13 shots they

1521
00:57:59,690 --> 00:57:58,440
have the pol gets imaged 13 times and in

1522
00:58:01,940 --> 00:57:59,700
the north Northern Hemisphere and

1523
00:58:05,000 --> 00:58:01,950
southern hemisphere we're skipping the

1524
00:58:06,380 --> 00:58:05,010
ecliptic and if anybody is going to see

1525
00:58:06,830 --> 00:58:06,390
us they're gonna see us along the

1526
00:58:15,020 --> 00:58:06,840
ecliptic

1527
00:58:18,290 --> 00:58:15,030
and plans for TST and torching sensors

1528
00:58:20,690 --> 00:58:18,300
with the Sun and the and the moon what

1529
00:58:22,010 --> 00:58:20,700
is the main reason for not scanning the

1530
00:58:23,360 --> 00:58:22,020
ecliptic because wouldn't that be the

1531
00:58:27,260 --> 00:58:23,370
neighborhood we want to look at to find

1532
00:58:29,210 --> 00:58:27,270
fine friends sure so actually said the

1533
00:58:30,830 --> 00:58:29,220
prime the prime test mission the first

1534
00:58:31,790 --> 00:58:30,840
two years is doing it as you said the

1535
00:58:33,710 --> 00:58:31,800
southern hemisphere and then the

1536
00:58:35,480 --> 00:58:33,720
northern hemisphere and the reason they

1537
00:58:36,650 --> 00:58:35,490
they kind of skipped the ecliptic was

1538
00:58:38,870 --> 00:58:36,660

because they really wanted to have that

1539
00:58:40,340 --> 00:58:38,880
overlap region at the poles so that they

1540
00:58:41,060 --> 00:58:40,350
could look for longer period planets

1541
00:58:43,160 --> 00:58:41,070
down there

1542
00:58:44,660 --> 00:58:43,170
the extended test mission there's no

1543
00:58:46,430 --> 00:58:44,670
reason why the test spacecraft has to

1544
00:58:48,350 --> 00:58:46,440
stop after two years in the orbit that

1545
00:58:49,310 --> 00:58:48,360
it's in actually the moon keeps it in

1546
00:58:51,590 --> 00:58:49,320
the orbit that it's in so it doesn't

1547
00:58:54,290 --> 00:58:51,600
need any fuel unlike Kepler which ran

1548
00:58:55,760 --> 00:58:54,300
out of fuel recently so in the extended

1549
00:58:57,350 --> 00:58:55,770
mission there is a proposal which still

1550
00:58:58,970 --> 00:58:57,360
has to get accepted by NASA for them to

1551
00:59:01,250 --> 00:58:58,980
turn those four cameras sideways and do

1552
00:59:02,960 --> 00:59:01,260
the ecliptic in a few chunks so we are

1553
00:59:04,490 --> 00:59:02,970
trying to get back to the ecliptic it's

1554
00:59:06,080 --> 00:59:04,500
just for the first two years we wanted

1555
00:59:07,850 --> 00:59:06,090
to get that coverage at the poles those

1556
00:59:09,590 --> 00:59:07,860
poles are also the James Webb Webb

1557
00:59:10,940 --> 00:59:09,600
continuous viewing zones of planets we

1558
00:59:13,610 --> 00:59:10,950
find they will be able to be observed by

1559
00:59:15,320 --> 00:59:13,620
James Webb all the time okay and the

1560
00:59:18,200 --> 00:59:15,330
companion question is what are your

1561
00:59:21,880 --> 00:59:18,210
thoughts on Drake's and new exoplanet

1562
00:59:25,090 --> 00:59:21,890
data and where the numbers kind of sit

1563
00:59:27,680 --> 00:59:25,100

the Drake Equation oh the Drake a 2's

1564
00:59:29,390 --> 00:59:27,690
right so this is something that is

1565
00:59:30,890 --> 00:59:29,400
important to the Future missions and

1566
00:59:33,170 --> 00:59:30,900
estimating how many plants you might see

1567
00:59:34,370 --> 00:59:33,180
is what's the frequency of them so I

1568
00:59:36,470 --> 00:59:34,380
mean jesse has really been one of the

1569
00:59:40,070 --> 00:59:36,480
leaders and telling how much Kepler was

1570
00:59:42,830 --> 00:59:40,080
able to add to that question I should

1571
00:59:44,740 --> 00:59:42,840
really defer to your answer I need the

1572
00:59:48,880 --> 00:59:44,750
new answer I always ask you the the

1573
00:59:51,890 --> 00:59:48,890
we've assumed about a 25% frequency for

1574
00:59:53,390 --> 00:59:51,900
rocky planets in habitable zones when

1575
00:59:55,539 --> 00:59:53,400
we've been planning the hab X and Louvre

1576
00:59:57,849 --> 00:59:55,549
our mission I

1577
00:59:59,200 --> 00:59:57,859
so some reanalysis of the Kepler data is

1578
01:00:00,910 --> 00:59:59,210
showing some smaller numbers some is

1579
01:00:02,200 --> 01:00:00,920
showing some larger numbers but that's

1580
01:00:04,329 --> 01:00:02,210
sort of the first step in the Drake

1581
01:00:05,650 --> 01:00:04,339
Equation that you've referred to is you

1582
01:00:07,989 --> 01:00:05,660
know how many stars are there like the

1583
01:00:09,370 --> 01:00:07,999
Sun how many of them have planets like

1584
01:00:11,200 --> 01:00:09,380
the earth at the right temperature how

1585
01:00:13,599 --> 01:00:11,210
many of them have the right composition

1586
01:00:15,370 --> 01:00:13,609
how many of them have life develop and

1587
01:00:16,930 --> 01:00:15,380
so forth we don't know how to answer

1588
01:00:19,299 --> 01:00:16,940

some of the terms in that equation but

1589
01:00:22,630 --> 01:00:19,309
the ones at the start we are really

1590
01:00:29,319 --> 01:00:22,640
answering scientifically now yeah thank

1591
01:00:31,960 --> 01:00:29,329
you so my understanding is that both the

1592
01:00:35,049 --> 01:00:31,970
transit method and the the Doppler where

1593
01:00:37,059 --> 01:00:35,059
you look for the who is is a highly

1594
01:00:39,730 --> 01:00:37,069
biased toward edge on it has to be edge

1595
01:00:42,579 --> 01:00:39,740
on systems you're looking at but my

1596
01:00:44,910 --> 01:00:42,589
understanding is the image message that

1597
01:00:48,249 --> 01:00:44,920
you're hoping to do could look at a

1598
01:00:53,380 --> 01:00:48,259
system that is not edge-on correct so

1599
01:00:55,269 --> 01:00:53,390
what is the expected gain how much how

1600
01:00:58,239 --> 01:00:55,279
many more systems would you see at a

1601
01:01:01,059 --> 01:00:58,249
given distance that are I mean just what

1602
01:01:02,950 --> 01:01:01,069
is the geometry in terms of of how many

1603
01:01:05,739 --> 01:01:02,960
more systems you would see right well so

1604
01:01:07,239 --> 01:01:05,749
the 25% number that I gave for the

1605
01:01:08,620 --> 01:01:07,249
frequency of rocky planets in a

1606
01:01:10,420 --> 01:01:08,630
habitable zone that came out of Kepler

1607
01:01:12,430 --> 01:01:10,430
it already includes a correction factor

1608
01:01:14,140 --> 01:01:12,440
for the fact that the Kepler could only

1609
01:01:16,029 --> 01:01:14,150
see the ones that were in edge-on orbits

1610
01:01:18,190 --> 01:01:16,039
so we've gone from a much you know lower

1611
01:01:20,729 --> 01:01:18,200
detection rate of Kepler to an estimated

1612
01:01:23,559 --> 01:01:20,739
detection at all inclination angles of

1613
01:01:26,710 --> 01:01:23,569

25% you are right that the imaging

1614
01:01:28,749 --> 01:01:26,720
missions can show us the planets and the

1615
01:01:30,519 --> 01:01:28,759
entire system at once without waiting

1616
01:01:32,470 --> 01:01:30,529
for them to transit and for any

1617
01:01:35,349 --> 01:01:32,480
inclination of the orbit so that'll let

1618
01:01:37,630 --> 01:01:35,359
us really investigate our neighbors more

1619
01:01:40,150 --> 01:01:37,640
fully than the transit method can yeah

1620
01:01:41,140 --> 01:01:40,160
but it'll be limited to shorter range is

1621
01:01:43,239 --> 01:01:41,150
what you're saying so would you say

1622
01:01:45,039 --> 01:01:43,249
neighbors yeah that's right I mean with

1623
01:01:46,960 --> 01:01:45,049
the transit method it doesn't really

1624
01:01:48,519 --> 01:01:46,970
matter how far away the star is just has

1625
01:01:51,130 --> 01:01:48,529
to be bright enough to give you enough

1626
01:01:53,170 --> 01:01:51,140
signal whereas in imaging if the system

1627
01:01:54,999 --> 01:01:53,180
is twice as far away then the planet

1628
01:01:57,069 --> 01:01:55,009
appears to be in a smaller angular

1629
01:01:59,859 --> 01:01:57,079
separation from its star so it's harder

1630
01:02:02,529 --> 01:01:59,869
to do so imaging is the nearby system

1631
01:02:04,239 --> 01:02:02,539
approach thank you United States the

1632
01:02:07,530 --> 01:02:04,249
further way that star is the further you

1633
01:02:11,380 --> 01:02:07,540
have to drive to see your spotlight yeah

1634
01:02:15,460 --> 01:02:11,390
it strikes me that much of the exoplanet

1635
01:02:19,569 --> 01:02:15,470
research is is based upon finding life

1636
01:02:22,890 --> 01:02:19,579
on other you know other planets assuming

1637
01:02:26,829 --> 01:02:22,900
the same chemical properties as on earth

1638
01:02:29,770 --> 01:02:26,839

do you think that's necessarily so I

1639
01:02:33,490 --> 01:02:29,780
mean even even on earth four billion

1640
01:02:38,200 --> 01:02:33,500
years ago I would the the atmosphere was

1641
01:02:42,760 --> 01:02:38,210
Tod would be toxic to us so how are we

1642
01:02:45,789 --> 01:02:42,770
going to I mean you can have like silica

1643
01:02:48,339 --> 01:02:45,799
can make self-replicating crystals of

1644
01:02:52,450 --> 01:02:48,349
itself which could be construed as life

1645
01:02:54,789 --> 01:02:52,460
right so I'm curious as to ask your

1646
01:02:56,349 --> 01:02:54,799
biological research into other chemical

1647
01:02:58,030 --> 01:02:56,359
pathways that life could follow that

1648
01:03:00,069 --> 01:02:58,040
doesn't rely on the same chemistry that

1649
01:03:01,569 --> 01:03:00,079
we do for instance Titan with its

1650
01:03:04,599 --> 01:03:01,579
methane lakes like could you have

1651
01:03:06,579 --> 01:03:04,609
something that lived in that in terms of

1652
01:03:09,490 --> 01:03:06,589
how we look for that because it's such

1653
01:03:11,740 --> 01:03:09,500
an unconstrained problem we don't really

1654
01:03:13,329 --> 01:03:11,750
have plans to like design missions to

1655
01:03:14,770 --> 01:03:13,339
look for that kind of thing because we

1656
01:03:16,690 --> 01:03:14,780
don't know what we're looking for you if

1657
01:03:18,069 --> 01:03:16,700
something if something emerges on our

1658
01:03:19,599 --> 01:03:18,079
studies that we're doing at the moment

1659
01:03:21,940 --> 01:03:19,609
we're like here's another critical

1660
01:03:23,319 --> 01:03:21,950
pathway where you could have some kind

1661
01:03:25,839 --> 01:03:23,329
of you know it's all about energy

1662
01:03:27,910 --> 01:03:25,849
gradients right if there's something

1663
01:03:29,140 --> 01:03:27,920

that works if there's some alternative

1664
01:03:30,700 --> 01:03:29,150
biology that works that can give

1665
01:03:32,079 --> 01:03:30,710
predictions we can go look for that but

1666
01:03:34,359 --> 01:03:32,089
at the moment we have no predictions and

1667
01:03:35,710 --> 01:03:34,369
it's hard to go to NASA and say please

1668
01:03:37,089 --> 01:03:35,720
give me money to build a big telescope

1669
01:03:39,099 --> 01:03:37,099
but I don't know what I'm looking for

1670
01:03:43,329 --> 01:03:39,109
yet but I know it when I see it I'm sure

1671
01:03:47,109 --> 01:03:43,339
it is let's take a question from the

1672
01:03:49,390 --> 01:03:47,119
YouTube audience blacks and asks us what

1673
01:03:53,220 --> 01:03:49,400
is the most distant exoplanet ever

1674
01:03:55,450 --> 01:03:53,230
detected are they all in our galaxy or

1675
01:03:57,910 --> 01:03:55,460
there was a claim of one of them in the

1676
01:03:59,770 --> 01:03:57,920
Magellanic Clouds a claim of a micro

1677
01:04:03,970 --> 01:03:59,780
lensing event in another galaxy but it

1678
01:04:07,329 --> 01:04:03,980
was fairly dicey dicey is the word I

1679
01:04:08,950 --> 01:04:07,339
would use so the most distant planets we

1680
01:04:11,260 --> 01:04:08,960
found are actually towards the middle of

1681
01:04:13,059 --> 01:04:11,270
the galaxy and that's using this method

1682
01:04:16,030 --> 01:04:13,069
that I just mentioned the car mentioned

1683
01:04:17,559 --> 01:04:16,040
the micro lensing method which is you

1684
01:04:18,579 --> 01:04:17,569
need to have basically from our

1685
01:04:18,990 --> 01:04:18,589
cleansing director you need to have this

1686
01:04:20,700 --> 01:04:19,000
back

1687
01:04:22,290 --> 01:04:20,710
on the screen of stars and then a star

1688
01:04:24,240 --> 01:04:22,300

in the foreground it has a planet around

1689
01:04:25,830 --> 01:04:24,250
it and then the movement of this star on

1690
01:04:27,660 --> 01:04:25,840
the background star you can work out

1691
01:04:28,830 --> 01:04:27,670
that there's a planet there so we need

1692
01:04:30,270 --> 01:04:28,840
to be looking towards the center of the

1693
01:04:32,070 --> 01:04:30,280
galaxy where we have this big background

1694
01:04:33,780 --> 01:04:32,080
screen of stars to find these so all of

1695
01:04:37,530 --> 01:04:33,790
the most distant star distant planets

1696
01:04:39,930 --> 01:04:37,540
that we found which are in the like hmm

1697
01:04:41,280 --> 01:04:39,940
about ten thousand parsecs I think is

1698
01:04:43,230 --> 01:04:41,290
like the farthest one away we found our

1699
01:04:45,600 --> 01:04:43,240
all towards the center of the galaxy ten

1700
01:04:48,150 --> 01:04:45,610
thousand parsecs and light-years like

1701
01:04:51,990 --> 01:04:48,160
that means anything to anybody but our

1702
01:04:55,230 --> 01:04:52,000
second between here and the alright hi

1703
01:04:57,390 --> 01:04:55,240
there okay I guess it connects a little

1704
01:04:59,220 --> 01:04:57,400
bit to what you just said the the

1705
01:05:02,520 --> 01:04:59,230
microlensing you've been talking about

1706
01:05:04,530 --> 01:05:02,530
you sort of promised to maybe explain a

1707
01:05:08,400 --> 01:05:04,540
little bit more about it I was just

1708
01:05:11,430 --> 01:05:08,410
wondering what the technology there is

1709
01:05:15,060 --> 01:05:11,440
in compostable opposed to what we had

1710
01:05:18,300 --> 01:05:15,070
before and is it already developed or is

1711
01:05:20,520 --> 01:05:18,310
it is there tests that have you have you

1712
01:05:22,050 --> 01:05:20,530
shot something from Earth is it possible

1713
01:05:23,640 --> 01:05:22,060

to see it somewhere is it even possible

1714
01:05:25,620 --> 01:05:23,650
I mean I don't understand how it works

1715
01:05:28,230 --> 01:05:25,630
completely micro buzzing technique is

1716
01:05:29,790 --> 01:05:28,240
another way of counting planets it uses

1717
01:05:31,200 --> 01:05:29,800
the same kind of measurement as the

1718
01:05:33,060 --> 01:05:31,210
transit method where he watched the

1719
01:05:35,610 --> 01:05:33,070
brightness of a star for something to

1720
01:05:36,990 --> 01:05:35,620
change but instead of the planet passing

1721
01:05:39,300 --> 01:05:37,000
in front of the star I'm blocking some

1722
01:05:40,950 --> 01:05:39,310
of its light now what's happening is for

1723
01:05:43,170 --> 01:05:40,960
a very distant star and a planet in

1724
01:05:45,030 --> 01:05:43,180
between the planet passes in front of

1725
01:05:47,370 --> 01:05:45,040
the star in actually gravitationally

1726
01:05:50,430 --> 01:05:47,380
magnifies the star according to the

1727
01:05:52,530 --> 01:05:50,440
theory of general relativity I mean how

1728
01:05:55,320 --> 01:05:52,540
do you capture it is it so you just very

1729
01:05:58,080 --> 01:05:55,330
patiently take image after image after

1730
01:06:00,150 --> 01:05:58,090
image staring at a very dense field of

1731
01:06:02,010 --> 01:06:00,160
stars and you'll see some star whose

1732
01:06:04,470 --> 01:06:02,020
brightness slowly starts to go up and

1733
01:06:06,930 --> 01:06:04,480
then after the lensing is finished it

1734
01:06:08,970 --> 01:06:06,940
starts to go back down and then if that

1735
01:06:10,530 --> 01:06:08,980
foreground star has a planet around it

1736
01:06:12,540 --> 01:06:10,540
there'll be a little blip that lasts for

1737
01:06:14,040 --> 01:06:12,550
a day or two where the planet lens is

1738
01:06:16,470 --> 01:06:14,050

the light of that distant background

1739
01:06:18,540 --> 01:06:16,480
star so these are great for telling us

1740
01:06:20,730 --> 01:06:18,550
how many more planets are out there it's

1741
01:06:23,280 --> 01:06:20,740
it's also though frustrating because

1742
01:06:24,930 --> 01:06:23,290
once the event is over it never repeats

1743
01:06:27,060 --> 01:06:24,940
so you could never go back and study

1744
01:06:29,340 --> 01:06:27,070
that planet again and get a spectrum of

1745
01:06:31,440 --> 01:06:29,350
it for example but nevertheless this has

1746
01:06:32,220 --> 01:06:31,450
got you know such promise for explaining

1747
01:06:33,780 --> 01:06:32,230
how many

1748
01:06:36,329 --> 01:06:33,790
kinds of planets there are out there

1749
01:06:38,370 --> 01:06:36,339
that w first emission is going to do a

1750
01:06:42,569 --> 01:06:38,380
lot of this when it launches in the mid

1751
01:06:44,520 --> 01:06:42,579
2020s so exoplanet study studies in

1752
01:06:47,370 --> 01:06:44,530
general involve a lot of staring and

1753
01:06:49,020 --> 01:06:47,380
waiting one patch of sky that's what

1754
01:06:50,460 --> 01:06:49,030
Kepler did right I mean it you just pick

1755
01:06:52,560 --> 01:06:50,470
they picked a patch of sky why do they

1756
01:06:54,540 --> 01:06:52,570
pick that particular direction to look

1757
01:06:56,430 --> 01:06:54,550
in with Kepler oh that's a good question

1758
01:06:59,910 --> 01:06:56,440
so not that your other questions have

1759
01:07:03,450 --> 01:06:59,920
been good precedent so it was a balance

1760
01:07:04,950 --> 01:07:03,460
they had to trade having enough stars so

1761
01:07:06,180 --> 01:07:04,960
that there was some chance of some of

1762
01:07:07,859 --> 01:07:06,190
them transiting so as we've talked about

1763
01:07:09,030 --> 01:07:07,869

there's a lot of stars that won't have

1764
01:07:10,980 --> 01:07:09,040
transiting planets cuz they're just not

1765
01:07:12,750 --> 01:07:10,990
lined up the right way so you have to

1766
01:07:14,250 --> 01:07:12,760
survey hundreds of thousands of stars to

1767
01:07:15,930 --> 01:07:14,260
have a good chance of finding the ones

1768
01:07:18,000 --> 01:07:15,940
that are lined up the right way so it's

1769
01:07:19,560 --> 01:07:18,010
an inefficient survey mechanism but if

1770
01:07:22,020 --> 01:07:19,570
you get too crowded if you're staring at

1771
01:07:23,730 --> 01:07:22,030
the Galactic bulge then you have many

1772
01:07:24,839 --> 01:07:23,740
stars along the same line of sight and

1773
01:07:27,270 --> 01:07:24,849
you don't know where the planet is and

1774
01:07:28,589 --> 01:07:27,280
it's very confusing so we had to kind of

1775
01:07:30,750 --> 01:07:28,599
get a little bit out of the Galactic

1776
01:07:32,609 --> 01:07:30,760
plane but not too far so they chose this

1777
01:07:33,870 --> 01:07:32,619
specific field of fuel to balance that

1778
01:07:37,460 --> 01:07:33,880
there were two hundred thousand stars

1779
01:07:39,540 --> 01:07:37,470
there that were enough but not too many

1780
01:07:42,210 --> 01:07:39,550
another question from our YouTube

1781
01:07:44,790 --> 01:07:42,220
audience Gary Hampton asks have we

1782
01:07:47,099 --> 01:07:44,800
noticed patterns in the materials

1783
01:07:49,500 --> 01:07:47,109
exoplanets contain in certain systems

1784
01:07:52,710 --> 01:07:49,510
are there I think that's asking about

1785
01:07:53,910 --> 01:07:52,720
the composition right well certainly in

1786
01:07:57,059 --> 01:07:53,920
terms of density there have been

1787
01:07:58,710 --> 01:07:57,069
patterns that have been seen yes so one

1788
01:08:00,349 --> 01:07:58,720

of the interesting things we found the

1789
01:08:03,059 --> 01:08:00,359
super-earths that I was talking about

1790
01:08:04,559 --> 01:08:03,069
there actually seemed to be two kinds of

1791
01:08:06,180 --> 01:08:04,569
super Earths the ones that are more

1792
01:08:08,640 --> 01:08:06,190
rocky and the ones that are more

1793
01:08:12,180 --> 01:08:08,650
volatile rich they have things more like

1794
01:08:14,010 --> 01:08:12,190
Neptune or Uranus and why some planets

1795
01:08:15,210 --> 01:08:14,020
end up becoming the the smaller ones and

1796
01:08:16,590 --> 01:08:15,220
why some of them end up becoming the

1797
01:08:17,940 --> 01:08:16,600
bigger ones is still a mystery there's a

1798
01:08:19,829 --> 01:08:17,950
bunch of different theories about why a

1799
01:08:21,300 --> 01:08:19,839
planet would decide to shed its

1800
01:08:22,890 --> 01:08:21,310
atmosphere and get us to become small

1801
01:08:24,900 --> 01:08:22,900
rocky or hold on to a bigger atmosphere

1802
01:08:26,550 --> 01:08:24,910
so that's one of the questions we're

1803
01:08:28,229 --> 01:08:26,560
trying to answer the other thing that's

1804
01:08:30,300 --> 01:08:28,239
really interesting that we'd really love

1805
01:08:32,220 --> 01:08:30,310
to know for jay diversity some planets

1806
01:08:34,559 --> 01:08:32,230
we looked at a cloudy and some of them

1807
01:08:36,959 --> 01:08:34,569
are clear so when a planet is cloudy

1808
01:08:38,370 --> 01:08:36,969
it's hard to see into its atmosphere so

1809
01:08:40,470 --> 01:08:38,380
this transmission spectroscopy this

1810
01:08:42,249 --> 01:08:40,480
backlit spectroscopy that Kyle was

1811
01:08:43,479 --> 01:08:42,259
talking about if there's just cry

1812
01:08:44,769 --> 01:08:43,489
the atmosphere and the atmosphere is

1813
01:08:47,079 --> 01:08:44,779

just opaque and you don't get to see

1814
01:08:48,849 --> 01:08:47,089
anything in there and so far it's been

1815
01:08:50,079 --> 01:08:48,859
hard for us to predict which planets are

1816
01:08:52,269 --> 01:08:50,089
gonna be cloudy and which ones are gonna

1817
01:08:54,189 --> 01:08:52,279
be clear so there's a lot of work going

1818
01:08:55,329 --> 01:08:54,199
into trying to see if there's a pattern

1819
01:08:57,339 --> 01:08:55,339
because if there is an underlying

1820
01:08:58,599 --> 01:08:57,349
pattern we know not to point j2 as tier

1821
01:09:01,689 --> 01:08:58,609
the cloudy ones will point about the

1822
01:09:02,620 --> 01:09:01,699
clear ones yeah having more spectra is

1823
01:09:04,059 --> 01:09:02,630
really going to help answer that

1824
01:09:06,609 --> 01:09:04,069
question if we only have a couple dozen

1825
01:09:08,200 --> 01:09:06,619
planets with spectra right now it's hard

1826
01:09:10,240 --> 01:09:08,210
to see patterns in a sample that's small

1827
01:09:14,379 --> 01:09:10,250
so ask again when we've got a couple

1828
01:09:16,930 --> 01:09:14,389
hundred there's also if I'm not mistaken

1829
01:09:19,329 --> 01:09:16,940
there's a there are patterns in in the

1830
01:09:20,769 --> 01:09:19,339
stars in the composition if we're

1831
01:09:23,109 --> 01:09:20,779
talking about composition this the

1832
01:09:25,209 --> 01:09:23,119
compositions of the stars that have the

1833
01:09:26,919 --> 01:09:25,219
planets that can help you predict some

1834
01:09:28,899 --> 01:09:26,929
things about the planetary system right

1835
01:09:29,979 --> 01:09:28,909
yes so actually this is very relevant to

1836
01:09:31,930 --> 01:09:29,989
my interest because I just put in a

1837
01:09:34,509 --> 01:09:31,940
proposal today to the NASA test mission

1838
01:09:36,789 --> 01:09:34,519

to look around the most metal-poor stars

1839
01:09:38,319 --> 01:09:36,799
so stars have a certain amount of heavy

1840
01:09:39,849 --> 01:09:38,329
elements in them mostly their hydrogen

1841
01:09:41,799 --> 01:09:39,859
and helium but they have some heavier

1842
01:09:44,140 --> 01:09:41,809
things in them too but some stars have a

1843
01:09:45,519 --> 01:09:44,150
lot more of that than other stars and we

1844
01:09:47,649 --> 01:09:45,529
think that the amount of heavy elements

1845
01:09:49,479 --> 01:09:47,659
that a star has in it might be related

1846
01:09:50,950 --> 01:09:49,489
to how many planets that can form so

1847
01:09:52,269 --> 01:09:50,960
stars with a lot of heavy elements might

1848
01:09:53,890 --> 01:09:52,279
be able to form more planets because

1849
01:09:55,299 --> 01:09:53,900
there's just more heavy stuff in the

1850
01:09:57,580 --> 01:09:55,309
disk that the star and the planets form

1851
01:10:00,729 --> 01:09:57,590
out of but no one's been able to study

1852
01:10:02,169 --> 01:10:00,739
the very most metal-poor stars but tests

1853
01:10:04,120 --> 01:10:02,179
because it's doing almost the whole sky

1854
01:10:06,069 --> 01:10:04,130
is looking at tens of thousands of these

1855
01:10:07,600 --> 01:10:06,079
very metal-poor stars so the proposal

1856
01:10:09,430 --> 01:10:07,610
that I put in today was to let me look

1857
01:10:11,229 --> 01:10:09,440
for planets around those because if we

1858
01:10:13,870 --> 01:10:11,239
find planets around these stars it'll be

1859
01:10:15,100 --> 01:10:13,880
you know like a bus coming through these

1860
01:10:16,330 --> 01:10:15,110
theories that says you can't form

1861
01:10:19,899 --> 01:10:16,340
planets around them and I love that kind

1862
01:10:21,910 --> 01:10:19,909
of thing well there are it was evidence

1863
01:10:23,919 --> 01:10:21,920

already for stars that have a lot of

1864
01:10:25,720 --> 01:10:23,929
metal in them that has elements other

1865
01:10:27,970 --> 01:10:25,730
than hydrogen and helium that they have

1866
01:10:29,470 --> 01:10:27,980
a more frequent occurrence of giant

1867
01:10:31,479 --> 01:10:29,480
planets like Jupiter this was found from

1868
01:10:34,720 --> 01:10:31,489
the early studies with a radial velocity

1869
01:10:36,850 --> 01:10:34,730
method in the 2000s so there's a very

1870
01:10:38,560 --> 01:10:36,860
definitely this trend that the the stars

1871
01:10:42,279 --> 01:10:38,570
that have more metal content seem to

1872
01:10:43,959 --> 01:10:42,289
have more giant planets that's my while

1873
01:10:45,160 --> 01:10:43,969
that is fascinating my favorite take

1874
01:10:47,350 --> 01:10:45,170
away from tonight is the fact that

1875
01:10:50,470 --> 01:10:47,360
astronomers refer to everything heavier

1876
01:10:52,500 --> 01:10:50,480
than helium as metal well look at your

1877
01:10:54,790 --> 01:10:52,510
periodic table

1878
01:10:56,950 --> 01:10:54,800
okay so we have one more question

1879
01:11:00,120 --> 01:10:56,960
tonight and it comes from YouTube it's

1880
01:11:02,560 --> 01:11:00,130
Gary Hampton who asks do we know about

1881
01:11:05,230 --> 01:11:02,570
exoplanets that are close to black holes

1882
01:11:07,120 --> 01:11:05,240
and I'm actually going to add on to

1883
01:11:09,580 --> 01:11:07,130
Gary's question because black holes are

1884
01:11:13,150 --> 01:11:09,590
dead stars I do we know about black

1885
01:11:15,700 --> 01:11:13,160
holes or any kind of you know star at

1886
01:11:17,080 --> 01:11:15,710
the end of its life or a dead star well

1887
01:11:19,270 --> 01:11:17,090
that refers back to this slide that

1888
01:11:22,150 --> 01:11:19,280

Jesse showed with the the different

1889
01:11:24,790 --> 01:11:22,160
choices for the first exoplanet in 1992

1890
01:11:27,460 --> 01:11:24,800
radio astronomers found that a pulsar

1891
01:11:30,190 --> 01:11:27,470
which is a dead remnant of a supernova

1892
01:11:32,080 --> 01:11:30,200
explosion from a massive star was

1893
01:11:33,250 --> 01:11:32,090
actually jiggling around because it had

1894
01:11:35,350 --> 01:11:33,260
a planet around it that seemed to be

1895
01:11:37,360 --> 01:11:35,360
roughly the mass of the moon and it was

1896
01:11:39,430 --> 01:11:37,370
even a second planet or asteroid like

1897
01:11:42,010 --> 01:11:39,440
object that was detected just from

1898
01:11:44,470 --> 01:11:42,020
watching how the radio signals played

1899
01:11:46,180 --> 01:11:44,480
out so not a black hole but something

1900
01:11:48,670 --> 01:11:46,190
pretty close to it the dead remnant of a

1901
01:11:51,640 --> 01:11:48,680
star having a planet searches of other

1902
01:11:54,010 --> 01:11:51,650
neutron stars and pulsars have not found

1903
01:11:55,750 --> 01:11:54,020
that this is very common and I can't

1904
01:11:57,700 --> 01:11:55,760
think I'm scanning my brain I'm scanning

1905
01:11:59,680 --> 01:11:57,710
my mental NASA exoplanet archive I don't

1906
01:12:00,760 --> 01:11:59,690
think we have found any that are in any

1907
01:12:02,620 --> 01:12:00,770
way associated with black holes

1908
01:12:05,230 --> 01:12:02,630
unfortunately we haven't found them but

1909
01:12:07,630 --> 01:12:05,240
are they are they conceivable there is

1910
01:12:10,150 --> 01:12:07,640
it possible for a for a system to have a

1911
01:12:11,590 --> 01:12:10,160
black hole with planets interesting so

1912
01:12:13,330 --> 01:12:11,600
when the star gets to end of its life

1913
01:12:15,640 --> 01:12:13,340

and go supernova and collapses down into

1914
01:12:17,620 --> 01:12:15,650
a black hole if there were planets

1915
01:12:18,790 --> 01:12:17,630
around them what would happen to them so

1916
01:12:20,800 --> 01:12:18,800
I think a lot of them would get blown

1917
01:12:22,510 --> 01:12:20,810
away by the supernova explosion there

1918
01:12:24,100 --> 01:12:22,520
might be remnants left behind the

1919
01:12:25,930 --> 01:12:24,110
question about these pulsar planets is

1920
01:12:27,400 --> 01:12:25,940
whether they're leftovers of the

1921
01:12:29,320 --> 01:12:27,410
original planets that were there or

1922
01:12:31,450 --> 01:12:29,330
whether after the explosion some matter

1923
01:12:34,240 --> 01:12:31,460
in the disk re coalesced and reforms

1924
01:12:35,860 --> 01:12:34,250
like second-generation planets so there

1925
01:12:37,600 --> 01:12:35,870
could be second-generation planets

1926
01:12:39,790 --> 01:12:37,610
around black holes they would be

1927
01:12:41,560 --> 01:12:39,800
incredibly difficult to find black holes

1928
01:12:42,790 --> 01:12:41,570
are notoriously hard to find you know

1929
01:12:47,410 --> 01:12:42,800
there's no transit method with black

1930
01:12:49,510 --> 01:12:47,420
holes yeah I think that's all the time

1931
01:12:51,220 --> 01:12:49,520
we have for tonight thanks to everyone

1932
01:12:53,650 --> 01:12:51,230
for being here and for watching online

1933
01:12:56,290 --> 01:12:53,660
and of course to our speakers please

1934
01:12:58,390 --> 01:12:56,300
join us again next month for a look at

1935
01:13:00,280 --> 01:12:58,400
clouds and their relationship to our

1936
01:13:10,350 --> 01:13:00,290
climate so we'll see you then good night