

1
00:00:00,000 --> 00:00:05,370
whilst our Rs Papas and if you want to

2
00:00:02,939 --> 00:00:07,830
know about it well simply flip over we

3
00:00:05,370 --> 00:00:09,719
have a description of it along with

4
00:00:07,830 --> 00:00:12,300
pointers for where you can get even more

5
00:00:09,718 --> 00:00:13,859
information about it grab those on your

6
00:00:12,300 --> 00:00:18,320
way out

7
00:00:13,859 --> 00:00:22,350
tonight we have how to find an inhabited

8
00:00:18,320 --> 00:00:24,600
exoplanet and purposely intriguing title

9
00:00:22,350 --> 00:00:28,289
which I know is going to also be an

10
00:00:24,600 --> 00:00:30,929
intriguing talk tonight next month a

11
00:00:28,289 --> 00:00:33,570
view from Mission Operations a lot of

12
00:00:30,928 --> 00:00:36,808
things that go on in the background

13
00:00:33,570 --> 00:00:39,390
behind all of the science results that

14
00:00:36,808 --> 00:00:41,729
we per we present how we actually

15
00:00:39,390 --> 00:00:45,299
operate the missions Courtney McManus as

16
00:00:41,729 --> 00:00:48,569
has agreed to give a talk about this

17
00:00:45,299 --> 00:00:50,729
this very important topic in September

18
00:00:48,570 --> 00:00:52,829
Nolan Walborn he's spoken here a few

19
00:00:50,729 --> 00:00:54,869
times we'll be talking about active

20
00:00:52,829 --> 00:00:57,989
luminous blue variables in the Large

21
00:00:54,869 --> 00:01:00,689
Magellanic Cloud that's a mouthful right

22
00:00:57,988 --> 00:01:02,578
that there are variable stars there are

23
00:01:00,689 --> 00:01:04,920
blue stars there are luminous blue

24
00:01:02,579 --> 00:01:07,049
variables and they are even active and

25
00:01:04,920 --> 00:01:09,750
they actually tell you an awful lot

26
00:01:07,049 --> 00:01:12,240
Nolan promises that he will challenge

27
00:01:09,750 --> 00:01:15,060
you okay so bring your thinking caps in

28
00:01:12,239 --> 00:01:18,239
September when Nolan speaks and in

29

00:01:15,060 --> 00:01:18,868
October one you won't want to miss bring

30
00:01:18,239 --> 00:01:22,140
the kids

31
00:01:18,868 --> 00:01:24,180
Cassini's grand finale at Saturn Cassini

32
00:01:22,140 --> 00:01:26,728
has been orbiting Saturn for over a

33
00:01:24,180 --> 00:01:29,549
decade I forget when they got there do

34
00:01:26,728 --> 00:01:32,459
you remember when it got to like 2006 or

35
00:01:29,549 --> 00:01:34,618
something so it is just amazing what

36
00:01:32,459 --> 00:01:37,259
Cassini has found at Saturday its grand

37
00:01:34,618 --> 00:01:38,519
finale is in September and our own

38
00:01:37,259 --> 00:01:41,430
bonnie monkey from the office of public

39
00:01:38,519 --> 00:01:43,949
outreach who specializes in saturn will

40
00:01:41,430 --> 00:01:46,200
be giving the talk to tell you how it

41
00:01:43,950 --> 00:01:47,519
executed his grand finale she'd have to

42
00:01:46,200 --> 00:01:49,920
have a talk that's six hours long to

43
00:01:47,519 --> 00:01:51,569

cover everything in Cassini has done but

44

00:01:49,920 --> 00:01:55,109

she's so crammed as much as you can into

45

00:01:51,569 --> 00:01:57,478

a one-hour talk the details are on our

46

00:01:55,109 --> 00:01:59,909

website just use your favorite search

47

00:01:57,478 --> 00:02:01,978

engine for Hubble public talks and you

48

00:01:59,909 --> 00:02:05,310

should find this page with a list of our

49

00:02:01,978 --> 00:02:08,489

upcoming lectures and we you can watch

50

00:02:05,310 --> 00:02:11,550

live online the this is the link to our

51

00:02:08,489 --> 00:02:13,709

web casting also you can watch past

52

00:02:11,550 --> 00:02:16,230

lectures all the way back to 2

53

00:02:13,709 --> 00:02:18,930

and five twelve years of astronomical

54

00:02:16,229 --> 00:02:22,169

goodness for you to explore you can also

55

00:02:18,930 --> 00:02:24,659

sign up for our email list here and a

56

00:02:22,169 --> 00:02:25,738

lot of you have taken advantage of that

57

00:02:24,658 --> 00:02:26,789

so I'm glad that there are a lot of

58
00:02:25,739 --> 00:02:29,819
people getting informed about our

59
00:02:26,789 --> 00:02:31,798
lectures the announcements sign up at

60
00:02:29,818 --> 00:02:33,899
the website if you want other ways of

61
00:02:31,799 --> 00:02:35,609
getting it to you you can for those you

62
00:02:33,900 --> 00:02:37,049
here in the audience you want to walk

63
00:02:35,609 --> 00:02:38,519
down and write your email address and

64
00:02:37,049 --> 00:02:41,188
hand it to me I'll make sure you get on

65
00:02:38,519 --> 00:02:44,359
the list if you want to contact us and

66
00:02:41,188 --> 00:02:48,989
ask us comments or give us us questions

67
00:02:44,359 --> 00:02:52,530
public lecture STScI dot edu of course

68
00:02:48,989 --> 00:02:54,658
we have the usual social media I will

69
00:02:52,530 --> 00:02:56,789
have to update this page at the end of

70
00:02:54,658 --> 00:02:59,009
this month because that woman right

71
00:02:56,789 --> 00:03:00,900
there has got a whole new suite of

72
00:02:59,009 --> 00:03:03,239
social media pushes that we're doing

73
00:03:00,900 --> 00:03:05,010
this month and she'll update me and make

74
00:03:03,239 --> 00:03:06,359
sure I have that so next month is slide

75
00:03:05,009 --> 00:03:08,370
will be updated but we have the usable

76
00:03:06,359 --> 00:03:10,439
Facebook and Twitter and Google Plus and

77
00:03:08,370 --> 00:03:12,989
Pinterest and a few more that she's

78
00:03:10,438 --> 00:03:14,608
gonna tell me about this month I have my

79
00:03:12,989 --> 00:03:16,709
blog and Facebook and Google Plus and

80
00:03:14,609 --> 00:03:18,989
Twitter that I use every now and then

81
00:03:16,709 --> 00:03:20,969
but I'm usually too enthused with my

82
00:03:18,989 --> 00:03:24,349
work I had to spend much time on social

83
00:03:20,969 --> 00:03:27,568
media so don't expect a lot from

84
00:03:24,348 --> 00:03:29,578
Observatory tonight yes it will be here

85
00:03:27,568 --> 00:03:31,619
weather permitting it looked like it was

86

00:03:29,579 --> 00:03:34,409
clear when I came in so I hope it will

87
00:03:31,620 --> 00:03:34,919
still be clear arenal and Bradys will be

88
00:03:34,408 --> 00:03:37,560
here

89
00:03:34,919 --> 00:03:39,599
I'll have her come down front and you

90
00:03:37,560 --> 00:03:42,569
guys can go with her and go across the

91
00:03:39,598 --> 00:03:44,698
street you cannot be a laggard on this

92
00:03:42,568 --> 00:03:46,138
when arena takes a group across if

93
00:03:44,699 --> 00:03:47,939
you're not with the group you don't get

94
00:03:46,139 --> 00:03:50,299
in the doors are locked so the whole

95
00:03:47,938 --> 00:03:52,560
group has to go in as one so

96
00:03:50,299 --> 00:03:53,849
unfortunately that means sometimes you

97
00:03:52,560 --> 00:03:55,859
can't hang around and ask the speaker

98
00:03:53,848 --> 00:03:58,649
questions if you want to go do the

99
00:03:55,859 --> 00:04:01,530
observing across the street alright and

100
00:03:58,650 --> 00:04:07,109

now my section news from the universe

101

00:04:01,530 --> 00:04:09,539

for July 2017 first story the curious

102

00:04:07,109 --> 00:04:11,790

instant of the star in the night time

103

00:04:09,539 --> 00:04:14,429

now who recognizes what that's a

104

00:04:11,789 --> 00:04:16,699

reference to and as I know she does who

105

00:04:14,430 --> 00:04:16,699

is it

106

00:04:18,199 --> 00:04:26,129

yes it's from actually from Sherlock

107

00:04:23,430 --> 00:04:28,168

Holmes is where I took it from where

108

00:04:26,129 --> 00:04:29,639

detective Gregory astronaut's Holmes is

109

00:04:28,168 --> 00:04:31,889

there any other point to which you would

110

00:04:29,639 --> 00:04:33,538

wish to draw my attention and he replies

111

00:04:31,889 --> 00:04:36,360

to the Curious Incident of the dog in

112

00:04:33,538 --> 00:04:37,110

the night-time the dog did nothing in

113

00:04:36,360 --> 00:04:40,919

the nighttime

114

00:04:37,110 --> 00:04:42,780

that was the Curious Incident now it's

115
00:04:40,918 --> 00:04:45,959
come down through folklore as the dog

116
00:04:42,779 --> 00:04:48,269
that didn't bark here we're going to

117
00:04:45,959 --> 00:04:51,448
talk about a star in the night time and

118
00:04:48,269 --> 00:04:54,448
stars do other things besides barking so

119
00:04:51,449 --> 00:04:57,030
this is a picture in 1984 of a certain

120
00:04:54,449 --> 00:05:00,560
particular star taken at the angle

121
00:04:57,029 --> 00:05:05,779
Australian Observatory and that star in

122
00:05:00,560 --> 00:05:09,839
1987 looked like this this was supernova

123
00:05:05,779 --> 00:05:12,719
1987a and so very massive stars at the

124
00:05:09,839 --> 00:05:15,388
end of their lifetime explode as these

125
00:05:12,720 --> 00:05:17,880
giant supernova explosions and they

126
00:05:15,389 --> 00:05:22,199
become incredibly bright basically as

127
00:05:17,879 --> 00:05:25,370
bright as an entire galaxy ok so that's

128
00:05:22,199 --> 00:05:28,470
how we expect these super massive

129
00:05:25,370 --> 00:05:30,329
supergiant stars to end their life let

130
00:05:28,470 --> 00:05:35,250
me tell you the story of a different

131
00:05:30,329 --> 00:05:37,019
star this one now there is a supernova

132
00:05:35,250 --> 00:05:38,970
search that's being run out of the Ohio

133
00:05:37,019 --> 00:05:40,259
State University and they're using a

134
00:05:38,970 --> 00:05:42,630
ground-based telescope the large

135
00:05:40,259 --> 00:05:45,029
binocular telescope and in order to find

136
00:05:42,629 --> 00:05:47,490
supernovae because you don't know which

137
00:05:45,029 --> 00:05:50,250
stars gonna go supernova at any time you

138
00:05:47,490 --> 00:05:52,769
monitor lots of galaxies over many years

139
00:05:50,250 --> 00:05:55,560
and on average you'll see a few

140
00:05:52,769 --> 00:05:56,639
supernovae in each galaxy and while in

141
00:05:55,560 --> 00:05:59,788
some of the galaxies that you're

142
00:05:56,639 --> 00:06:03,050
monitoring well this will star hate here

143

00:05:59,788 --> 00:06:06,089
turns out to be a 25 solar mass star

144
00:06:03,050 --> 00:06:10,500
it's in the galaxies you what is it NGC

145
00:06:06,089 --> 00:06:14,429
69 46 and this star was observed

146
00:06:10,500 --> 00:06:17,098
brightened in the year 2009 but since

147
00:06:14,430 --> 00:06:18,750
then it is faded away now when I say it

148
00:06:17,098 --> 00:06:21,300
brightened in 2009 it didn't go

149
00:06:18,750 --> 00:06:23,788
supernova you saw that huge brightness a

150
00:06:21,300 --> 00:06:25,829
change there it did not bright enough to

151
00:06:23,788 --> 00:06:29,339
say it went supernova it brightened a

152
00:06:25,829 --> 00:06:30,419
bit but it did not brighten to a huge

153
00:06:29,339 --> 00:06:31,799
amount

154
00:06:30,420 --> 00:06:34,040
and then it faded away such the

155
00:06:31,800 --> 00:06:36,840
ground-based telescopes could not see it

156
00:06:34,040 --> 00:06:38,879
well they wondered what was going on was

157
00:06:36,839 --> 00:06:41,099

this star just enshrouded and dust and

158

00:06:38,879 --> 00:06:43,500

we couldn't see it or maybe it had faded

159

00:06:41,100 --> 00:06:45,840

away to such it was undetectable by

160

00:06:43,500 --> 00:06:47,579

ground-based so what do you do you call

161

00:06:45,839 --> 00:06:52,159

in the space telescopes for follow-up

162

00:06:47,579 --> 00:06:56,159

all right this is what Hubble saw

163

00:06:52,160 --> 00:06:58,650

nothing it was not that the star had

164

00:06:56,160 --> 00:07:01,590

just faded below observable level from

165

00:06:58,649 --> 00:07:03,779

the ground then they looked with the

166

00:07:01,589 --> 00:07:06,179

spitzer space telescope perhaps it was

167

00:07:03,779 --> 00:07:08,429

shrouded in dust and therefore obscured

168

00:07:06,180 --> 00:07:10,410

in optical bandpass but that would be

169

00:07:08,430 --> 00:07:15,840

invisible in the infrared bandpass of

170

00:07:10,410 --> 00:07:18,240

Spitzer Spitzer also saw nothing it's

171

00:07:15,839 --> 00:07:21,329

not visible an optical light it's not

172
00:07:18,240 --> 00:07:26,670
visible in infrared light what happened

173
00:07:21,329 --> 00:07:30,180
to this 25 solar mass star well the

174
00:07:26,670 --> 00:07:34,170
conclusion is this is not the dog that

175
00:07:30,180 --> 00:07:38,329
didn't bark this is the star that didn't

176
00:07:34,170 --> 00:07:42,270
explode this they both star they believe

177
00:07:38,329 --> 00:07:45,209
collapsed to a black hole without going

178
00:07:42,269 --> 00:07:47,549
through a supernova normally we believe

179
00:07:45,209 --> 00:07:49,620
that stars except that at the end of the

180
00:07:47,550 --> 00:07:51,449
star's light it collapses it explodes

181
00:07:49,620 --> 00:07:54,660
and the core collapses to either a

182
00:07:51,449 --> 00:07:57,620
neutron star or a black hole this is

183
00:07:54,660 --> 00:08:01,530
evidence that stars may collapse

184
00:07:57,620 --> 00:08:05,250
directly to a black hole without going

185
00:08:01,529 --> 00:08:07,289
through the supernova phase this had not

186
00:08:05,250 --> 00:08:10,319
been seen before this is the first one

187
00:08:07,290 --> 00:08:13,200
of what they call failed supernovas and

188
00:08:10,319 --> 00:08:15,719
in their survey they saw a six or seven

189
00:08:13,199 --> 00:08:17,550
other supernovae in the galaxies they

190
00:08:15,720 --> 00:08:20,070
were monitoring and that starts to give

191
00:08:17,550 --> 00:08:22,949
them some statistics about how many of

192
00:08:20,069 --> 00:08:25,589
these very massive stars might collapse

193
00:08:22,949 --> 00:08:28,699
directly to black holes without leaving

194
00:08:25,589 --> 00:08:32,189
the tell-tale explosion of a supernova

195
00:08:28,699 --> 00:08:34,860
so there's a new way for forming a black

196
00:08:32,190 --> 00:08:37,200
hole we believe that we you can form

197
00:08:34,860 --> 00:08:40,229
black holes from the standard model

198
00:08:37,200 --> 00:08:41,700
where you have an explosion and you get

199
00:08:40,229 --> 00:08:43,830
the supernova explosion and you get the

200

00:08:41,700 --> 00:08:45,420
black hole but here we

201
00:08:43,830 --> 00:08:47,790
evidence that you can get a super you

202
00:08:45,419 --> 00:08:52,069
can get a black hole without having a

203
00:08:47,789 --> 00:08:56,958
supernova explosion that's really cool

204
00:08:52,070 --> 00:09:00,028
now third story a stellar light weight

205
00:08:56,958 --> 00:09:01,828
so if you want to weigh a star you want

206
00:09:00,028 --> 00:09:04,860
to understand the mass of a star you

207
00:09:01,828 --> 00:09:07,949
have to figure out how much gravity That

208
00:09:04,860 --> 00:09:10,110
star has and the usual way to do it is

209
00:09:07,950 --> 00:09:13,110
if you've got a planet or another star

210
00:09:10,110 --> 00:09:15,720
orbiting around it the characteristics

211
00:09:13,110 --> 00:09:17,430
of that orbit will tell you the amount

212
00:09:15,720 --> 00:09:20,278
of gravity that is in the system and

213
00:09:17,429 --> 00:09:23,429
therefore the mass of the star this is a

214
00:09:20,278 --> 00:09:27,328

dynamical measurement of the mass of a

215

00:09:23,429 --> 00:09:29,399

star but if a star is isolated doesn't

216

00:09:27,328 --> 00:09:33,199

have anything orbiting around it how do

217

00:09:29,399 --> 00:09:37,740

you tell its mass generally you can't

218

00:09:33,200 --> 00:09:41,459

accept the mass of a star can also do

219

00:09:37,740 --> 00:09:43,649

something else we in deine steins

220

00:09:41,458 --> 00:09:46,559

relativity we think of the fabric of

221

00:09:43,649 --> 00:09:49,708

space-time okay and let's represent it

222

00:09:46,559 --> 00:09:53,849

here as this grid but the presence of a

223

00:09:49,708 --> 00:09:57,869

star creates a deformation in the grid

224

00:09:53,850 --> 00:10:02,610

of space-time light that passes through

225

00:09:57,870 --> 00:10:04,828

that deformation changes direction so

226

00:10:02,610 --> 00:10:07,470

and the amount of directional change is

227

00:10:04,828 --> 00:10:11,039

going to be proportional to the mass of

228

00:10:07,470 --> 00:10:13,440

That star so if you can measure that you

229
00:10:11,039 --> 00:10:16,259
can measure the mass of the star and

230
00:10:13,440 --> 00:10:20,760
this is what Hubble is trying to do for

231
00:10:16,259 --> 00:10:23,789
this star Stein 2:05 1b and actually I

232
00:10:20,759 --> 00:10:26,669
just lied to you it's not a star it's a

233
00:10:23,789 --> 00:10:28,769
white dwarf now you'll always hear being

234
00:10:26,669 --> 00:10:30,870
called a white dwarf star but a white

235
00:10:28,769 --> 00:10:33,629
dwarf isn't a star because there's no

236
00:10:30,870 --> 00:10:36,120
nuclear fusion going on in its core it's

237
00:10:33,629 --> 00:10:38,490
a dead star it's a stellar remnant all

238
00:10:36,120 --> 00:10:40,679
the nuclear fusion has ceased it's just

239
00:10:38,490 --> 00:10:42,629
a really really hot ball basically of

240
00:10:40,679 --> 00:10:44,819
carbon now you can sort of think it as a

241
00:10:42,629 --> 00:10:46,740
giant charcoal briquette that will burn

242
00:10:44,820 --> 00:10:48,720
for trillions of trillions of years you

243
00:10:46,740 --> 00:10:55,169
can have a really really long barbecue

244
00:10:48,720 --> 00:10:56,889
with this so Stein 2:05 1b you might

245
00:10:55,169 --> 00:10:59,169
think that it has a planet around it or

246
00:10:56,889 --> 00:11:02,379
another star nearby it but it doesn't

247
00:10:59,169 --> 00:11:05,649
this is actually passing in front of a

248
00:11:02,379 --> 00:11:08,589
star that's 5,000 light years away when

249
00:11:05,649 --> 00:11:12,188
there's sign - Oh fun bee is only 17

250
00:11:08,589 --> 00:11:13,899
light years away so stein 205 1 b being

251
00:11:12,188 --> 00:11:16,208
very close and this other star being

252
00:11:13,899 --> 00:11:19,448
very far away they move relative to one

253
00:11:16,208 --> 00:11:22,928
another in the sky and as stye no 205

254
00:11:19,448 --> 00:11:24,909
one b passes by that star we should be

255
00:11:22,928 --> 00:11:28,269
able to measure the gravitational

256
00:11:24,909 --> 00:11:31,600
lensing of the background star so here's

257

00:11:28,269 --> 00:11:34,209
the diagram this is the white dwarf okay

258
00:11:31,600 --> 00:11:36,730
here is Hubble's observed star position

259
00:11:34,208 --> 00:11:38,469
and here's where the star person really

260
00:11:36,730 --> 00:11:40,899
should be and we can measure that

261
00:11:38,470 --> 00:11:44,528
deflection we can then measure the mass

262
00:11:40,899 --> 00:11:46,539
of the star here's how here isn't a

263
00:11:44,528 --> 00:11:49,838
diagram attic this is an illustration of

264
00:11:46,539 --> 00:11:54,458
the idea that as the white dwarf passes

265
00:11:49,839 --> 00:11:58,660
by the position of that star will change

266
00:11:54,458 --> 00:12:01,118
okay now that's incredibly overstated

267
00:11:58,659 --> 00:12:03,129
alright that's an illustration of it

268
00:12:01,119 --> 00:12:05,350
just to give you the idea of it do you

269
00:12:03,129 --> 00:12:07,808
want to see the real data I'm happy to

270
00:12:05,350 --> 00:12:14,918
show you the real data this is the real

271
00:12:07,808 --> 00:12:18,188

data did you all see that motion of

272

00:12:14,918 --> 00:12:21,668
course you didn't okay because the

273

00:12:18,188 --> 00:12:25,568
motion of that background star is offset

274

00:12:21,668 --> 00:12:27,730
by two milli arcseconds to thousands of

275

00:12:25,568 --> 00:12:29,469
an arc second where an arc second is one

276

00:12:27,730 --> 00:12:31,928
sixtieth of an arc minute and an arc

277

00:12:29,470 --> 00:12:33,639
minute is one sixtieth of a degree okay

278

00:12:31,928 --> 00:12:36,009
so one thirty six hundredth of a degree

279

00:12:33,639 --> 00:12:39,759
and then to one thousandth of that

280

00:12:36,009 --> 00:12:43,269
that's a really small angle but Hubble

281

00:12:39,759 --> 00:12:46,178
was able to measure it and using this

282

00:12:43,269 --> 00:12:48,249
Hubble was able to measure the mass of

283

00:12:46,178 --> 00:12:50,288
the white dwarf star the result being

284

00:12:48,249 --> 00:12:52,119
about two thirds of the mass of the Sun

285

00:12:50,288 --> 00:12:55,328
which fits in with our theoretical

286
00:12:52,119 --> 00:12:56,709
expectations for the masses of white

287
00:12:55,328 --> 00:12:58,778
dwarfs and actually it fits written with

288
00:12:56,708 --> 00:13:03,099
our other observations of the masses of

289
00:12:58,778 --> 00:13:06,909
white dwarfs this actually is the second

290
00:13:03,100 --> 00:13:08,360
star for which it had been done when was

291
00:13:06,909 --> 00:13:13,069
it done the first time

292
00:13:08,360 --> 00:13:16,789
a hundred years ago during the 1919

293
00:13:13,070 --> 00:13:19,490
total solar eclipse just after general

294
00:13:16,789 --> 00:13:22,159
relativity was was put forth in the

295
00:13:19,490 --> 00:13:24,350
paper they recognized that they could

296
00:13:22,159 --> 00:13:27,199
see this gravitational lensing of

297
00:13:24,350 --> 00:13:29,480
different background stars during a

298
00:13:27,200 --> 00:13:30,860
solar eclipse so what they did is they

299
00:13:29,480 --> 00:13:32,839
measured you see all those stars I've

300
00:13:30,860 --> 00:13:34,550
got pointed out there they measured

301
00:13:32,839 --> 00:13:37,310
those stars well before the Eclipse

302
00:13:34,549 --> 00:13:39,889
where their positions were and then when

303
00:13:37,309 --> 00:13:41,809
the Sun underwent the total solar

304
00:13:39,889 --> 00:13:43,309
eclipse and the moon was blocking it

305
00:13:41,809 --> 00:13:45,739
they could actually see those stars

306
00:13:43,309 --> 00:13:48,458
passing through the gravitational field

307
00:13:45,740 --> 00:13:51,409
of the Sun they could measure the

308
00:13:48,458 --> 00:13:55,699
deflection of light to test general

309
00:13:51,409 --> 00:13:59,719
relativity and they did this in 1919 so

310
00:13:55,700 --> 00:14:03,160
Hubble is finally doing for external

311
00:13:59,720 --> 00:14:05,540
stars what was done for our own star in

312
00:14:03,159 --> 00:14:06,169
1919 and we have a new way to measure

313
00:14:05,539 --> 00:14:11,019
start

314

00:14:06,169 --> 00:14:15,229
Celer masses which also gives us a good

315
00:14:11,019 --> 00:14:18,169
entry into reminding you Hey where will

316
00:14:15,230 --> 00:14:20,629
you be when the light goes out just want

317
00:14:18,169 --> 00:14:25,639
to make sure you all remember that next

318
00:14:20,629 --> 00:14:27,439
month on August 21st 2017 we have the

319
00:14:25,639 --> 00:14:29,990
greatest total solar eclipse so far in

320
00:14:27,440 --> 00:14:33,079
my lifetime in the United States it

321
00:14:29,990 --> 00:14:37,370
passes from Oregon all the way down

322
00:14:33,078 --> 00:14:39,620
through South Carolina alright about two

323
00:14:37,370 --> 00:14:41,659
minutes to two minutes and 40 seconds

324
00:14:39,620 --> 00:14:48,230
duration if you're on this if you're on

325
00:14:41,659 --> 00:14:50,000
the centerline it's on a Monday make

326
00:14:48,230 --> 00:14:52,009
sure that there are all sorts of things

327
00:14:50,000 --> 00:14:53,629
if you can't get to the centerline you

328
00:14:52,009 --> 00:14:56,019

can see that the entire continental

329

00:14:53,629 --> 00:15:00,259

United States will have some level of

330

00:14:56,019 --> 00:15:03,289

the partial solar eclipse there are all

331

00:15:00,259 --> 00:15:05,299

sorts of cool tools online for example

332

00:15:03,289 --> 00:15:07,610

this one is an interactive map and if

333

00:15:05,299 --> 00:15:11,149

you click on Salem you find that Salem

334

00:15:07,610 --> 00:15:13,959

is in the path of totality it will have

335

00:15:11,149 --> 00:15:16,190

a 1 minute and 55 second total totality

336

00:15:13,958 --> 00:15:17,419

however if you don't leave here if you

337

00:15:16,190 --> 00:15:19,970

stay at the Johns Hopkins University

338

00:15:17,419 --> 00:15:23,059

campus in Baltimore Maryland you will

339

00:15:19,970 --> 00:15:25,009

only get an 80% obscure

340

00:15:23,059 --> 00:15:27,138

and here are the times of the Eclipse

341

00:15:25,009 --> 00:15:30,828

you can find all these incredible tools

342

00:15:27,139 --> 00:15:33,230

online I'm not gonna we gave a talk on

343
00:15:30,828 --> 00:15:35,120
this in January if you go to our web

344
00:15:33,230 --> 00:15:38,690
casting site and go back to our January

345
00:15:35,120 --> 00:15:40,278
1 you can find our talk on that although

346
00:15:38,690 --> 00:15:42,769
I'm sure there's a lot more cool stuff

347
00:15:40,278 --> 00:15:45,259
on the web now because everyone's hyping

348
00:15:42,769 --> 00:15:49,278
up for this I will only say one thing

349
00:15:45,259 --> 00:15:52,629
you must have certified solar viewing

350
00:15:49,278 --> 00:15:55,250
glasses I cannot say this enough ok

351
00:15:52,629 --> 00:15:57,169
sunglasses are not good enough ok a

352
00:15:55,250 --> 00:15:58,850
mylar balloon which some people think is

353
00:15:57,169 --> 00:16:01,039
good enough is not good enough

354
00:15:58,850 --> 00:16:02,600
what's your Uncle Joe from Montana tells

355
00:16:01,039 --> 00:16:05,629
you was good enough isn't good enough

356
00:16:02,600 --> 00:16:08,149
unless he says you need certified solar

357
00:16:05,629 --> 00:16:10,039
viewing glasses ok so please make sure

358
00:16:08,149 --> 00:16:12,519
that your if you're going to watch the

359
00:16:10,039 --> 00:16:16,669
solar eclipse you keep your eyes safe

360
00:16:12,519 --> 00:16:28,820
alright and that's our news for July you

361
00:16:16,669 --> 00:16:30,409
have a question here well 1919 the Maine

362
00:16:28,820 --> 00:16:32,600
alright so the question I've got a

363
00:16:30,409 --> 00:16:34,698
repeated for the online audience the

364
00:16:32,600 --> 00:16:36,079
mass of the Sun it measured in 1919 how

365
00:16:34,698 --> 00:16:39,278
does it compare to the mass we would

366
00:16:36,078 --> 00:16:42,528
measure today and the main point of the

367
00:16:39,278 --> 00:16:45,139
Eclipse expeditions in 1919 was actually

368
00:16:42,528 --> 00:16:47,899
to test whether those stars actually

369
00:16:45,139 --> 00:16:49,639
really moved whether general activity

370
00:16:47,899 --> 00:16:52,220
was correct because this was a

371

00:16:49,639 --> 00:16:55,250
mathematical theory that you know

372
00:16:52,220 --> 00:16:57,050
stretched the imagination a bit ahead

373
00:16:55,250 --> 00:16:59,570
and so the main point of it so I don't

374
00:16:57,049 --> 00:17:02,028
really know whether they measured the

375
00:16:59,570 --> 00:17:03,920
mass of the Sun that but I think they

376
00:17:02,028 --> 00:17:05,838
probably put in the mass of the Sun as

377
00:17:03,919 --> 00:17:08,418
one of their parameters to measure how

378
00:17:05,838 --> 00:17:12,289
much the stars should move in the light

379
00:17:08,419 --> 00:17:15,110
deflection equation we have obviously

380
00:17:12,289 --> 00:17:16,240
planets orbiting the Sun so we can

381
00:17:15,109 --> 00:17:19,058
measure the mass

382
00:17:16,240 --> 00:17:21,308
I'm pretty accurately using that I don't

383
00:17:19,058 --> 00:17:23,949
know if that light deflection actually

384
00:17:21,308 --> 00:17:27,279
would improve on that in any way but

385
00:17:23,949 --> 00:17:31,630

yeah it's a good question thank you yes

386

00:17:27,279 --> 00:17:35,649

first story about the the starter was 25

387

00:17:31,630 --> 00:17:39,010

solar masses is that rare for a star to

388

00:17:35,650 --> 00:17:41,559

be that big or so in the story of the

389

00:17:39,009 --> 00:17:43,539

star star that didn't explode is it

390

00:17:41,558 --> 00:17:45,849

unusual to have us 25 solar mass star

391

00:17:43,539 --> 00:17:48,609

yes okay

392

00:17:45,849 --> 00:17:51,459

the meek inherit the universe the tiny

393

00:17:48,609 --> 00:17:53,678

very small stars smaller than the Sun

394

00:17:51,460 --> 00:17:56,740

are the most numerous in the entire

395

00:17:53,679 --> 00:17:58,660

universe the red dwarf stars are really

396

00:17:56,740 --> 00:18:00,308

the most unit numerous as you get up to

397

00:17:58,660 --> 00:18:04,150

larger and larger stars they're much

398

00:18:00,308 --> 00:18:07,750

much rarer and so a 25 solar mass star

399

00:18:04,150 --> 00:18:09,910

is is a relatively rare star and I think

400
00:18:07,750 --> 00:18:11,799
the stars getting you have to get above

401
00:18:09,910 --> 00:18:14,590
at least eight solar masses to have it

402
00:18:11,799 --> 00:18:19,210
at a supernova and those are the O and

403
00:18:14,589 --> 00:18:20,619
the B stars those those are the you know

404
00:18:19,210 --> 00:18:22,808
few and far between those are the big

405
00:18:20,619 --> 00:18:27,939
monster stars inside the star clusters

406
00:18:22,808 --> 00:18:31,240
all right okay let's move on to our

407
00:18:27,940 --> 00:18:34,539
featured speaker I am extremely pleased

408
00:18:31,240 --> 00:18:36,429
to have Dave Charbonneau of the Harvard

409
00:18:34,539 --> 00:18:41,529
University here tonight he is a

410
00:18:36,429 --> 00:18:44,650
professor of astronomy he's a professor

411
00:18:41,529 --> 00:18:47,369
of astronomy at Harvard University and

412
00:18:44,650 --> 00:18:50,320
his research as you might guess is on

413
00:18:47,369 --> 00:18:53,469
exoplanets and you hear a lot of his

414
00:18:50,319 --> 00:18:57,039
stuff here tonight he has worked on the

415
00:18:53,470 --> 00:18:58,929
both the Kepler mission and he's working

416
00:18:57,039 --> 00:19:02,379
on the upcoming test mission the

417
00:18:58,929 --> 00:19:04,890
transiting extrasolar surveys extra

418
00:19:02,380 --> 00:19:04,890
solar

419
00:19:09,480 --> 00:19:14,640
when I'm talking to the public yes you

420
00:19:12,359 --> 00:19:18,359
guess you yes you went to exoplanet all

421
00:19:14,640 --> 00:19:20,910
right let's see he did his undergraduate

422
00:19:18,359 --> 00:19:25,439
work at the University of Toronto before

423
00:19:20,910 --> 00:19:28,110
doing his PhD at Harvard postdoc no

424
00:19:25,440 --> 00:19:32,390
postdoc at Caltech so he's hitting all

425
00:19:28,109 --> 00:19:32,389
of the high points of the universities

426
00:19:34,579 --> 00:19:39,899
the NASA medal for exceptional

427
00:19:36,569 --> 00:19:41,759
scientific achievement scientist of the

428

00:19:39,900 --> 00:19:43,590
year from Discovery magazine these

429
00:19:41,759 --> 00:19:46,379
members National Academy Sciences yada

430
00:19:43,589 --> 00:19:48,569
yada yada usual stuff that we have you

431
00:19:46,380 --> 00:19:51,540
know I only get you the best speakers

432
00:19:48,569 --> 00:19:54,689
okay but the most important thing is

433
00:19:51,539 --> 00:19:57,389
he's the father of four girls he is a

434
00:19:54,690 --> 00:20:00,720
hockey coach and he tells me he's

435
00:19:57,390 --> 00:20:07,410
probably the only male to be a Girl

436
00:20:00,720 --> 00:20:09,210
Scout leader one of the few rare males

437
00:20:07,410 --> 00:20:13,769
to be a Girl Scout leader

438
00:20:09,210 --> 00:20:16,500
so a definite Renaissance guy please

439
00:20:13,769 --> 00:20:23,889
welcome Dave Charbonneau

440
00:20:16,500 --> 00:20:23,890
[Applause]

441
00:20:23,950 --> 00:20:29,059
well thanks for the really kind

442
00:20:26,960 --> 00:20:30,650

introduction so I'm really looking

443

00:20:29,059 --> 00:20:33,109

forward to this what I want to do is

444

00:20:30,650 --> 00:20:35,269

just tell you about what I think is the

445

00:20:33,109 --> 00:20:38,000

most exciting thing going on in all of

446

00:20:35,269 --> 00:20:40,039

science maybe I'm a little biased but

447

00:20:38,000 --> 00:20:43,160

this is a very very special moment to be

448

00:20:40,039 --> 00:20:45,230

alive and be interested in this question

449

00:20:43,160 --> 00:20:51,019

of whether or not we're the only

450

00:20:45,230 --> 00:20:53,750

inhabited planet out there okay so you

451

00:20:51,019 --> 00:20:56,329

know I'm sure you are all aware that if

452

00:20:53,750 --> 00:20:58,579

you if you if you take a telescope out

453

00:20:56,329 --> 00:21:00,349

to a dark point on the earth and you

454

00:20:58,579 --> 00:21:02,269

point it up at the night sky and you

455

00:21:00,349 --> 00:21:04,730

just take a long exposure you know it's

456

00:21:02,269 --> 00:21:06,859

just it's stars all the way down right

457
00:21:04,730 --> 00:21:09,410
so it's not just the stars that you see

458
00:21:06,859 --> 00:21:10,699
in the image but the fact that you know

459
00:21:09,410 --> 00:21:12,830
there's all these kind of unresolved

460
00:21:10,700 --> 00:21:14,809
stars I mean that if we add them all up

461
00:21:12,829 --> 00:21:19,369
there's something like 300 billion stars

462
00:21:14,809 --> 00:21:21,259
in the galaxy okay and often when I'm

463
00:21:19,369 --> 00:21:24,019
talking to folks about whether or not

464
00:21:21,259 --> 00:21:25,369
we're alone they say look you know we

465
00:21:24,019 --> 00:21:27,859
now know that there's planets around

466
00:21:25,369 --> 00:21:29,869
other stars there's 300 billion stars

467
00:21:27,859 --> 00:21:31,250
out there in our own galaxy there's you

468
00:21:29,869 --> 00:21:33,829
know hundreds of billions of other

469
00:21:31,250 --> 00:21:38,420
galaxies isn't it inevitable that

470
00:21:33,829 --> 00:21:41,389
there's life and I find that answer to

471
00:21:38,420 --> 00:21:43,340
be awful I find that to be really

472
00:21:41,390 --> 00:21:45,860
unsatisfying I don't want to know that

473
00:21:43,339 --> 00:21:47,769
there's a mathematical possibility that

474
00:21:45,859 --> 00:21:51,109
there's probably life I want to actually

475
00:21:47,769 --> 00:21:53,240
find the life and I want to see if it's

476
00:21:51,109 --> 00:21:55,219
got DNA and I want to see if it's

477
00:21:53,240 --> 00:21:58,309
multicellular maybe even if it's

478
00:21:55,220 --> 00:21:59,750
intelligent okay so so it's not enough

479
00:21:58,309 --> 00:22:01,190
to do the calculation we have to

480
00:21:59,750 --> 00:22:05,059
actually go I think and actually look

481
00:22:01,190 --> 00:22:07,130
for um what I do want to point out is

482
00:22:05,059 --> 00:22:09,109
that this is not a new idea okay we're

483
00:22:07,130 --> 00:22:11,210
not the first generation to really worry

484
00:22:09,109 --> 00:22:14,209
about these things if you go back

485

00:22:11,210 --> 00:22:18,380
through at least more than 2,000 years

486
00:22:14,210 --> 00:22:20,120
of human written thought you can find

487
00:22:18,380 --> 00:22:21,710
that people have been thinking about

488
00:22:20,119 --> 00:22:25,159
whether or not we're alone for a long

489
00:22:21,710 --> 00:22:30,200
time okay so so here we have Epicurus

490
00:22:25,160 --> 00:22:32,600
okay writing in 300 BC there is an

491
00:22:30,200 --> 00:22:34,970
infinite number of worlds some like this

492
00:22:32,599 --> 00:22:35,449
world and others unlike it some of these

493
00:22:34,970 --> 00:22:37,250
worlds

494
00:22:35,450 --> 00:22:39,440
contain the seeds out of which animals

495
00:22:37,250 --> 00:22:41,089
and plants arise and all the rest of the

496
00:22:39,440 --> 00:22:43,399
things that we see so they so the Greeks

497
00:22:41,089 --> 00:22:46,069
didn't even really know that the points

498
00:22:43,398 --> 00:22:47,449
of light in the night sky were stars and

499
00:22:46,069 --> 00:22:49,369

there might be planets around those

500

00:22:47,450 --> 00:22:51,288

stars but even without that knowledge

501

00:22:49,369 --> 00:22:53,778

they had this thought that there might

502

00:22:51,288 --> 00:22:56,028

be alien worlds and we would somehow

503

00:22:53,778 --> 00:23:01,339

come into contact with with these

504

00:22:56,028 --> 00:23:05,240

unknown places ok here you know much

505

00:23:01,339 --> 00:23:06,349

more modern only gosh you know 450 years

506

00:23:05,240 --> 00:23:09,679

ago

507

00:23:06,349 --> 00:23:11,869

we've got Giordano Bruno so he was a

508

00:23:09,679 --> 00:23:14,330

medieval scholar and he said there are

509

00:23:11,869 --> 00:23:16,459

countless suns and countless earths all

510

00:23:14,329 --> 00:23:17,778

rotating around their Suns in exactly

511

00:23:16,460 --> 00:23:20,600

the same way as the planets of our

512

00:23:17,778 --> 00:23:23,388

system the countless worlds are no worse

513

00:23:20,599 --> 00:23:26,240

and no less inhabited than our earth so

514
00:23:23,388 --> 00:23:27,648
so he now knew that the other that the

515
00:23:26,240 --> 00:23:29,808
points of light in the night sky really

516
00:23:27,648 --> 00:23:30,979
were stars he didn't know that there

517
00:23:29,808 --> 00:23:32,750
were planets but he thought well they're

518
00:23:30,980 --> 00:23:35,028
probably planets we just can't see them

519
00:23:32,750 --> 00:23:39,169
and he thought well maybe some of them

520
00:23:35,028 --> 00:23:42,230
have life what what's so special is that

521
00:23:39,169 --> 00:23:44,120
for thousands of years people have only

522
00:23:42,230 --> 00:23:46,460
been able to theorize they've been able

523
00:23:44,119 --> 00:23:49,158
to use their imaginations and say gee I

524
00:23:46,460 --> 00:23:51,230
wonder but we're all alive at this

525
00:23:49,159 --> 00:23:53,330
special moment in human history where we

526
00:23:51,230 --> 00:23:55,970
have the technological ability to

527
00:23:53,329 --> 00:23:58,388
actually go and answer that question ok

528
00:23:55,970 --> 00:24:02,028
so so this is a very very special time

529
00:23:58,388 --> 00:24:02,898
how are we gonna do it right how are we

530
00:24:02,028 --> 00:24:04,099
gonna do it how are we actually gonna

531
00:24:02,898 --> 00:24:05,689
find out I mean there's only one

532
00:24:04,099 --> 00:24:11,839
generation that gets to do it you only

533
00:24:05,690 --> 00:24:13,940
find out you're not alone once so so

534
00:24:11,839 --> 00:24:15,678
here's here's kind of one one idea maybe

535
00:24:13,940 --> 00:24:18,200
we should build spaceships right and and

536
00:24:15,679 --> 00:24:22,159
often when I'm talking to folks they say

537
00:24:18,200 --> 00:24:23,389
you know is that a possibility and you

538
00:24:22,159 --> 00:24:25,340
know I want to point out that of course

539
00:24:23,388 --> 00:24:27,259
that's not really the way that's not

540
00:24:25,339 --> 00:24:31,519
really a realistic possibility for

541
00:24:27,259 --> 00:24:32,869
discovering life on other planets there

542

00:24:31,519 --> 00:24:34,370
aren't people thinking about what it

543
00:24:32,869 --> 00:24:36,739
would take to send probes to other stars

544
00:24:34,369 --> 00:24:38,209
and that's that's very very exciting but

545
00:24:36,740 --> 00:24:39,769
it's not the way the first discoveries

546
00:24:38,210 --> 00:24:41,808
are going to be made and it's a really

547
00:24:39,769 --> 00:24:44,120
difficult challenge ok so if you take

548
00:24:41,808 --> 00:24:46,428
the fastest spacecraft that we've ever

549
00:24:44,119 --> 00:24:48,979
made and you pointed it directly at the

550
00:24:46,429 --> 00:24:50,509
closest star and you fired the engines

551
00:24:48,980 --> 00:24:53,809
you're still talking something like ten

552
00:24:50,509 --> 00:24:58,069
thousand years ten thousand years to get

553
00:24:53,809 --> 00:24:59,629
there okay so I am impatient I've got

554
00:24:58,069 --> 00:25:01,669
things that I gotta go coach my hockey

555
00:24:59,630 --> 00:25:06,290
team so I got I can't I can't wait that

556
00:25:01,670 --> 00:25:07,550

long so here's another idea right the

557

00:25:06,289 --> 00:25:11,599

search for extraterrestrial intelligence

558

00:25:07,549 --> 00:25:14,480

so we should listen for radio signals or

559

00:25:11,599 --> 00:25:17,299

for laser signals from intelligent life

560

00:25:14,480 --> 00:25:20,450

that's trying to communicate with us now

561

00:25:17,299 --> 00:25:23,839

I am really glad that people are trying

562

00:25:20,450 --> 00:25:26,180

to do this but I don't think it's the

563

00:25:23,839 --> 00:25:28,250

way to make the first discovery and the

564

00:25:26,180 --> 00:25:30,049

reason is it has a lot of assumptions

565

00:25:28,250 --> 00:25:32,539

right it's not enough that there's life

566

00:25:30,049 --> 00:25:35,059

out there the life has to be interested

567

00:25:32,539 --> 00:25:38,720

in technology it has to be interested in

568

00:25:35,059 --> 00:25:41,419

radio telescopes or lasers and it has to

569

00:25:38,720 --> 00:25:45,319

want to communicate okay maybe that's

570

00:25:41,420 --> 00:25:47,150

just unfortunately a human desire so the

571
00:25:45,319 --> 00:25:48,289
more I really think about SETI I think

572
00:25:47,150 --> 00:25:50,750
well we're really kind of looking for

573
00:25:48,289 --> 00:25:53,059
ourselves now I'd hate to I'd hate to

574
00:25:50,750 --> 00:25:56,119
miss it and gosh if they find something

575
00:25:53,059 --> 00:25:58,819
I'll be the first you know celebrate it

576
00:25:56,119 --> 00:26:00,319
but it's those additional assumptions

577
00:25:58,819 --> 00:26:02,240
that make me a little bit nervous and so

578
00:26:00,319 --> 00:26:03,859
what we're trying to do as astronomers

579
00:26:02,240 --> 00:26:06,710
is we're trying to come up with a much

580
00:26:03,859 --> 00:26:08,929
broader net something a very robust idea

581
00:26:06,710 --> 00:26:10,579
that's going to go and find life even if

582
00:26:08,930 --> 00:26:13,880
the life is is not interested in

583
00:26:10,579 --> 00:26:18,649
actually being found okay all right so

584
00:26:13,880 --> 00:26:22,160
what's that idea well to put it in

585
00:26:18,650 --> 00:26:24,470
perspective the difficulty is of course

586
00:26:22,160 --> 00:26:26,450
we first have to find the likely places

587
00:26:24,470 --> 00:26:29,509
for life and we think those are planets

588
00:26:26,450 --> 00:26:31,880
all right so so just to remind you how

589
00:26:29,509 --> 00:26:34,009
hard it is to find planets it's only

590
00:26:31,880 --> 00:26:35,380
about 20 years ago that we found the

591
00:26:34,009 --> 00:26:38,750
first planet orbiting another star

592
00:26:35,380 --> 00:26:40,040
sun-like star and to put that in

593
00:26:38,750 --> 00:26:42,680
perspective let me show you the earth

594
00:26:40,039 --> 00:26:45,529
okay everything you know and love all

595
00:26:42,680 --> 00:26:47,660
the history of humans and all of our

596
00:26:45,529 --> 00:26:50,089
wonderful art and theater and and

597
00:26:47,660 --> 00:26:52,850
thought throughout generations it's all

598
00:26:50,089 --> 00:26:55,009
that blue marble and of course if you

599

00:26:52,849 --> 00:26:57,019
put it in perspective next to even

600
00:26:55,009 --> 00:26:58,700
another planet in the solar system it

601
00:26:57,019 --> 00:27:01,220
looks kind of small right there's

602
00:26:58,700 --> 00:27:02,509
Jupiter and of course if I keep the

603
00:27:01,220 --> 00:27:05,659
scale everything here is drawn

604
00:27:02,509 --> 00:27:09,889
the scale and I now put the Sun up on

605
00:27:05,659 --> 00:27:11,389
here okay then then you can see that the

606
00:27:09,888 --> 00:27:13,878
earth really doesn't amount to very much

607
00:27:11,388 --> 00:27:17,689
so very very precious for us but really

608
00:27:13,878 --> 00:27:21,078
not a big player in the solar system so

609
00:27:17,690 --> 00:27:23,119
that's why progress was so slow progress

610
00:27:21,078 --> 00:27:24,828
was slow because planets are small and

611
00:27:23,118 --> 00:27:26,388
they don't put out much light so

612
00:27:24,828 --> 00:27:28,388
compared to the stars they orbit they're

613
00:27:26,388 --> 00:27:31,269

simply overwhelmed and we don't see them

614

00:27:28,388 --> 00:27:33,618

so how are we gonna find those planets

615

00:27:31,269 --> 00:27:34,069

well I actually I showed you the answer

616

00:27:33,618 --> 00:27:37,428

right away

617

00:27:34,069 --> 00:27:40,939

did you see it they just you know so of

618

00:27:37,429 --> 00:27:42,169

course at the end of the title is that's

619

00:27:40,940 --> 00:27:45,379

not a that's I hope you weren't that's

620

00:27:42,169 --> 00:27:47,059

not a period that's an actual image

621

00:27:45,378 --> 00:27:48,918

that's a real image this is not

622

00:27:47,058 --> 00:27:53,749

something I did in Photoshop that's a

623

00:27:48,919 --> 00:27:56,629

real image taken in 2012 when of course

624

00:27:53,749 --> 00:27:59,868

Venus went in front of the Sun and did

625

00:27:56,628 --> 00:28:02,598

anybody here see that yes

626

00:27:59,868 --> 00:28:04,249

did anybody decide that you needed a two

627

00:28:02,598 --> 00:28:08,479

week family vacation in Hawaii to see

628
00:28:04,249 --> 00:28:11,868
the whole thing yes okay good

629
00:28:08,479 --> 00:28:15,078
so so that's that's Venus going in front

630
00:28:11,868 --> 00:28:16,578
of the Sun and that's how we're gonna

631
00:28:15,078 --> 00:28:18,709
find these planets that idea of a

632
00:28:16,578 --> 00:28:20,598
transit so they as the planets are gonna

633
00:28:18,709 --> 00:28:22,129
go in front of their stars they're gonna

634
00:28:20,598 --> 00:28:23,689
make their presence known because

635
00:28:22,128 --> 00:28:25,908
they're gonna block some of the light

636
00:28:23,690 --> 00:28:27,889
from the star so all of a sudden the

637
00:28:25,909 --> 00:28:29,479
star goes from being an adversary that's

638
00:28:27,888 --> 00:28:31,668
really bright thing blocking our view of

639
00:28:29,479 --> 00:28:33,649
a faint thing to an ally the star's

640
00:28:31,669 --> 00:28:37,038
light is now what's going to betray the

641
00:28:33,648 --> 00:28:39,678
presence of those planets now if we zoom

642
00:28:37,038 --> 00:28:41,239
in on the planet and we look very

643
00:28:39,679 --> 00:28:43,639
carefully we see something very very

644
00:28:41,239 --> 00:28:44,959
intriguing and Tom I don't know if it's

645
00:28:43,638 --> 00:28:47,439
possible just to bring the lights down a

646
00:28:44,959 --> 00:28:52,459
little bit for this one slide please

647
00:28:47,440 --> 00:28:54,818
okay so in 17 in the 1760s a Russian

648
00:28:52,459 --> 00:28:57,440
scientist by the name of Lomonosov was

649
00:28:54,818 --> 00:28:59,538
observing a transit of Venus these are

650
00:28:57,440 --> 00:29:01,940
very rare he was observing a transit of

651
00:28:59,538 --> 00:29:02,778
Venus and he noticed this is Venus now

652
00:29:01,940 --> 00:29:05,389
okay

653
00:29:02,778 --> 00:29:07,009
the Sun is enormous at the scale the Sun

654
00:29:05,388 --> 00:29:08,628
would go down several stories right so

655
00:29:07,009 --> 00:29:11,690
we're just zoomed in the planet and what

656

00:29:08,628 --> 00:29:14,388
he noticed was that the part of Venus

657
00:29:11,690 --> 00:29:16,670
that wasn't yet in front of the Sun was

658
00:29:14,388 --> 00:29:20,799
still illuminated you see

659
00:29:16,670 --> 00:29:23,779
there's that light arc and he said oh oh

660
00:29:20,799 --> 00:29:26,779
I bet you that's refraction that's the

661
00:29:23,779 --> 00:29:29,710
bending of light and so if light is

662
00:29:26,779 --> 00:29:33,920
bending there must be an atmosphere and

663
00:29:29,710 --> 00:29:35,509
so he deduced that Venus had an

664
00:29:33,920 --> 00:29:37,039
atmosphere that other planets had

665
00:29:35,509 --> 00:29:38,450
atmospheres it wasn't just a property of

666
00:29:37,039 --> 00:29:43,849
the earth and he was right it's an

667
00:29:38,450 --> 00:29:45,950
amazing induction that he made from a

668
00:29:43,849 --> 00:29:48,230
very large distance never actually going

669
00:29:45,950 --> 00:29:49,910
to the planet directly using this

670
00:29:48,230 --> 00:29:52,279

geometry he was able to infer that

671

00:29:49,910 --> 00:29:58,190

planets and atmospheres that is how

672

00:29:52,279 --> 00:30:00,259

we're gonna make progress okay so so so

673

00:29:58,190 --> 00:30:02,960

here are really kind of the goals that I

674

00:30:00,259 --> 00:30:04,640

want to tackle today really I want to I

675

00:30:02,960 --> 00:30:07,279

wanna do three things I want to describe

676

00:30:04,640 --> 00:30:08,540

the methods by which we find and

677

00:30:07,279 --> 00:30:10,579

characterize these planets and I think

678

00:30:08,539 --> 00:30:11,420

I've already kind of played my hand here

679

00:30:10,579 --> 00:30:15,199

which is it's going to be through

680

00:30:11,420 --> 00:30:16,370

transits I want to describe our current

681

00:30:15,200 --> 00:30:18,559

state of knowledge of earth-like

682

00:30:16,369 --> 00:30:21,500

exoplanets okay so what do we actually

683

00:30:18,559 --> 00:30:23,869

know about planets that are similar to

684

00:30:21,500 --> 00:30:26,119

the earth and then I really want to

685
00:30:23,869 --> 00:30:28,369
describe a kind of a first opportunity

686
00:30:26,119 --> 00:30:30,139
for going in detecting life okay so

687
00:30:28,369 --> 00:30:31,549
there's many many ideas astronomers I'm

688
00:30:30,140 --> 00:30:33,350
actually I'm here because there's

689
00:30:31,549 --> 00:30:36,649
there's a conference right now going on

690
00:30:33,349 --> 00:30:37,730
about about how we might use a future

691
00:30:36,650 --> 00:30:39,530
great observatory which I'm going to

692
00:30:37,730 --> 00:30:41,180
tell you about so astronomers are

693
00:30:39,529 --> 00:30:43,759
thinking hard about this issue and this

694
00:30:41,180 --> 00:30:45,410
is this is this is my thoughts on how

695
00:30:43,759 --> 00:30:47,329
we're actually our first opportunity

696
00:30:45,410 --> 00:30:49,960
might not work but it's the first time

697
00:30:47,329 --> 00:30:52,220
we have a genuine shot at this thing

698
00:30:49,960 --> 00:30:53,630
okay so just to remind you how we

699
00:30:52,220 --> 00:30:55,579
actually do go and find those planets

700
00:30:53,630 --> 00:30:58,850
there's of course the Doppler wobbles so

701
00:30:55,579 --> 00:31:02,359
the idea is the star is not fixed but

702
00:30:58,849 --> 00:31:04,129
the planet and the star dosey doe around

703
00:31:02,359 --> 00:31:06,079
each other sort of like sort of picture

704
00:31:04,130 --> 00:31:08,270
them is like to dance partners but but

705
00:31:06,079 --> 00:31:10,579
one dance partner weighs like you know

706
00:31:08,269 --> 00:31:13,250
300 thousand times more than another

707
00:31:10,579 --> 00:31:14,569
dance partner okay but if you looked at

708
00:31:13,250 --> 00:31:15,710
the big dance partner you would still

709
00:31:14,569 --> 00:31:17,419
see that they were kind of you know

710
00:31:15,710 --> 00:31:19,880
wobbling around and you didn't further

711
00:31:17,420 --> 00:31:20,960
there was another another body there so

712
00:31:19,880 --> 00:31:22,130
that's the Doppler method that's

713

00:31:20,960 --> 00:31:24,380
important because that gives us the

714
00:31:22,130 --> 00:31:26,030
planet's mass then the transit method

715
00:31:24,380 --> 00:31:27,260
I've already described that that that's

716
00:31:26,029 --> 00:31:29,450
the idea where the planet goes in front

717
00:31:27,259 --> 00:31:30,440
of its star and the fraction of light

718
00:31:29,450 --> 00:31:32,480
that it blocks

719
00:31:30,440 --> 00:31:34,009
if it blocks a lot of light it must be a

720
00:31:32,480 --> 00:31:36,230
big planet if it doesn't block very much

721
00:31:34,009 --> 00:31:37,849
light it must be a small planet and so

722
00:31:36,230 --> 00:31:39,798
if you can put these ideas together if

723
00:31:37,849 --> 00:31:42,079
you have a planet and you can measure

724
00:31:39,798 --> 00:31:45,019
its mass and you can measure its size

725
00:31:42,079 --> 00:31:46,908
then you can you can calculate a density

726
00:31:45,019 --> 00:31:48,919
and so without ever having been to the

727
00:31:46,909 --> 00:31:51,980

planet we can figure out is it a rocky

728

00:31:48,919 --> 00:31:53,450

planet or is it a gas giant planet we

729

00:31:51,980 --> 00:31:54,710

don't think gas giants planets are going

730

00:31:53,450 --> 00:31:56,808

to be good places for life we think we

731

00:31:54,710 --> 00:32:00,788

have to find rocky planets with a thin

732

00:31:56,808 --> 00:32:04,069

ocean so we're looking for rocky planets

733

00:32:00,788 --> 00:32:06,528

the other exciting thing about transits

734

00:32:04,069 --> 00:32:10,428

is that they allow us to go after the

735

00:32:06,528 --> 00:32:12,589

atmosphere ok so as the planet passes in

736

00:32:10,429 --> 00:32:14,809

front of the star some of the light from

737

00:32:12,589 --> 00:32:19,009

the star is going to pass through this

738

00:32:14,808 --> 00:32:21,769

little onion skin and imprinted on that

739

00:32:19,009 --> 00:32:23,480

star light which then travels through

740

00:32:21,769 --> 00:32:25,669

space and we capture with our telescopes

741

00:32:23,480 --> 00:32:27,649

imprinted on That star light is the

742
00:32:25,669 --> 00:32:29,690
chemical fingerprint of whatever atoms

743
00:32:27,648 --> 00:32:33,979
or molecules are present in the

744
00:32:29,690 --> 00:32:35,149
atmosphere ok so so we're never gonna

745
00:32:33,980 --> 00:32:37,038
see these planets we're not going to

746
00:32:35,148 --> 00:32:39,288
take a picture of them there's not gonna

747
00:32:37,038 --> 00:32:41,210
be any photographs but we can figure out

748
00:32:39,288 --> 00:32:43,038
their size we can figure out their mass

749
00:32:41,210 --> 00:32:44,990
we can figure out what their composition

750
00:32:43,038 --> 00:32:46,970
is by their density we can even study

751
00:32:44,990 --> 00:32:48,859
what the Ramah spheres are made of all

752
00:32:46,970 --> 00:32:51,740
by kind of clever thinking about how to

753
00:32:48,859 --> 00:32:54,229
make the star and a lie and this field

754
00:32:51,740 --> 00:32:56,509
has really taken off okay so in 2001

755
00:32:54,230 --> 00:32:58,278
there was one such planet

756
00:32:56,509 --> 00:33:00,128
there was one such planet and we just

757
00:32:58,278 --> 00:33:05,769
figured out how to study its atmosphere

758
00:33:00,128 --> 00:33:08,869
in 2017 there are more than 5000 such

759
00:33:05,769 --> 00:33:11,359
worlds and we've studied the atmospheres

760
00:33:08,869 --> 00:33:17,959
for a little over probably a hundred of

761
00:33:11,359 --> 00:33:20,028
them I thought about many ways to try to

762
00:33:17,960 --> 00:33:22,129
express the following idea and here I

763
00:33:20,028 --> 00:33:24,888
really have to give credit to Zack Berta

764
00:33:22,128 --> 00:33:26,509
Thompson who's a professor at the

765
00:33:24,888 --> 00:33:29,269
University of Colorado who I see has

766
00:33:26,509 --> 00:33:34,339
joined us Zack was also my student at

767
00:33:29,269 --> 00:33:37,069
Harvard and he he captured it in a

768
00:33:34,339 --> 00:33:38,750
nutshell through an image the idea is

769
00:33:37,069 --> 00:33:40,700
that there's something really special

770

00:33:38,750 --> 00:33:44,028
about the earth right if you were an

771
00:33:40,700 --> 00:33:44,269
alien looking at all the planets of the

772
00:33:44,028 --> 00:33:46,788
soul

773
00:33:44,269 --> 00:33:48,108
system you would see that there's

774
00:33:46,788 --> 00:33:50,358
something really different about the

775
00:33:48,108 --> 00:33:52,819
earth the earth has been transformed by

776
00:33:50,358 --> 00:33:55,338
biological activity the continents are

777
00:33:52,819 --> 00:33:58,098
green right they should be brown if it's

778
00:33:55,338 --> 00:34:00,499
just rock okay like Mars but they're

779
00:33:58,098 --> 00:34:02,808
green and sometimes they change color

780
00:34:00,499 --> 00:34:04,669
because the vegetation grows and and

781
00:34:02,808 --> 00:34:07,398
disappears in the fall and comes back in

782
00:34:04,669 --> 00:34:10,039
the spring and importantly the air on

783
00:34:07,398 --> 00:34:12,348
that planet is full of oxygen now you

784
00:34:10,039 --> 00:34:13,760

would know that oxygen likes to react

785

00:34:12,349 --> 00:34:16,220

with things there shouldn't be a lot of

786

00:34:13,760 --> 00:34:18,679

oxygen but yet here's this planet with

787

00:34:16,219 --> 00:34:20,959

twenty twenty-one percent oxygen in its

788

00:34:18,679 --> 00:34:23,990

atmosphere driven by biological activity

789

00:34:20,960 --> 00:34:26,358

so that's the idea it's not radio

790

00:34:23,989 --> 00:34:29,388

signals it's not spaceships it's that

791

00:34:26,358 --> 00:34:32,838

the inevitable chemistry of life the the

792

00:34:29,389 --> 00:34:34,700

waste products of life really change the

793

00:34:32,838 --> 00:34:36,409

appearance of a planet life has

794

00:34:34,699 --> 00:34:39,108

radically transformed the way the earth

795

00:34:36,409 --> 00:34:41,419

looks and the way it smells and the

796

00:34:39,108 --> 00:34:42,889

things in its atmosphere and those are

797

00:34:41,418 --> 00:34:45,019

the things that we look for remotely

798

00:34:42,889 --> 00:34:46,309

with our powerful telescopes whether or

799

00:34:45,019 --> 00:34:51,168

not life has any interest in

800

00:34:46,309 --> 00:34:53,359

communicating okay so now connect that

801

00:34:51,168 --> 00:34:55,608

idea to the possible what you know

802

00:34:53,358 --> 00:34:57,699

there's there's the ideas of what's out

803

00:34:55,608 --> 00:35:01,460

there and then there's what can I do

804

00:34:57,699 --> 00:35:05,449

this is the opportunity the James Webb

805

00:35:01,460 --> 00:35:08,690

Space Telescope okay so here we are you

806

00:35:05,449 --> 00:35:10,608

know at that at the at the at the place

807

00:35:08,690 --> 00:35:12,470

where I'm here for this to and after

808

00:35:10,608 --> 00:35:15,710

meeting talking about how to use James

809

00:35:12,469 --> 00:35:19,129

Webb to study planets and here we are

810

00:35:15,710 --> 00:35:22,699

only about a year away from launch James

811

00:35:19,130 --> 00:35:25,670

Webb is the successor both in terms of

812

00:35:22,699 --> 00:35:27,199

hardware and in terms of ideas from the

813
00:35:25,670 --> 00:35:29,450
Hubble Space Telescope and the Spitzer

814
00:35:27,199 --> 00:35:31,669
Space Telescope but of course it's an

815
00:35:29,449 --> 00:35:35,629
enormous ly much much larger and much

816
00:35:31,670 --> 00:35:37,670
more powerful Observatory as as many of

817
00:35:35,630 --> 00:35:40,849
you probably know it was as it's a it's

818
00:35:37,670 --> 00:35:43,159
a local kid okay it was assembled at the

819
00:35:40,849 --> 00:35:44,480
Goddard Space Flight Center and some of

820
00:35:43,159 --> 00:35:46,399
you maybe even got a chance to actually

821
00:35:44,480 --> 00:35:47,179
see it being assembled and it is

822
00:35:46,400 --> 00:35:49,309
enormous

823
00:35:47,179 --> 00:35:51,980
okay it's six and a half meters in size

824
00:35:49,309 --> 00:35:54,890
okay these are these are normal size to

825
00:35:51,980 --> 00:35:57,619
humans you're working on working on the

826
00:35:54,889 --> 00:35:58,129
telescope okay and these are the

827

00:35:57,619 --> 00:36:00,440
individual

828
00:35:58,130 --> 00:36:02,240
all mirrors some of which have covers on

829
00:36:00,440 --> 00:36:05,240
them and some of them which don't and

830
00:36:02,239 --> 00:36:08,088
they have that kind of gold look if you

831
00:36:05,239 --> 00:36:10,608
didn't get a chance to see James Webb

832
00:36:08,088 --> 00:36:13,429
I'm a Ford I'm sad to say it's it's it's

833
00:36:10,608 --> 00:36:14,869
gone now it's moved to Texas and the

834
00:36:13,429 --> 00:36:16,009
reason is that there's a whole bunch of

835
00:36:14,869 --> 00:36:18,108
testing that you have to go through

836
00:36:16,009 --> 00:36:24,710
before you get to go to space okay and

837
00:36:18,108 --> 00:36:29,389
so now it's gone to Texas to I use this

838
00:36:24,710 --> 00:36:31,190
enormous cryogenic testing chamber and

839
00:36:29,389 --> 00:36:33,710
they're going to put the James Webb

840
00:36:31,190 --> 00:36:36,679
Space Telescope in there cool it down

841
00:36:33,710 --> 00:36:38,509

over many months I believe and do

842

00:36:36,679 --> 00:36:41,778

various tests and make sure that

843

00:36:38,509 --> 00:36:43,548

everything performs exactly as it should

844

00:36:41,778 --> 00:36:46,579

so that it was out in the coldness of

845

00:36:43,548 --> 00:36:48,679

space there are no surprises James Webb

846

00:36:46,579 --> 00:36:50,240

will be so far from the earth there was

847

00:36:48,679 --> 00:36:51,169

no chance to go and service it the way

848

00:36:50,239 --> 00:36:53,449

we did with the Hubble Space Telescope

849

00:36:51,170 --> 00:36:55,460

it is farther from the earth it will be

850

00:36:53,449 --> 00:36:57,048

farther from the earth than any human

851

00:36:55,460 --> 00:37:00,440

has ever been right the farthest people

852

00:36:57,048 --> 00:37:02,329

have been is the moon you might worry by

853

00:37:00,440 --> 00:37:08,990

the way is it gonna fit and I want to

854

00:37:02,329 --> 00:37:11,568

point out it does barely fit okay but of

855

00:37:08,989 --> 00:37:12,979

course NASA was very good with precision

856
00:37:11,568 --> 00:37:14,000
so they knew they knew going down there

857
00:37:12,980 --> 00:37:16,338
was going to be a tight fit but a

858
00:37:14,000 --> 00:37:18,048
possible one okay so the idea is James

859
00:37:16,338 --> 00:37:19,849
Webb very special opportunity much more

860
00:37:18,048 --> 00:37:21,739
powerful telescope very good infrared

861
00:37:19,849 --> 00:37:23,630
telescope much bigger than anything

862
00:37:21,739 --> 00:37:25,008
that's been put out in space maybe it

863
00:37:23,630 --> 00:37:27,829
can do something for exoplanet

864
00:37:25,009 --> 00:37:29,630
atmospheres I want to introduce another

865
00:37:27,829 --> 00:37:31,400
telescope that you might not be so

866
00:37:29,630 --> 00:37:33,559
familiar with which is the giant

867
00:37:31,400 --> 00:37:38,028
Magellan telescope giant Magellan

868
00:37:33,559 --> 00:37:40,640
telescope is enormous okay it at the

869
00:37:38,028 --> 00:37:42,559
time that it is constructed we think

870
00:37:40,639 --> 00:37:44,480
it's going to be finished around 2023

871
00:37:42,559 --> 00:37:47,539
it's going to be the largest optical

872
00:37:44,480 --> 00:37:49,608
telescope ever built but it's on the

873
00:37:47,539 --> 00:37:51,528
ground okay James Webb is six and a half

874
00:37:49,608 --> 00:37:52,969
meters that's the biggest thing we know

875
00:37:51,528 --> 00:37:54,380
how to get up into space right now it's

876
00:37:52,969 --> 00:37:56,419
obviously very expensive very heavy to

877
00:37:54,380 --> 00:37:58,430
get things up into space this is a much

878
00:37:56,420 --> 00:38:00,769
much bigger telescope but it's going to

879
00:37:58,429 --> 00:38:02,598
be located in Chile okay so it has to

880
00:38:00,768 --> 00:38:07,098
look up through the Earth's atmosphere

881
00:38:02,599 --> 00:38:08,450
to make these measurements just just to

882
00:38:07,099 --> 00:38:09,980
just to make sure that you all

883
00:38:08,449 --> 00:38:11,329
understand how truly enormous this

884

00:38:09,980 --> 00:38:14,599
telescope is it

885
00:38:11,329 --> 00:38:15,309
composed of one two three four five six

886
00:38:14,599 --> 00:38:19,099
seven

887
00:38:15,309 --> 00:38:25,639
giant mirrors each one of these mirrors

888
00:38:19,099 --> 00:38:28,610
is about 25 feet 25 feet in diameter so

889
00:38:25,639 --> 00:38:32,299
the James Webb Space Telescope it's its

890
00:38:28,610 --> 00:38:35,930
entire mirror is smaller than one of

891
00:38:32,300 --> 00:38:37,340
these mirrors okay so there's a person

892
00:38:35,929 --> 00:38:40,129
remember we had people dangling down

893
00:38:37,340 --> 00:38:42,289
before okay look how big a person is now

894
00:38:40,130 --> 00:38:44,869
compared to this entire thing in fact if

895
00:38:42,289 --> 00:38:46,130
you take this middle mirror which has

896
00:38:44,869 --> 00:38:47,210
got a hole in it because when it's all

897
00:38:46,130 --> 00:38:49,160
assembled that's where the light goes

898
00:38:47,210 --> 00:38:50,809

through to be studied if you take that

899

00:38:49,159 --> 00:38:53,420

middle mirror there it is it's not

900

00:38:50,809 --> 00:38:56,299

polished yet but all these people are

901

00:38:53,420 --> 00:38:57,800

sitting on the mirror blank okay before

902

00:38:56,300 --> 00:39:00,950

we go through the actual polishing which

903

00:38:57,800 --> 00:39:03,680

is all being done in Arizona so we've

904

00:39:00,949 --> 00:39:05,809

got the James Webb Space Telescope which

905

00:39:03,679 --> 00:39:07,909

is undergoing testing ready to launch in

906

00:39:05,809 --> 00:39:10,730

2018 going to be up in space giant

907

00:39:07,909 --> 00:39:12,769

Magellan telescope we you know are still

908

00:39:10,730 --> 00:39:14,420

figuring out how to pay for it but we

909

00:39:12,769 --> 00:39:15,710

started construction that's a real

910

00:39:14,420 --> 00:39:18,800

challenge it is not a federally funded

911

00:39:15,710 --> 00:39:21,829

project okay it is a very interesting

912

00:39:18,800 --> 00:39:23,240

collaboration of us partners and the

913
00:39:21,829 --> 00:39:25,309
National Science Foundation's of many

914
00:39:23,239 --> 00:39:26,569
other countries but it's not fully

915
00:39:25,309 --> 00:39:27,079
funded that is the main challenge with

916
00:39:26,570 --> 00:39:29,510
the GMT

917
00:39:27,079 --> 00:39:33,110
but confident that we'll get this thing

918
00:39:29,510 --> 00:39:35,150
together in 2023 so so if I put these

919
00:39:33,110 --> 00:39:36,950
together right we've got these two

920
00:39:35,150 --> 00:39:38,690
really unprecedented observatories the

921
00:39:36,949 --> 00:39:40,759
giant Magellan telescope and the James

922
00:39:38,690 --> 00:39:44,329
Webb Space Telescope they will have the

923
00:39:40,760 --> 00:39:47,540
power to access the atmospheres perhaps

924
00:39:44,329 --> 00:39:49,219
of earth-like planets so what is the

925
00:39:47,539 --> 00:39:50,529
challenge given that these telescopes

926
00:39:49,219 --> 00:39:53,480
are getting built

927
00:39:50,530 --> 00:39:57,019
okay the challenge is we don't yet know

928
00:39:53,480 --> 00:39:58,789
where to point them so so it may sound

929
00:39:57,019 --> 00:40:01,579
shocking but we actually haven't found

930
00:39:58,789 --> 00:40:05,719
the planets orbiting the very closest

931
00:40:01,579 --> 00:40:07,190
stars to us right so so for four we

932
00:40:05,719 --> 00:40:09,889
actually have found a lot of planets

933
00:40:07,190 --> 00:40:11,780
that are at somewhat larger distances

934
00:40:09,889 --> 00:40:13,400
out in the galaxy but we haven't

935
00:40:11,780 --> 00:40:14,570
actually figured out which of the very

936
00:40:13,400 --> 00:40:16,970
closest stars which were the most

937
00:40:14,570 --> 00:40:19,550
accessible to telescopes actually have

938
00:40:16,969 --> 00:40:23,029
that the planets that we seek so how do

939
00:40:19,550 --> 00:40:24,980
we how do we remedy that okay

940
00:40:23,030 --> 00:40:29,060
so again to remind you the challenge

941

00:40:24,980 --> 00:40:31,429
here is a picture of the Sun okay and

942
00:40:29,059 --> 00:40:33,889
can anybody see the earth-like planet in

943
00:40:31,429 --> 00:40:35,389
front of the Sun dropped one in there

944
00:40:33,889 --> 00:40:37,039
just a mimic it okay it's not these are

945
00:40:35,389 --> 00:40:40,549
some these are star spots they're bigger

946
00:40:37,039 --> 00:40:45,139
than the earth often but it's right over

947
00:40:40,550 --> 00:40:47,869
here okay so that's roughly how big the

948
00:40:45,139 --> 00:40:50,839
earth would look going in front of a

949
00:40:47,869 --> 00:40:53,090
sun-like star viewed from the distance

950
00:40:50,840 --> 00:40:54,829
of another star so that's really really

951
00:40:53,090 --> 00:40:56,990
hard to discover that's really really

952
00:40:54,829 --> 00:41:01,579
hard to find such a small thing going in

953
00:40:56,989 --> 00:41:02,959
front of such a big thing so NASA knew

954
00:41:01,579 --> 00:41:05,150
how to tackle that that was the Kepler

955
00:41:02,960 --> 00:41:06,889

mission right I hope you've all heard of

956

00:41:05,150 --> 00:41:09,410

the Kepler mission the Kepler mission

957

00:41:06,889 --> 00:41:11,329

launched in 2009 operated for four years

958

00:41:09,409 --> 00:41:13,429

it's now still operating but in a

959

00:41:11,329 --> 00:41:15,559

different way because of a hardware

960

00:41:13,429 --> 00:41:17,269

failure that that prevented it from

961

00:41:15,559 --> 00:41:18,739

gathering data the way it had been

962

00:41:17,269 --> 00:41:20,150

gathering data for four years and that's

963

00:41:18,739 --> 00:41:22,429

called the k2 mission which I won't

964

00:41:20,150 --> 00:41:24,980

focus on here but during these four

965

00:41:22,429 --> 00:41:28,909

years it studied a hundred and fifty

966

00:41:24,980 --> 00:41:31,820

thousand stars and the purpose was to

967

00:41:28,909 --> 00:41:34,879

figure out how common planets were

968

00:41:31,820 --> 00:41:37,039

around stars in general so with 150,000

969

00:41:34,880 --> 00:41:39,230

stars it can actually do statistics okay

970
00:41:37,039 --> 00:41:41,150
now it found all sorts of different

971
00:41:39,230 --> 00:41:44,240
kinds of planets it found small planets

972
00:41:41,150 --> 00:41:45,800
big planets wild architectures there

973
00:41:44,239 --> 00:41:47,839
where there are planetary systems where

974
00:41:45,800 --> 00:41:49,340
you have a gas giant and a rocky planet

975
00:41:47,840 --> 00:41:51,050
and then a gas giant and then a rocky

976
00:41:49,340 --> 00:41:52,990
planet and then a gas giant completely

977
00:41:51,050 --> 00:41:57,500
unlike the solar system where things are

978
00:41:52,989 --> 00:41:59,179
nicely divided but there's one there's

979
00:41:57,500 --> 00:42:03,739
one result in particular that I want to

980
00:41:59,179 --> 00:42:06,049
focus on of course what what I'm

981
00:42:03,739 --> 00:42:06,858
interested in if we want to answer this

982
00:42:06,050 --> 00:42:11,810
question of whether or not we're alone

983
00:42:06,858 --> 00:42:13,969
is how common our earth-like planets so

984
00:42:11,809 --> 00:42:16,489
to be earth-like you have to be rocky

985
00:42:13,969 --> 00:42:18,500
you have to be sir science and you also

986
00:42:16,489 --> 00:42:21,829
have to be the right temperature right

987
00:42:18,500 --> 00:42:26,019
so if I take rocky planet and I put it

988
00:42:21,829 --> 00:42:29,989
too close to a star then the water will

989
00:42:26,019 --> 00:42:32,420
boil and it'll be it'll be gaseous if I

990
00:42:29,989 --> 00:42:34,909
move it too far from the star it's good

991
00:42:32,420 --> 00:42:37,460
good for hockey but bad for life which

992
00:42:34,909 --> 00:42:38,449
is it's all frozen so you have to be in

993
00:42:37,460 --> 00:42:42,230
kind of this

994
00:42:38,449 --> 00:42:43,819
this Goldilocks zone so of all the

995
00:42:42,230 --> 00:42:47,659
hundred and fifty thousand stars that

996
00:42:43,820 --> 00:42:48,800
Kepler studied you know most the time we

997
00:42:47,659 --> 00:42:50,389
didn't see planets because they just

998

00:42:48,800 --> 00:42:52,339
didn't happen to be lying a longer line

999
00:42:50,389 --> 00:42:55,009
of sight but there was still enough that

1000
00:42:52,338 --> 00:42:58,940
that we could do statistics and I really

1001
00:42:55,010 --> 00:43:01,400
am delighted to say that we now know how

1002
00:42:58,940 --> 00:43:04,039
common earth-like planets are in the

1003
00:43:01,400 --> 00:43:06,769
galaxy we actually know how common is it

1004
00:43:04,039 --> 00:43:10,099
that the typical star in the galaxy has

1005
00:43:06,769 --> 00:43:14,358
a planet that's the same size and the

1006
00:43:10,099 --> 00:43:16,220
same temperature as the earth and what

1007
00:43:14,358 --> 00:43:18,319
I'm particularly proud of is that that

1008
00:43:16,219 --> 00:43:19,608
result so there was an enormous amount

1009
00:43:18,320 --> 00:43:20,660
of work that went into the Kepler

1010
00:43:19,608 --> 00:43:22,699
mission okay it was hundreds of

1011
00:43:20,659 --> 00:43:24,019
scientists and engineers they produced

1012
00:43:22,699 --> 00:43:26,000

the state of the data was used for many

1013

00:43:24,019 --> 00:43:27,559

different studies but the particular

1014

00:43:26,000 --> 00:43:29,630

question of the statistics of earth-like

1015

00:43:27,559 --> 00:43:31,608

planets that was figured out by Courtney

1016

00:43:29,630 --> 00:43:33,980

addressing Courtney was a graduate

1017

00:43:31,608 --> 00:43:35,509

student working with me at Harvard and

1018

00:43:33,980 --> 00:43:36,858

she was the first person ever know how

1019

00:43:35,510 --> 00:43:39,260

common they were so it could have been

1020

00:43:36,858 --> 00:43:40,699

one in a million it could have been the

1021

00:43:39,260 --> 00:43:41,780

Star Trek universe where every star has

1022

00:43:40,699 --> 00:43:44,779

an earth-like planet

1023

00:43:41,780 --> 00:43:53,109

Courtley found out the answer is one in

1024

00:43:44,780 --> 00:43:56,390

four okay so so one in four stars has a

1025

00:43:53,108 --> 00:43:58,400

has a has an earth-like planet which is

1026

00:43:56,389 --> 00:44:00,379

fantastic news if you want to go and

1027
00:43:58,400 --> 00:44:01,700
follow them up because if it had been

1028
00:44:00,380 --> 00:44:03,858
one in a million let's say one in a

1029
00:44:01,699 --> 00:44:05,389
million stars had had such a planet then

1030
00:44:03,858 --> 00:44:07,909
that would mean the closest one to us

1031
00:44:05,389 --> 00:44:10,219
would still be so far away that it would

1032
00:44:07,909 --> 00:44:11,960
be beyond our ability to study it with

1033
00:44:10,219 --> 00:44:13,368
things like the James Webb Space

1034
00:44:11,960 --> 00:44:15,949
Telescope and the giant Magellan

1035
00:44:13,369 --> 00:44:17,780
telescope but this now gives us hope

1036
00:44:15,949 --> 00:44:25,039
this means that even the closest stars

1037
00:44:17,780 --> 00:44:26,990
might perhaps have such a planet so how

1038
00:44:25,039 --> 00:44:28,608
do we actually go and find the planet we

1039
00:44:26,989 --> 00:44:30,828
want to study well we can't use the ones

1040
00:44:28,608 --> 00:44:32,779
that Kepler found Kepler was looking at

1041
00:44:30,829 --> 00:44:35,568
150,000 stars but the stars were all

1042
00:44:32,780 --> 00:44:37,339
quite far away if we want to study the

1043
00:44:35,568 --> 00:44:39,800
atmosphere of a planet we need the star

1044
00:44:37,338 --> 00:44:42,259
to have have two features first the star

1045
00:44:39,800 --> 00:44:43,730
has to be very very close buying okay if

1046
00:44:42,260 --> 00:44:44,810
the star is close to us obviously it's a

1047
00:44:43,730 --> 00:44:47,630
lot brighter we get a lot more

1048
00:44:44,809 --> 00:44:50,358
information from it more quickly and we

1049
00:44:47,630 --> 00:44:52,280
also care about how big the star is

1050
00:44:50,358 --> 00:44:56,250
compared to the plan

1051
00:44:52,280 --> 00:44:57,930
if I can shrink the star then the

1052
00:44:56,250 --> 00:44:59,579
planet's atmosphere blocks

1053
00:44:57,929 --> 00:45:01,500
proportionately more light

1054
00:44:59,579 --> 00:45:03,029
okay the atmosphere doesn't change I'm

1055

00:45:01,500 --> 00:45:05,280
not changing the size of the earth but

1056
00:45:03,030 --> 00:45:06,780
if I can shrink the star then a relative

1057
00:45:05,280 --> 00:45:08,850
to the star the atmosphere starts to

1058
00:45:06,780 --> 00:45:10,650
look very big and it makes my

1059
00:45:08,849 --> 00:45:12,389
measurement easier so it's a very

1060
00:45:10,650 --> 00:45:15,360
opportunistic thing okay

1061
00:45:12,389 --> 00:45:17,129
I I simply want to find closeby stars

1062
00:45:15,360 --> 00:45:18,720
and I want them to be as small as I can

1063
00:45:17,130 --> 00:45:19,829
make them and that gives me the best

1064
00:45:18,719 --> 00:45:26,939
chance for going and setting the

1065
00:45:19,829 --> 00:45:30,239
atmospheres of those planets as it turns

1066
00:45:26,940 --> 00:45:32,849
out I was I was told a big lie in high

1067
00:45:30,239 --> 00:45:35,069
school by my science teacher did any of

1068
00:45:32,849 --> 00:45:37,349
you get the same I was told the Sun was

1069
00:45:35,070 --> 00:45:38,780

an average star heard this all the time

1070

00:45:37,349 --> 00:45:41,579

in high school Sun is an average star

1071

00:45:38,780 --> 00:45:45,210

big lie the Sun is not an average star

1072

00:45:41,579 --> 00:45:46,860

the Sun is much much bigger and more

1073

00:45:45,210 --> 00:45:48,900

massive and puts out a lot more light

1074

00:45:46,860 --> 00:45:52,200

than the typical star the typical star

1075

00:45:48,900 --> 00:45:55,740

is what we call a red dwarf star it's

1076

00:45:52,199 --> 00:45:59,579

about 1/4 of the size of the Sun it's

1077

00:45:55,739 --> 00:46:01,469

about 1/4 the mass of the Sun and it

1078

00:45:59,579 --> 00:46:04,590

puts out about one one thousandth the

1079

00:46:01,469 --> 00:46:07,259

amount of light ok so so if you know the

1080

00:46:04,590 --> 00:46:09,180

Sun is like a big thousand watt light

1081

00:46:07,260 --> 00:46:12,420

bulb this is this is a little Christmas

1082

00:46:09,179 --> 00:46:14,639

tree light ok but that's that's the

1083

00:46:12,420 --> 00:46:16,829

dominant mode of star formation in the

1084
00:46:14,639 --> 00:46:20,909
galaxy sun-like stars are actually quite

1085
00:46:16,829 --> 00:46:22,500
quite rare great news right great news

1086
00:46:20,909 --> 00:46:24,179
if you want to go and find earth-like

1087
00:46:22,500 --> 00:46:28,710
planets because I just told you I want

1088
00:46:24,179 --> 00:46:31,159
to make the star small that also has the

1089
00:46:28,710 --> 00:46:34,679
benefit of shrinking the habitable zone

1090
00:46:31,159 --> 00:46:37,379
so the idea is you know you want to find

1091
00:46:34,679 --> 00:46:38,759
the distance around the star at which

1092
00:46:37,380 --> 00:46:41,070
your planet is going to have the right

1093
00:46:38,760 --> 00:46:44,550
temperature if the star is very very

1094
00:46:41,070 --> 00:46:46,950
bright you have to move far away but if

1095
00:46:44,550 --> 00:46:49,110
the star puts out very little light then

1096
00:46:46,949 --> 00:46:51,059
then the planets want to kind of huddle

1097
00:46:49,110 --> 00:46:53,760
in close to just have the right

1098
00:46:51,059 --> 00:46:55,980
temperature once again the benefit of

1099
00:46:53,760 --> 00:46:57,630
that is if they're in close they go

1100
00:46:55,980 --> 00:46:59,039
around much more frequently so instead

1101
00:46:57,630 --> 00:47:00,960
of having to wait for a signal that I

1102
00:46:59,039 --> 00:47:02,670
see once a year right if an alien was

1103
00:47:00,960 --> 00:47:04,720
studying us they would only get to see

1104
00:47:02,670 --> 00:47:06,460
us go in front of the Sun once a year

1105
00:47:04,719 --> 00:47:10,779
now they might go in front of the Sun

1106
00:47:06,460 --> 00:47:13,179
maybe once every 15 or 20 days okay so

1107
00:47:10,780 --> 00:47:14,800
small stars are the most common but they

1108
00:47:13,179 --> 00:47:16,059
also are exactly what we're looking for

1109
00:47:14,800 --> 00:47:17,410
it makes it a lot easier to study the

1110
00:47:16,059 --> 00:47:23,590
atmosphere because the signal is bigger

1111
00:47:17,409 --> 00:47:25,659
and it's more frequent if I draw a

1112

00:47:23,590 --> 00:47:27,820
bubble if I were to go out in space and

1113
00:47:25,659 --> 00:47:30,309
draw a giant bubble just around the

1114
00:47:27,820 --> 00:47:33,609
nearby stars so let's go out to say

1115
00:47:30,309 --> 00:47:35,920
about 30 light-years okay and I count up

1116
00:47:33,608 --> 00:47:38,380
all the stars in that bubble then here's

1117
00:47:35,920 --> 00:47:40,869
what you get okay so there are no oh

1118
00:47:38,380 --> 00:47:43,210
stars no B stars these are the really

1119
00:47:40,869 --> 00:47:44,980
really massive stars there's a small

1120
00:47:43,210 --> 00:47:46,900
number of a and F stars and there's

1121
00:47:44,980 --> 00:47:49,389
about 20 sun-like stars what astronomers

1122
00:47:46,900 --> 00:47:52,090
called G stars so after 30 light years

1123
00:47:49,389 --> 00:47:55,480
we're talking about 20 g-type stars in

1124
00:47:52,090 --> 00:47:58,809
that same volume of space how many of

1125
00:47:55,480 --> 00:48:04,358
these red dwarf stars are there okay

1126
00:47:58,809 --> 00:48:05,829

there's 246 okay so in in in the same

1127

00:48:04,358 --> 00:48:08,739

amount of space where you have 20 of

1128

00:48:05,829 --> 00:48:11,739

these sun-like stars you've got 246 of

1129

00:48:08,739 --> 00:48:14,739

these M dwarfs so they owe number us 12

1130

00:48:11,739 --> 00:48:17,079

to 1 so if you're interested in life on

1131

00:48:14,739 --> 00:48:18,699

other planets red dwarf stars are great

1132

00:48:17,079 --> 00:48:20,799

because it's easier to find that life

1133

00:48:18,699 --> 00:48:22,838

but they're also great because they just

1134

00:48:20,800 --> 00:48:25,330

outnumber us twelve to one I mean if if

1135

00:48:22,838 --> 00:48:26,559

if planets form around those kinds of

1136

00:48:25,329 --> 00:48:28,210

stars the same way they form around

1137

00:48:26,559 --> 00:48:30,309

sun-like stars it's kind of inevitable

1138

00:48:28,210 --> 00:48:31,510

that the closest one to us is going to

1139

00:48:30,309 --> 00:48:33,369

be around an M dwarf just because

1140

00:48:31,510 --> 00:48:37,930

they're so common these little red dwarf

1141
00:48:33,369 --> 00:48:40,750
stars so with that idea in mind I set

1142
00:48:37,929 --> 00:48:44,649
out a number of years ago now about nine

1143
00:48:40,750 --> 00:48:46,030
years to build a special project called

1144
00:48:44,650 --> 00:48:50,500
the mirth project which was going to

1145
00:48:46,030 --> 00:48:53,170
focus on finding planets that are small

1146
00:48:50,500 --> 00:48:56,108
like the earth and going in front of the

1147
00:48:53,170 --> 00:48:57,309
very closest small red dwarf stars so

1148
00:48:56,108 --> 00:48:59,679
because we were trying to find

1149
00:48:57,309 --> 00:49:02,309
earth-like planets in front of m-type

1150
00:48:59,679 --> 00:49:05,199
stars we called it the mirth project and

1151
00:49:02,309 --> 00:49:06,909
here is what we came up with the idea

1152
00:49:05,199 --> 00:49:09,129
was we didn't need very big telescopes

1153
00:49:06,909 --> 00:49:10,629
because the Stars were very nearby but

1154
00:49:09,130 --> 00:49:13,059
we needed a lot of telescopes because

1155
00:49:10,630 --> 00:49:14,619
the stars were all over the sky so we

1156
00:49:13,059 --> 00:49:16,779
had a list of the very closest few

1157
00:49:14,619 --> 00:49:18,030
thousand stars but some one was over

1158
00:49:16,780 --> 00:49:19,680
here one was over here

1159
00:49:18,030 --> 00:49:21,000
was over here so we needed different

1160
00:49:19,679 --> 00:49:22,619
telescopes to look at them all at the

1161
00:49:21,000 --> 00:49:27,510
same time we couldn't get by with one

1162
00:49:22,619 --> 00:49:29,159
big telescope we wanted to see stars in

1163
00:49:27,510 --> 00:49:32,250
both the Northern Hemisphere and the

1164
00:49:29,159 --> 00:49:34,379
southern hemisphere and so in the North

1165
00:49:32,250 --> 00:49:38,610
we're located in Arizona and then much

1166
00:49:34,380 --> 00:49:41,130
more recently just about two years two

1167
00:49:38,610 --> 00:49:42,809
and a half years ago we began operating

1168
00:49:41,130 --> 00:49:45,090
in in Chile

1169

00:49:42,809 --> 00:49:46,259
okay and that gives us access to both

1170
00:49:45,090 --> 00:49:49,650
the Northern Hemisphere and the southern

1171
00:49:46,260 --> 00:49:51,450
hemisphere and every night these

1172
00:49:49,650 --> 00:49:53,849
telescopes go about their business they

1173
00:49:51,449 --> 00:49:55,889
are frantically surveying all the nearby

1174
00:49:53,849 --> 00:49:57,029
stars and I want to show you what that

1175
00:49:55,889 --> 00:49:58,829
looks like and again if we could just

1176
00:49:57,030 --> 00:49:59,940
Tom if we could just bring down the

1177
00:49:58,829 --> 00:50:09,150
light a little bit face for the next

1178
00:49:59,940 --> 00:50:10,740
image okay so here's a time-lapse of the

1179
00:50:09,150 --> 00:50:12,480
observatory in action so you can see all

1180
00:50:10,739 --> 00:50:14,639
these different telescopes as the stars

1181
00:50:12,480 --> 00:50:17,639
scroll overhead but this particular

1182
00:50:14,639 --> 00:50:19,619
telescope I'm plotting its data and it's

1183
00:50:17,639 --> 00:50:20,789

studying one star and nothing much is

1184

00:50:19,619 --> 00:50:24,179
happening until it gets to this

1185

00:50:20,789 --> 00:50:26,670
observation right here boom it slow

1186

00:50:24,179 --> 00:50:29,159
the telescope realizes that in real time

1187

00:50:26,670 --> 00:50:32,039
and it changes the way it was gathering

1188

00:50:29,159 --> 00:50:33,989
data it notices the Stars fainter than

1189

00:50:32,039 --> 00:50:36,809
it had been earlier in the evening and

1190

00:50:33,989 --> 00:50:38,519
so it follows that star until it notices

1191

00:50:36,809 --> 00:50:41,449
that it brightens up again and then it

1192

00:50:38,519 --> 00:50:44,730
goes back to its survey observations

1193

00:50:41,449 --> 00:50:47,159
this is great for family life I'm it's

1194

00:50:44,730 --> 00:50:51,869
fully robotic I'm home with the kids I'm

1195

00:50:47,159 --> 00:50:54,690
making dinner and and lo and behold of

1196

00:50:51,869 --> 00:50:56,819
course then we find out the next morning

1197

00:50:54,690 --> 00:50:58,710
that mirth is found a planet okay so

1198
00:50:56,820 --> 00:51:00,780
that's what that signal looks like it's

1199
00:50:58,710 --> 00:51:02,490
blocking only a few parts in a thousand

1200
00:51:00,780 --> 00:51:04,500
of the light from the star but that's

1201
00:51:02,489 --> 00:51:09,209
our first hint that there is this rocky

1202
00:51:04,500 --> 00:51:12,179
world okay and and this discovery was

1203
00:51:09,210 --> 00:51:17,960
led by Zak who I just mentioned earlier

1204
00:51:12,179 --> 00:51:22,259
in the talk okay so that was a discovery

1205
00:51:17,960 --> 00:51:26,460
of a nearby rocky world and then more

1206
00:51:22,260 --> 00:51:27,870
recently just recently we we found the

1207
00:51:26,460 --> 00:51:31,440
one that we're really looking for so

1208
00:51:27,869 --> 00:51:35,909
that's what I want to tell you about so

1209
00:51:31,440 --> 00:51:39,179
so in September of 2014 our Observatory

1210
00:51:35,909 --> 00:51:40,348
mirth found a dip a dip of one of the

1211
00:51:39,179 --> 00:51:41,699
stars that we've been surveying so is

1212
00:51:40,349 --> 00:51:44,220
this anonymous star it's got this

1213
00:51:41,699 --> 00:51:45,719
catalog name LHS 11:40 so even though

1214
00:51:44,219 --> 00:51:47,818
it's a very nearby star it's just got

1215
00:51:45,719 --> 00:51:49,500
this completely anonymous name but we

1216
00:51:47,818 --> 00:51:52,500
didn't we didn't really think very much

1217
00:51:49,500 --> 00:51:54,358
of it ok and then a student Jason

1218
00:51:52,500 --> 00:51:57,809
Dittman went back and reanalyzed the

1219
00:51:54,358 --> 00:51:59,699
data using a very clever software that

1220
00:51:57,809 --> 00:52:01,170
he wrote a machine learning software if

1221
00:51:59,699 --> 00:52:02,639
you're into that kind of thing and he

1222
00:52:01,170 --> 00:52:04,289
found that those data were were

1223
00:52:02,639 --> 00:52:07,828
persuasive he thought we should go and

1224
00:52:04,289 --> 00:52:10,799
and try to and try to do some follow up

1225
00:52:07,829 --> 00:52:12,539
so we began to do Doppler monitoring so

1226

00:52:10,798 --> 00:52:14,338
instead of waiting for another transit

1227
00:52:12,539 --> 00:52:15,839
to occur we thought well you know if the

1228
00:52:14,338 --> 00:52:17,130
planets actually out in the habitable

1229
00:52:15,838 --> 00:52:18,838
zone we're not going to see another

1230
00:52:17,130 --> 00:52:21,358
Eclipse we're just gonna see one those

1231
00:52:18,838 --> 00:52:23,190
are pretty rare so instead what Jason

1232
00:52:21,358 --> 00:52:24,568
had us doing was to actually start to

1233
00:52:23,190 --> 00:52:27,510
measure the wobble of the star and sure

1234
00:52:24,568 --> 00:52:30,659
enough the star wobbled okay and it took

1235
00:52:27,510 --> 00:52:32,880
about 25 days to complete its wobble and

1236
00:52:30,659 --> 00:52:34,769
then based on that wobble we were able

1237
00:52:32,880 --> 00:52:37,440
to predict when the other eclipses would

1238
00:52:34,769 --> 00:52:39,329
occur you can see that it took about two

1239
00:52:37,440 --> 00:52:40,139
years for us to sort that out and then

1240
00:52:39,329 --> 00:52:43,019

we measured them

1241
00:52:40,139 --> 00:52:49,139
September 1st September 25th October

1242
00:52:43,019 --> 00:52:51,210
20th based on the wobble of the star

1243
00:52:49,139 --> 00:52:54,058
we're able to figure out how heavy the

1244
00:52:51,210 --> 00:52:57,679
planet was and we measured the mass and

1245
00:52:54,059 --> 00:52:57,680
it's about 6 times the mass of the earth

1246
00:52:58,699 --> 00:53:03,598
the period of the planet though was very

1247
00:53:02,010 --> 00:53:05,490
long compared to most of the other

1248
00:53:03,599 --> 00:53:07,859
planets that we've been studying the the

1249
00:53:05,489 --> 00:53:11,009
planet takes about 25 days to go around

1250
00:53:07,858 --> 00:53:12,659
its star remember what I told you

1251
00:53:11,010 --> 00:53:14,640
earlier that means that for this red

1252
00:53:12,659 --> 00:53:18,259
dwarf star it's nice and cool it's not

1253
00:53:14,639 --> 00:53:20,278
too hot and in fact at 25 days it is

1254
00:53:18,260 --> 00:53:23,369
probably the same temperature as the

1255
00:53:20,278 --> 00:53:25,619
earth ok so it gets about half the light

1256
00:53:23,369 --> 00:53:28,500
from its star that the earth gets from

1257
00:53:25,619 --> 00:53:30,180
the Sun not 20 or 30 times not a hundred

1258
00:53:28,500 --> 00:53:32,130
times the way so many planets do with

1259
00:53:30,179 --> 00:53:36,929
superhot planets this one was actually

1260
00:53:32,130 --> 00:53:38,548
nice and cool and importantly of course

1261
00:53:36,929 --> 00:53:40,798
because we have the transit we could

1262
00:53:38,548 --> 00:53:43,048
measure the size of the planet so we

1263
00:53:40,798 --> 00:53:44,759
measured the size to be about 40% larger

1264
00:53:43,048 --> 00:53:46,829
than the earth and so it looked like we

1265
00:53:44,760 --> 00:53:48,210
truly had what we've been looking for is

1266
00:53:46,829 --> 00:53:51,480
a planet that had the right temperature

1267
00:53:48,210 --> 00:53:53,490
but was definitely rocky ok it was

1268
00:53:51,480 --> 00:53:55,500
bigger than the earth ok was not 1 times

1269
00:53:53,489 --> 00:53:56,969
the Earth's Earth's mass it was 6 times

1270
00:53:55,500 --> 00:54:01,139
the Earth's mass so it was a super earth

1271
00:53:56,969 --> 00:54:04,288
but a rocky world around this star LHS

1272
00:54:01,139 --> 00:54:06,509
11:40 and we announced that in April so

1273
00:54:04,289 --> 00:54:07,920
just this this discovery finally came

1274
00:54:06,510 --> 00:54:09,510
together and published it very very

1275
00:54:07,920 --> 00:54:10,889
recently so if I'd been here last year

1276
00:54:09,510 --> 00:54:15,809
wouldn't been able to tell you anything

1277
00:54:10,889 --> 00:54:17,879
about this ok so so what's so exciting

1278
00:54:15,809 --> 00:54:19,950
is how quickly this field is moving so

1279
00:54:17,880 --> 00:54:23,130
if I had given this talk a year ago I

1280
00:54:19,949 --> 00:54:26,159
would have said if we could find such

1281
00:54:23,130 --> 00:54:27,960
planets then we will use the James Webb

1282
00:54:26,159 --> 00:54:30,058
Space Telescope and the giant Magellan

1283

00:54:27,960 --> 00:54:31,500
telescope to study their atmospheres but

1284
00:54:30,059 --> 00:54:33,660
I don't have to say the if anymore

1285
00:54:31,500 --> 00:54:36,269
now I can say we have found those

1286
00:54:33,659 --> 00:54:38,278
planets we hope to find even better ones

1287
00:54:36,269 --> 00:54:42,719
closer ones but we have found the first

1288
00:54:38,278 --> 00:54:44,219
targets for these kinds of studies the

1289
00:54:42,719 --> 00:54:47,818
one I just told you about that's the one

1290
00:54:44,219 --> 00:54:49,259
that I got to be part of la just 1140

1291
00:54:47,818 --> 00:54:52,679
but of course I'm sure you've heard

1292
00:54:49,260 --> 00:54:56,520
about Trappist same idea right Trappist

1293
00:54:52,679 --> 00:54:57,960
is a small nearby red dwarf star but it

1294
00:54:56,519 --> 00:55:01,170
doesn't have just one planet it's got

1295
00:54:57,960 --> 00:55:06,480
seven of them ok roughly the same

1296
00:55:01,170 --> 00:55:08,338
distance from us as LHS 11:40 now all

1297
00:55:06,480 --> 00:55:10,829

all the systems are different in their

1298

00:55:08,338 --> 00:55:12,449
own way I would say 11:40 what's special

1299

00:55:10,829 --> 00:55:13,890
about that is we know the mass of the

1300

00:55:12,449 --> 00:55:16,348
planet so we know that the planet is

1301

00:55:13,889 --> 00:55:18,900
definitely rocky a real requirement for

1302

00:55:16,349 --> 00:55:20,190
life but it's only one planet as far as

1303

00:55:18,900 --> 00:55:20,579
we know although we hope others will be

1304

00:55:20,190 --> 00:55:22,528
found

1305

00:55:20,579 --> 00:55:23,970
Trappist one there are seven worlds

1306

00:55:22,528 --> 00:55:25,048
which means we've got kind of seven

1307

00:55:23,969 --> 00:55:27,179
chances to go and study their

1308

00:55:25,048 --> 00:55:28,949
atmospheres but actually it's very hard

1309

00:55:27,179 --> 00:55:30,538
to get the masses for Travis one so we

1310

00:55:28,949 --> 00:55:34,858
don't truly know yet that their rocky

1311

00:55:30,539 --> 00:55:38,309
time will tell and then Proxima

1312
00:55:34,858 --> 00:55:41,788
so about nine months ago Proxima was

1313
00:55:38,309 --> 00:55:43,440
announced to have a planet as well in

1314
00:55:41,789 --> 00:55:45,480
the habitable zone Proxima is the very

1315
00:55:43,440 --> 00:55:47,909
closest star to us but it doesn't

1316
00:55:45,480 --> 00:55:49,409
transit so we can't quite use the

1317
00:55:47,909 --> 00:55:51,449
methods I've been talking about but now

1318
00:55:49,409 --> 00:55:53,848
we have three nearby stars all very

1319
00:55:51,449 --> 00:55:55,889
close to us that have what we think are

1320
00:55:53,849 --> 00:55:57,210
potentially habitable worlds so a really

1321
00:55:55,889 --> 00:56:02,009
fundamental change from even

1322
00:55:57,210 --> 00:56:04,740
months ago okay so how are we gonna put

1323
00:56:02,010 --> 00:56:07,670
this all together so I I think what I

1324
00:56:04,739 --> 00:56:09,359
want to emphasize is the the

1325
00:56:07,670 --> 00:56:10,260
complementarity of these two great

1326
00:56:09,360 --> 00:56:13,650
observatories

1327
00:56:10,260 --> 00:56:16,290
okay so if we just use the giant

1328
00:56:13,650 --> 00:56:18,840
Magellan telescope or if we just used

1329
00:56:16,289 --> 00:56:20,940
the James Webb Space Telescope I don't

1330
00:56:18,840 --> 00:56:22,110
think no matter how good the data was I

1331
00:56:20,940 --> 00:56:23,909
don't think we'd be able to conclude

1332
00:56:22,110 --> 00:56:27,720
that there was life on one of these

1333
00:56:23,909 --> 00:56:32,519
planets okay and the and and and here's

1334
00:56:27,719 --> 00:56:34,469
why what we want to do with the GMT is

1335
00:56:32,519 --> 00:56:35,940
we want to go and detect oxygen it

1336
00:56:34,469 --> 00:56:38,129
studies the right wavelengths of light

1337
00:56:35,940 --> 00:56:41,280
so that we can actually detect molecular

1338
00:56:38,130 --> 00:56:43,250
oxygen which is the kind of the giveaway

1339
00:56:41,280 --> 00:56:45,330
that there's life right life

1340

00:56:43,250 --> 00:56:47,250
photosynthetic life makes oxygen the

1341
00:56:45,329 --> 00:56:50,670
oxygen accumulates in the atmosphere the

1342
00:56:47,250 --> 00:56:52,650
oxygen is entirely due to life on the

1343
00:56:50,670 --> 00:56:54,590
earth and so that would tell us that

1344
00:56:52,650 --> 00:56:57,119
there really was life on the planet

1345
00:56:54,590 --> 00:56:59,190
however if all we have is oxygen that

1346
00:56:57,119 --> 00:57:00,210
doesn't work because of course

1347
00:56:59,190 --> 00:57:01,320
astronomers have been thinking about

1348
00:57:00,210 --> 00:57:03,389
this problem and they said well you know

1349
00:57:01,320 --> 00:57:06,180
on the earth the oxygen is all made by

1350
00:57:03,389 --> 00:57:08,009
life but they can concoct schemes where

1351
00:57:06,179 --> 00:57:10,440
an other planets the oxygen would not be

1352
00:57:08,010 --> 00:57:12,240
due to life the oxygen would be due to

1353
00:57:10,440 --> 00:57:14,909
for example ultraviolet light from the

1354
00:57:12,239 --> 00:57:16,649

star hitting water and breaking the

1355

00:57:14,909 --> 00:57:18,690

water up into its hydrogen and it's

1356

00:57:16,650 --> 00:57:21,030

oxygen and maybe that's how you make

1357

00:57:18,690 --> 00:57:25,860

oxygen so if you just saw oxygen you

1358

00:57:21,030 --> 00:57:27,720

could be fooled that's why you need the

1359

00:57:25,860 --> 00:57:30,090

James Webb Space Telescope what James

1360

00:57:27,719 --> 00:57:32,399

Webb can do is it can detect all sorts

1361

00:57:30,090 --> 00:57:34,650

of other molecules that will distinguish

1362

00:57:32,400 --> 00:57:36,809

between those two scenarios whether the

1363

00:57:34,650 --> 00:57:41,480

oxygen is made by life or whether the

1364

00:57:36,809 --> 00:57:41,480

oxygen is made by some geologic or photo

1365

00:57:41,570 --> 00:57:48,809

photolysis process so putting them both

1366

00:57:47,099 --> 00:57:51,449

together I think we actually can go and

1367

00:57:48,809 --> 00:57:54,210

and interpret the data correctly so

1368

00:57:51,449 --> 00:57:57,779

perhaps they can do it together GMT is

1369
00:57:54,210 --> 00:57:59,220
able to detect molecular oxygen James

1370
00:57:57,780 --> 00:58:00,360
Webb really can't do that because of the

1371
00:57:59,219 --> 00:58:03,629
wavelength it just doesn't study the

1372
00:58:00,360 --> 00:58:06,120
right wavelengths to do that but by the

1373
00:58:03,630 --> 00:58:08,010
same token GMT can't gather the

1374
00:58:06,119 --> 00:58:09,480
ancillary information that will really

1375
00:58:08,010 --> 00:58:09,910
allow us to interpret the oxygen

1376
00:58:09,480 --> 00:58:12,490
detector

1377
00:58:09,909 --> 00:58:13,750
and James Webb Space Telescope is going

1378
00:58:12,489 --> 00:58:16,500
to be awesome at doing that it's got

1379
00:58:13,750 --> 00:58:19,780
infrared sensitivity it can detect water

1380
00:58:16,500 --> 00:58:22,030
carbon dioxide carbon monoxide methane

1381
00:58:19,780 --> 00:58:24,510
all the things that put that oxygen in

1382
00:58:22,030 --> 00:58:24,510
perspective

1383
00:58:24,719 --> 00:58:31,899
okay so so you know big picture I really

1384
00:58:29,170 --> 00:58:33,220
think that that's our first opportunity

1385
00:58:31,900 --> 00:58:37,059
to go and find life on other planets

1386
00:58:33,219 --> 00:58:38,798
with these new observatories I think we

1387
00:58:37,059 --> 00:58:40,420
really have a shot at this it's the

1388
00:58:38,798 --> 00:58:42,159
first time humanity's been able to make

1389
00:58:40,420 --> 00:58:43,480
that claim I might be wrong there might

1390
00:58:42,159 --> 00:58:44,889
be lots of reasons why there's no life

1391
00:58:43,480 --> 00:58:46,838
around planets orbiting and Dwarfs I'm

1392
00:58:44,889 --> 00:58:48,009
happy to talk about that but it's the

1393
00:58:46,838 --> 00:58:50,529
first time we can take a shot at this

1394
00:58:48,010 --> 00:58:52,119
thing and the point I want to leave you

1395
00:58:50,530 --> 00:58:54,760
with is that the impact really will

1396
00:58:52,119 --> 00:58:56,798
extend well beyond astronomy and I think

1397

00:58:54,760 --> 00:58:59,500
even science I think when I talked to

1398
00:58:56,798 --> 00:59:01,659
people I think knowing whether or not

1399
00:58:59,500 --> 00:59:04,809
we're it whether there's other inhabited

1400
00:59:01,659 --> 00:59:06,909
worlds and what that relationship of

1401
00:59:04,809 --> 00:59:08,859
life is relative to life on the earth I

1402
00:59:06,909 --> 00:59:11,259
think speaks very deeply to people

1403
00:59:08,858 --> 00:59:16,088
beyond just just the astronomical

1404
00:59:11,260 --> 00:59:17,799
questions that it will answer so in in

1405
00:59:16,088 --> 00:59:21,308
preparing a public talk about a year ago

1406
00:59:17,798 --> 00:59:24,670
I I wrote some of my students and I said

1407
00:59:21,309 --> 00:59:26,769
you know I'm trying to convey the

1408
00:59:24,670 --> 00:59:28,240
importance of telescopes for this work

1409
00:59:26,769 --> 00:59:30,849
you know I said this is like for me a

1410
00:59:28,239 --> 00:59:32,348
telescope is like telescope is like that

1411
00:59:30,849 --> 00:59:33,818

spaceship it allows me to kind of go to

1412

00:59:32,349 --> 00:59:37,660

other worlds see the local conditions

1413

00:59:33,818 --> 00:59:38,858

discover life but of course over you

1414

00:59:37,659 --> 00:59:40,989

know without having to overcome this

1415

00:59:38,858 --> 00:59:43,179

this technological miracle of actual

1416

00:59:40,989 --> 00:59:44,469

we're actually traveling to other stars

1417

00:59:43,179 --> 00:59:47,679

I can just go there kind of with my

1418

00:59:44,469 --> 00:59:49,269

telescopes what what do what do these

1419

00:59:47,679 --> 00:59:50,588

giant telescopes mean to you and so my

1420

00:59:49,269 --> 00:59:53,349

students wrote back and I just wanted to

1421

00:59:50,588 --> 00:59:55,900

share one quote this is from Hannah

1422

00:59:53,349 --> 00:59:59,410

diamond Lowe Hannah was in the first

1423

00:59:55,900 --> 01:00:00,940

year of her PhD working with me and I

1424

00:59:59,409 --> 01:00:02,440

loved what she wrote she said spending

1425

01:00:00,940 --> 01:00:03,880

time at one of the biggest telescopes in

1426
01:00:02,440 --> 01:00:05,470
the world has given me a grand

1427
01:00:03,880 --> 01:00:07,390
perspective on the accomplishments of

1428
01:00:05,469 --> 01:00:08,919
humanity from this vantage point

1429
01:00:07,389 --> 01:00:11,048
detecting signs of extraterrestrial life

1430
01:00:08,920 --> 01:00:14,019
seems well within our reach so I love

1431
01:00:11,048 --> 01:00:16,650
the fact that you know for me this just

1432
01:00:14,019 --> 01:00:18,400
all seems like this incredible

1433
01:00:16,650 --> 01:00:21,818
opportunity that I would have never

1434
01:00:18,400 --> 01:00:22,980
foreseen when I was doing my PhD which

1435
01:00:21,818 --> 01:00:25,789
was

1436
01:00:22,980 --> 01:00:28,079
fifteen 20 years ago for Hana it seems

1437
01:00:25,789 --> 01:00:29,608
like it's really something that's on the

1438
01:00:28,079 --> 01:00:31,619
table we could really go and actually

1439
01:00:29,608 --> 01:00:32,639
make these discoveries and that's that's

1440
01:00:31,619 --> 01:00:34,070
a picture of Hana in front of the

1441
01:00:32,639 --> 01:00:39,118
Magellan Observatory where she was

1442
01:00:34,070 --> 01:00:40,890
gathering data and Hannah is here at the

1443
01:00:39,119 --> 01:00:43,230
conference and she's giving a scientific

1444
01:00:40,889 --> 01:00:45,150
presentation on her results tomorrow but

1445
01:00:43,230 --> 01:00:48,030
I we haven't discovered life yet just

1446
01:00:45,150 --> 01:00:49,889
just you know okay I want to thank the

1447
01:00:48,030 --> 01:00:51,410
funding agencies that really made this

1448
01:00:49,889 --> 01:00:53,250
all possible it's really nice

1449
01:00:51,409 --> 01:00:54,500
collaboration between the federal

1450
01:00:53,250 --> 01:00:56,219
funding agencies and the private

1451
01:00:54,500 --> 01:00:58,380
foundations the National Science

1452
01:00:56,219 --> 01:01:00,419
Foundation NASA the David and Lucile

1453
01:00:58,380 --> 01:01:02,608
Packard Foundation and the John

1454

01:01:00,420 --> 01:01:05,820
Templeton Foundation and then most

1455
01:01:02,608 --> 01:01:09,090
importantly these folks who do all the

1456
01:01:05,820 --> 01:01:11,280
work Zak Berta Thompson Jason Ditman

1457
01:01:09,090 --> 01:01:14,010
Courtney dressing Rafael Heywood

1458
01:01:11,280 --> 01:01:17,220
Jonathan Irwin Mercedes Lopez Morales

1459
01:01:14,010 --> 01:01:19,650
Elizabeth Newton Joey Rodriguez and and

1460
01:01:17,219 --> 01:01:21,929
Jennifer winters I've showed you all of

1461
01:01:19,650 --> 01:01:23,519
their results all put together in this

1462
01:01:21,929 --> 01:01:27,269
picture of the progress that we're

1463
01:01:23,519 --> 01:01:31,108
trying to make on this big question okay

1464
01:01:27,269 --> 01:01:33,119
so so this is my final slide but I want

1465
01:01:31,108 --> 01:01:37,049
to make sure that when in the morning

1466
01:01:33,119 --> 01:01:38,700
you're talking to family friends you

1467
01:01:37,050 --> 01:01:40,800
wake up and tweet or whatever this is

1468
01:01:38,699 --> 01:01:42,868

what you should be talking about okay

1469

01:01:40,800 --> 01:01:44,070

all right these are the real takeaways

1470

01:01:42,869 --> 01:01:47,760

that you've got it you've got to go home

1471

01:01:44,070 --> 01:01:50,160

with one red dwarf stars are the most

1472

01:01:47,760 --> 01:01:52,500

common star in the galaxy and there's at

1473

01:01:50,159 --> 01:01:56,250

least one habitable planet for every

1474

01:01:52,500 --> 01:01:59,280

four of them okay a fundamental advance

1475

01:01:56,250 --> 01:02:00,840

in our understanding that is hot off the

1476

01:01:59,280 --> 01:02:05,369

presses that that result is only a

1477

01:02:00,840 --> 01:02:07,350

couple years old okay - we have begun to

1478

01:02:05,369 --> 01:02:09,750

find the closest transiting earths okay

1479

01:02:07,349 --> 01:02:12,059

though those results are only a couple

1480

01:02:09,750 --> 01:02:13,320

months old and we are planning to study

1481

01:02:12,059 --> 01:02:15,210

their atmospheres with the next

1482

01:02:13,320 --> 01:02:18,600

generation of power telescopes powerful

1483
01:02:15,210 --> 01:02:20,220
telescopes and then and then finally the

1484
01:02:18,599 --> 01:02:22,440
search for atmospheric biomarkers such

1485
01:02:20,219 --> 01:02:24,000
as oxygen I think really is humanity's

1486
01:02:22,440 --> 01:02:25,079
first attempt to answer this great

1487
01:02:24,000 --> 01:02:28,619
question of whether or not we're alone

1488
01:02:25,079 --> 01:02:31,489
and that's the end of my talk thank you

1489
01:02:28,619 --> 01:02:34,750
[Applause]

1490
01:02:31,489 --> 01:02:34,750
[Music]

1491
01:02:41,039 --> 01:02:56,119
[Music]

1492
01:02:43,789 --> 01:02:59,429
okay if you looked at Earth's atmosphere

1493
01:02:56,119 --> 01:03:02,068
during times of extreme climates such as

1494
01:02:59,429 --> 01:03:04,348
the I say you know what earth have

1495
01:03:02,068 --> 01:03:07,079
appeared habitable because it strikes me

1496
01:03:04,349 --> 01:03:10,170
you're looking at these planets in a

1497
01:03:07,079 --> 01:03:13,260
very narrow time in their existence and

1498
01:03:10,170 --> 01:03:49,588
that doesn't tell you what the future

1499
01:03:13,260 --> 01:03:52,230
may have yeah so so that's right so the

1500
01:03:49,588 --> 01:03:54,029
the recent ice ages so you know the

1501
01:03:52,230 --> 01:03:56,699
recent ice ages are tens of thousands of

1502
01:03:54,030 --> 01:03:57,660
years ago the oxygen content of the

1503
01:03:56,699 --> 01:03:58,858
Earth's atmosphere didn't change

1504
01:03:57,659 --> 01:04:00,449
significantly there was still plenty of

1505
01:03:58,858 --> 01:04:02,730
oxygen which is a signal kind of measure

1506
01:04:00,449 --> 01:04:05,159
but to broaden your point a little bit

1507
01:04:02,730 --> 01:04:06,240
the earth has definitely changed over

1508
01:04:05,159 --> 01:04:09,149
four-and-a-half billion years

1509
01:04:06,239 --> 01:04:11,459
when it started out it took billions of

1510
01:04:09,150 --> 01:04:13,380
years for the oxygen to build up to the

1511

01:04:11,460 --> 01:04:15,838
point where it was something astronomers

1512
01:04:13,380 --> 01:04:18,660
could ever detect remotely okay so for a

1513
01:04:15,838 --> 01:04:21,239
very long time even after there was a

1514
01:04:18,659 --> 01:04:23,489
photosynthetic bacteria they were made

1515
01:04:21,239 --> 01:04:25,709
of oxygen the oxygen was probably going

1516
01:04:23,489 --> 01:04:28,709
and reacting chemically with exposed

1517
01:04:25,710 --> 01:04:31,369
rock on the surface so that's right so I

1518
01:04:28,710 --> 01:04:34,108
what I'm talking about is trying to find

1519
01:04:31,369 --> 01:04:37,140
evidence for life as the earth has

1520
01:04:34,108 --> 01:04:39,119
appeared for roughly the past half of

1521
01:04:37,139 --> 01:04:41,909
its existence but not for all four and a

1522
01:04:39,119 --> 01:04:43,559
half billion years I would love to come

1523
01:04:41,909 --> 01:04:45,598
up with an idea with the tool

1524
01:04:43,559 --> 01:04:48,028
with even broader net and allow me to

1525
01:04:45,599 --> 01:04:49,469

look for life that we're taking all the

1526

01:04:48,028 --> 01:04:52,170

way back to when life first appeared on

1527

01:04:49,469 --> 01:04:54,269

the earth but I just I don't know how to

1528

01:04:52,170 --> 01:04:56,400

master that from afar time so this is

1529

01:04:54,268 --> 01:05:03,538

this is what I've got to present as a

1530

01:04:56,400 --> 01:05:05,670

tool for planets going up orbiting the

1531

01:05:03,539 --> 01:05:09,449

red dwarfs with a magnetic field be as

1532

01:05:05,670 --> 01:05:12,059

important as it would around the larger

1533

01:05:09,449 --> 01:05:13,858

star or side so the question is for

1534

01:05:12,059 --> 01:05:16,319

planets orbiting a red dwarf with the

1535

01:05:13,858 --> 01:05:18,438

magnetic field be as important as it

1536

01:05:16,318 --> 01:05:21,298

might be for a larger star like the song

1537

01:05:18,438 --> 01:05:26,129

yes do you mean the magnetic field of

1538

01:05:21,298 --> 01:05:28,858

the star protecting it from yes so a big

1539

01:05:26,130 --> 01:05:31,469

question is since these planets are in

1540
01:05:28,858 --> 01:05:33,179
close to their stars can they hold on to

1541
01:05:31,469 --> 01:05:35,639
their atmospheres if the star has a

1542
01:05:33,179 --> 01:05:37,108
strong seller win for example would it

1543
01:05:35,639 --> 01:05:39,420
simply remove the atmosphere of the

1544
01:05:37,108 --> 01:05:42,298
planet and then obviously be habitable

1545
01:05:39,420 --> 01:05:45,449
so yes I think that it is a requirement

1546
01:05:42,298 --> 01:05:51,538
of planets to be habitable have a go

1547
01:05:45,449 --> 01:05:54,509
here and field narrows to Mars probably

1548
01:05:51,539 --> 01:05:56,130
lost its atmosphere because it is cooled

1549
01:05:54,509 --> 01:05:58,170
all the way through so it no longer has

1550
01:05:56,130 --> 01:06:00,269
a molten core that means it doesn't have

1551
01:05:58,170 --> 01:06:02,099
this coherent magnetic field and over

1552
01:06:00,268 --> 01:06:03,718
time the solar wind is able to strip

1553
01:06:02,099 --> 01:06:06,150
away the atmosphere of Mars it also was

1554
01:06:03,719 --> 01:06:08,969
lower surface gravity so it's easier to

1555
01:06:06,150 --> 01:06:11,009
let that gas go for the out of interest

1556
01:06:08,969 --> 01:06:11,309
for the planet that we've that I was

1557
01:06:11,009 --> 01:06:13,889
talking about

1558
01:06:11,309 --> 01:06:16,199
LHS 11:40 it's more massive than the

1559
01:06:13,889 --> 01:06:18,509
earth so almost certainly its core has

1560
01:06:16,199 --> 01:06:20,068
not solidified so it's it's got a better

1561
01:06:18,509 --> 01:06:22,108
chance of keeping magnetic field and

1562
01:06:20,068 --> 01:06:23,728
also the stronger surface gravity would

1563
01:06:22,108 --> 01:06:27,108
allow it to protect its atmosphere just

1564
01:06:23,728 --> 01:06:27,108
through gravitational effects as well

1565
01:06:29,958 --> 01:06:34,608
you mentioned that in 2001 there was one

1566
01:06:33,179 --> 01:06:38,670
extra planet now now we know a

1567
01:06:34,608 --> 01:06:41,248
considerably more you envision that

1568

01:06:38,670 --> 01:06:44,539
exponential growth and understanding to

1569
01:06:41,248 --> 01:06:47,259
continue about this in this field like

1570
01:06:44,539 --> 01:06:49,210
we got

1571
01:06:47,260 --> 01:06:53,740
transiting exoplanets in the past two

1572
01:06:49,210 --> 01:06:55,360
decades how long does that so I'd like

1573
01:06:53,739 --> 01:06:57,579
to wait and the question was to

1574
01:06:55,360 --> 01:07:01,180
anticipate the same exponential growth

1575
01:06:57,579 --> 01:07:03,699
and understanding and and I would say I

1576
01:07:01,179 --> 01:07:07,029
don't expect the same exponential growth

1577
01:07:03,699 --> 01:07:10,899
in number but in understanding I do so

1578
01:07:07,030 --> 01:07:15,190
so what you know that most of you come

1579
01:07:10,900 --> 01:07:22,420
from one NASA mission okay there are

1580
01:07:15,190 --> 01:07:26,079
other missions coming up the NASA test

1581
01:07:22,420 --> 01:07:28,960
mission should launch in spring of next

1582
01:07:26,079 --> 01:07:32,590

year we expect that to find hundreds or

1583

01:07:28,960 --> 01:07:34,420

maybe a thousand planets and then

1584

01:07:32,590 --> 01:07:36,700

there's a European mission called Plato

1585

01:07:34,420 --> 01:07:39,220

that should also find you know of order

1586

01:07:36,699 --> 01:07:41,109

thousands of planets so we will continue

1587

01:07:39,219 --> 01:07:43,239

to increase the numbers but it's not

1588

01:07:41,110 --> 01:07:44,769

going to be exponential okay the way

1589

01:07:43,239 --> 01:07:47,559

that Kepler Kepler really took us from

1590

01:07:44,769 --> 01:07:49,150

kind of hundreds to 5,000 but the point

1591

01:07:47,559 --> 01:07:50,590

is we're finding planets that are closer

1592

01:07:49,150 --> 01:07:52,570

to our understanding I don't think we

1593

01:07:50,590 --> 01:07:54,070

need a lot more planets to do I mean

1594

01:07:52,570 --> 01:07:56,260

we'd love to have them but I think now

1595

01:07:54,070 --> 01:07:57,820

the issue is moving from statistics to

1596

01:07:56,260 --> 01:08:00,790

actually a detailed understanding of the

1597
01:07:57,820 --> 01:08:02,559
properties and compositions by finding

1598
01:08:00,789 --> 01:08:05,880
the nearby examples of the planets the

1599
01:08:02,559 --> 01:08:05,880
kepler told us must be there

1600
01:08:17,279 --> 01:08:20,459
[Applause]

1601
01:08:35,689 --> 01:08:43,000
[Music]

1602
01:08:40,689 --> 01:08:47,349
because I show these curves for things

1603
01:08:43,000 --> 01:08:49,509
that I know how to recognize and so so

1604
01:08:47,350 --> 01:08:50,680
why you know I think what we've done is

1605
01:08:49,509 --> 01:08:53,949
we've come up with a plan where we can

1606
01:08:50,680 --> 01:08:55,600
say ah okay oxygen and the combination

1607
01:08:53,949 --> 01:08:58,389
of their molecules on a planet that has

1608
01:08:55,600 --> 01:09:01,088
a certain temperature I would be able to

1609
01:08:58,390 --> 01:09:03,190
really conclude that that was due to

1610
01:09:01,088 --> 01:09:05,829
life but you're right there could be

1611
01:09:03,189 --> 01:09:08,169
life that is more than what we call

1612
01:09:05,829 --> 01:09:09,759
extremophiles here on earth

1613
01:09:08,170 --> 01:09:11,829
there certainly is lots of life that

1614
01:09:09,759 --> 01:09:13,238
doesn't make oxygen and of course we can

1615
01:09:11,829 --> 01:09:14,979
imagine other kind of life that doesn't

1616
01:09:13,238 --> 01:09:18,789
exist on the earth but maybe would work

1617
01:09:14,979 --> 01:09:20,500
chemically and and yeah I think we would

1618
01:09:18,789 --> 01:09:23,019
I think we would easily miss that so

1619
01:09:20,500 --> 01:09:25,988
what I presented here is an idea to

1620
01:09:23,020 --> 01:09:27,370
recognize life that is that is pretty

1621
01:09:25,988 --> 01:09:28,809
similar to what we find in the earth

1622
01:09:27,369 --> 01:09:31,180
that certainly life that's been around

1623
01:09:28,810 --> 01:09:32,710
for billions of years of the earth

1624
01:09:31,180 --> 01:09:34,720
because I have the ground truth of the

1625

01:09:32,710 --> 01:09:36,489
earth I've known and recognized it and I

1626
01:09:34,720 --> 01:09:39,190
hope that kind of mining students are

1627
01:09:36,488 --> 01:09:41,619
going to come up with even broader tests

1628
01:09:39,189 --> 01:09:45,789
Twitter to broaden that and think of

1629
01:09:41,619 --> 01:09:46,960
ways to find life that we can't

1630
01:09:45,789 --> 01:09:54,100
currently figure out how to recognize

1631
01:09:46,960 --> 01:09:57,279
but I don't are there any atmospheric

1632
01:09:54,100 --> 01:09:59,920
markers that are created only by living

1633
01:09:57,279 --> 01:10:06,389
organisms there any atmosphere of Mars

1634
01:09:59,920 --> 01:10:06,390
that are yeah

1635
01:10:10,238 --> 01:10:16,399
there are definitely a lot I would say I

1636
01:10:14,238 --> 01:10:17,779
would say you know certain kind of

1637
01:10:16,399 --> 01:10:21,399
industrial pollutants and things like

1638
01:10:17,779 --> 01:10:28,609
that I think that any interesting

1639
01:10:21,399 --> 01:10:29,899

biomarker of oxygen is so you know

1640

01:10:28,609 --> 01:10:30,949

methane methane on the earth is a

1641

01:10:29,899 --> 01:10:32,569

biomarker methane

1642

01:10:30,949 --> 01:10:34,069

although methane in the Earth's

1643

01:10:32,569 --> 01:10:35,779

atmosphere if you just said if there

1644

01:10:34,069 --> 01:10:38,000

wasn't my and I just did a chemical

1645

01:10:35,779 --> 01:10:39,590

calculation how much methane should

1646

01:10:38,000 --> 01:10:40,909

there being here it's atmosphere and the

1647

01:10:39,590 --> 01:10:54,100

answer is there should be less than one

1648

01:10:40,909 --> 01:10:56,899

molecule of methane in the entire okay

1649

01:10:54,100 --> 01:10:58,820

so that's another kind of bible it's a

1650

01:10:56,899 --> 01:11:01,069

very phrase guess it's much much less

1651

01:10:58,819 --> 01:11:03,829

abundant than oxygen so I would say that

1652

01:11:01,069 --> 01:11:05,779

yes I can think of those gases but but

1653

01:11:03,829 --> 01:11:07,340

all the ones that I can think about that

1654
01:11:05,779 --> 01:11:09,500
are actually detectable astronomically

1655
01:11:07,340 --> 01:11:11,480
but very large quantities things I know

1656
01:11:09,500 --> 01:11:14,090
how to go ahead measure they all are

1657
01:11:11,479 --> 01:11:27,679
pretty simple molecules that that

1658
01:11:14,090 --> 01:11:30,440
certainly could be produce yeah for

1659
01:11:27,680 --> 01:11:31,520
those that are looking for life in the

1660
01:11:30,439 --> 01:11:35,210
solar system

1661
01:11:31,520 --> 01:11:38,840
they are looking not at the planets but

1662
01:11:35,210 --> 01:11:41,230
at moons of planets like Europa No

1663
01:11:38,840 --> 01:11:44,810
is there any chance you'd be able to

1664
01:11:41,229 --> 01:11:58,639
detect moves around some of these

1665
01:11:44,810 --> 01:12:00,830
exoplanets the reasons is because we

1666
01:11:58,640 --> 01:12:02,960
need planets that have the right

1667
01:12:00,829 --> 01:12:04,939
temperature and the way the earth of

1668
01:12:02,960 --> 01:12:06,500
course maintains temperatures

1669
01:12:04,939 --> 01:12:08,149
radiation from the Sun but another way

1670
01:12:06,500 --> 01:12:09,770
to defeat your planet is to have an

1671
01:12:08,149 --> 01:12:11,329
orbiting gas giant and to be tidally

1672
01:12:09,770 --> 01:12:14,040
stretched and that's stretching and

1673
01:12:11,329 --> 01:12:15,630
pulling the friction heats the planet

1674
01:12:14,039 --> 01:12:18,449
so for example there are there are

1675
01:12:15,630 --> 01:12:20,159
planets of Sadler's or moons of Saturn

1676
01:12:18,449 --> 01:12:23,239
and Jupiter that that are much warmer

1677
01:12:20,159 --> 01:12:28,289
than they should we do that tidal energy

1678
01:12:23,239 --> 01:12:32,099
so yes there is a very healthy interest

1679
01:12:28,289 --> 01:12:35,340
in finding moons orbiting exoplanets and

1680
01:12:32,100 --> 01:12:36,360
people work very hard and nobody has

1681
01:12:35,340 --> 01:12:37,500
found a single one

1682

01:12:36,359 --> 01:12:40,380
please ever found a moving around

1683
01:12:37,500 --> 01:12:41,939
another refinery other star I think this

1684
01:12:40,380 --> 01:12:43,230
a new planet that we just found out with

1685
01:12:41,939 --> 01:12:44,699
just level 40 that would be a good

1686
01:12:43,229 --> 01:12:46,379
candidate for a movement so we're going

1687
01:12:44,699 --> 01:12:49,319
to go hunting but we haven't gotten data

1688
01:12:46,380 --> 01:12:51,300
yet people are searching through the

1689
01:12:49,319 --> 01:12:52,199
Kepler data hadn't been able to find can

1690
01:12:51,300 --> 01:12:54,000
you think that there's always a moment

1691
01:12:52,199 --> 01:12:56,220
that can improve that you know we're not

1692
01:12:54,000 --> 01:12:57,899
going to get more copy data from the

1693
01:12:56,220 --> 01:12:59,909
original mission but we can improve the

1694
01:12:57,899 --> 01:13:09,929
quality of the data by smarter data

1695
01:12:59,909 --> 01:13:12,449
analysis you have to wait to the second

1696
01:13:09,930 --> 01:13:15,600

half of her history to get oxygen in the

1697

01:13:12,449 --> 01:13:18,179

air but you the thing you're really

1698

01:13:15,600 --> 01:13:28,920

looking for is water and you can't even

1699

01:13:18,180 --> 01:13:30,900

detect water in the atmosphere that

1700

01:13:28,920 --> 01:13:33,690

great great question so the Russian ones

1701

01:13:30,899 --> 01:13:35,339

you know oxygen is a fairly recent

1702

01:13:33,689 --> 01:13:37,439

phenomenon meaning half of the Earth's

1703

01:13:35,340 --> 01:13:38,909

history maybe a little bit less water

1704

01:13:37,439 --> 01:13:40,589

has always been around

1705

01:13:38,909 --> 01:13:44,340

so yes I'm proud to say we're really

1706

01:13:40,590 --> 01:13:46,949

good at was hectic water water has a big

1707

01:13:44,340 --> 01:13:49,079

signature for astronomers it blocks a

1708

01:13:46,949 --> 01:13:50,489

lot of light in fact it's a terrible

1709

01:13:49,079 --> 01:13:51,689

paint-connect when you do is stronger

1710

01:13:50,489 --> 01:13:53,010

from the ground you have to look out

1711
01:13:51,689 --> 01:13:54,479
through the Earth's atmosphere and

1712
01:13:53,010 --> 01:13:57,560
there's all these parts of the Earth's

1713
01:13:54,479 --> 01:13:59,509
atmosphere that are blocked by water and

1714
01:13:57,560 --> 01:14:00,920
forever wavelengths when you're under

1715
01:13:59,510 --> 01:14:02,630
space you don't agree with that and

1716
01:14:00,920 --> 01:14:04,579
you're looking at other planets so yes

1717
01:14:02,630 --> 01:14:06,670
water has been intended on management

1718
01:14:04,579 --> 01:14:10,069
that's orbiting other stars

1719
01:14:06,670 --> 01:14:12,020
not yet down for long paths because

1720
01:14:10,069 --> 01:14:12,979
that's a more challenging nest egg one

1721
01:14:12,020 --> 01:14:22,730
of the first things that people are

1722
01:14:12,979 --> 01:14:25,009
going to do with the James what do you

1723
01:14:22,729 --> 01:14:34,839
think are the chances of finding life in

1724
01:14:25,010 --> 01:14:34,840
a social system on a moon like Europe so

1725
01:14:36,069 --> 01:14:42,439
[Music]

1726
01:14:38,800 --> 01:14:43,630
open-minded I truly don't know if the

1727
01:14:42,439 --> 01:14:49,699
answer is going to be there is life

1728
01:14:43,630 --> 01:14:58,520
outside sources or in it or not so I you

1729
01:14:49,699 --> 01:15:00,439
know there really could be life I think

1730
01:14:58,520 --> 01:15:02,330
we have to go I think I think the only

1731
01:15:00,439 --> 01:15:04,009
way to answer is you've got to go and I

1732
01:15:02,329 --> 01:15:06,340
think we have to send probes out to

1733
01:15:04,010 --> 01:15:08,390
those bodies to do a lot of interesting

1734
01:15:06,340 --> 01:15:10,640
planetary science and also actually go

1735
01:15:08,390 --> 01:15:13,579
and look for life I hope that's not a

1736
01:15:10,640 --> 01:15:15,590
deeply unsatisfying answer to you but

1737
01:15:13,579 --> 01:15:18,019
that's honestly how I feel I really I

1738
01:15:15,590 --> 01:15:19,880
really think that we could find we are

1739

01:15:18,020 --> 01:15:22,220
truly alone to the best of our ability

1740
01:15:19,880 --> 01:15:23,539
to study or we could find out that in a

1741
01:15:22,220 --> 01:15:25,850
moment we can finally get to another

1742
01:15:23,539 --> 01:15:27,350
planet or moon whether it's in this

1743
01:15:25,850 --> 01:15:28,730
whole system or out that kind of

1744
01:15:27,350 --> 01:15:29,930
remotely had the right temperature

1745
01:15:28,729 --> 01:15:33,579
chemistry we're going to find life and

1746
01:15:29,930 --> 01:15:33,579
life this is kind of inevitable Oh

1747
01:15:34,460 --> 01:15:44,760
we should all see we've never done

1748
01:15:36,779 --> 01:15:46,769
experiment so to put things I've never

1749
01:15:44,760 --> 01:15:54,719
wanted to leave Jake Gyllenhaal's scope

1750
01:15:46,770 --> 01:15:57,060
its back in will it be in ultraviolet no

1751
01:15:54,719 --> 01:15:58,079
invoicing won't to look at all for all

1752
01:15:57,060 --> 01:16:00,600
the wavelengths to really have to go to

1753
01:15:58,079 --> 01:16:02,960

space Fortson from us all product

1754

01:16:00,600 --> 01:16:08,969

radiation is mostly blocked by our

1755

01:16:02,960 --> 01:16:10,829

sphere and instead really the preeminent

1756

01:16:08,969 --> 01:16:13,649

Observatory for ultraviolet observations

1757

01:16:10,829 --> 01:16:25,380

as the hospitals yeah so PMT really can

1758

01:16:13,649 --> 01:16:27,839

and if you look at this yeah so oxygen

1759

01:16:25,380 --> 01:16:31,800

has a very strong spectroscopic a

1760

01:16:27,840 --> 01:16:35,610

feature in kind of the red optical so so

1761

01:16:31,800 --> 01:16:37,350

a wavelength light that's very favorable

1762

01:16:35,609 --> 01:16:39,599

and in fact we look after yourselves

1763

01:16:37,350 --> 01:16:41,340

here it's very prominent and that's and

1764

01:16:39,600 --> 01:16:43,079

there's a trick actually how you how you

1765

01:16:41,340 --> 01:16:44,819

studied with the GMT you actually have

1766

01:16:43,079 --> 01:16:46,439

to get so much light you can do in a

1767

01:16:44,819 --> 01:16:48,509

very high resolution and the lines that

1768
01:16:46,439 --> 01:16:50,879
are due to oxygen move out of phase with

1769
01:16:48,510 --> 01:16:53,219
the lines review the alien oxygen

1770
01:16:50,880 --> 01:16:57,739
because of the relative speed of the

1771
01:16:53,219 --> 01:16:59,609
that star does so so the oxygen is

1772
01:16:57,738 --> 01:17:01,619
something you would do in visible light

1773
01:16:59,609 --> 01:17:05,579
with the ground-based telescope but

1774
01:17:01,619 --> 01:17:07,399
things like water methane carbon dioxide

1775
01:17:05,579 --> 01:17:09,119
carbon dioxide preserves mostly

1776
01:17:07,399 --> 01:17:12,329
exception those are mostly things have

1777
01:17:09,119 --> 01:17:14,460
all begun to space with alright so we

1778
01:17:12,329 --> 01:17:22,079
have a question from the internet when

1779
01:17:14,460 --> 01:17:23,520
you study a star system yeah great

1780
01:17:22,079 --> 01:17:26,369
question do we have a good investment

1781
01:17:23,520 --> 01:17:31,889
agency start so for Emma four stars for

1782
01:17:26,369 --> 01:17:34,019
these red dwarf stars so they basically

1783
01:17:31,889 --> 01:17:37,679
once they form they do not show their

1784
01:17:34,020 --> 01:17:38,369
age so so if you meet a red dwarf star

1785
01:17:37,679 --> 01:17:42,359
you

1786
01:17:38,368 --> 01:17:45,000
if it is 1 million years old or if it is

1787
01:17:42,359 --> 01:17:46,618
12 billion years old and the fact many

1788
01:17:45,000 --> 01:17:48,448
that will continue to live long in the

1789
01:17:46,618 --> 01:17:50,939
future so some red dwarf stars will live

1790
01:17:48,448 --> 01:17:53,609
for hundreds of billions of years they

1791
01:17:50,939 --> 01:17:54,299
have very little hydrogen in the core if

1792
01:17:53,609 --> 01:17:56,539
they burn it

1793
01:17:54,300 --> 01:17:59,760
there there there they burn it so slowly

1794
01:17:56,539 --> 01:18:01,019
that they they really don't have changed

1795
01:17:59,760 --> 01:18:02,989
of course for the sign and changes

1796

01:18:01,020 --> 01:18:05,909
because it's eating on the hydrogen ring

1797
01:18:02,988 --> 01:18:08,819
but but we do have a way to get their

1798
01:18:05,908 --> 01:18:11,219
ages now which is that we've learned

1799
01:18:08,819 --> 01:18:14,609
that over time the stars spin down and

1800
01:18:11,219 --> 01:18:16,500
one thing that I'm very proud of data

1801
01:18:14,609 --> 01:18:17,939
coming from the mirth Observatory was

1802
01:18:16,500 --> 01:18:19,529
we're able to get rotation here it's how

1803
01:18:17,939 --> 01:18:21,629
these spin periods for this various

1804
01:18:19,529 --> 01:18:23,550
regular stars and we think that that's a

1805
01:18:21,630 --> 01:18:25,319
proxy for age and so we can tell which

1806
01:18:23,550 --> 01:18:27,029
among them are the oldest stars which

1807
01:18:25,319 --> 01:18:29,368
are the younger stars and that was work

1808
01:18:27,029 --> 01:18:30,809
that by another PhD student Elizabeth

1809
01:18:29,368 --> 01:18:32,819
Newton

1810
01:18:30,810 --> 01:18:34,560

there's a another way to get the ages of

1811

01:18:32,819 --> 01:18:36,090

stars and that's after seismologist so

1812

01:18:34,560 --> 01:18:38,070

if you have really good data stars

1813

01:18:36,090 --> 01:18:39,569

actually pulsated and those are sound

1814

01:18:38,069 --> 01:18:41,099

waves most sound waves go all the way

1815

01:18:39,569 --> 01:18:42,658

through the star and they tell you about

1816

01:18:41,099 --> 01:18:44,520

what's going on in the core of the star

1817

01:18:42,658 --> 01:18:46,710

which is something that changes with age

1818

01:18:44,520 --> 01:18:48,150

and so as the seismology is a really

1819

01:18:46,710 --> 01:18:50,460

great way to do it for something stars

1820

01:18:48,149 --> 01:19:00,929

but unfortunately it doesn't work but

1821

01:18:50,460 --> 01:19:02,849

his works he wore the machine learning

1822

01:19:00,929 --> 01:19:05,819

model like what kind of type would oh

1823

01:19:02,849 --> 01:19:11,039

isn't how is it but look what was a

1824

01:19:05,819 --> 01:19:12,630

trade flip was a trade Oh birth

1825
01:19:11,039 --> 01:19:15,238
telescopes and the machine learning

1826
01:19:12,630 --> 01:19:16,409
didn't to be able to identify things

1827
01:19:15,238 --> 01:19:18,988
yeah okay great

1828
01:19:16,408 --> 01:19:22,189
that's what sir Jason I Devon was EHS

1829
01:19:18,988 --> 01:19:25,678
didn't work with me and he had basically

1830
01:19:22,189 --> 01:19:27,178
like I think one thing and Christians

1831
01:19:25,679 --> 01:19:29,940
because he just had learn about this on

1832
01:19:27,179 --> 01:19:31,199
its own and he he'll tell me who said I

1833
01:19:29,939 --> 01:19:33,178
had a hammer I'm looking for a nail

1834
01:19:31,198 --> 01:19:34,779
answer he said I'm gonna try this on and

1835
01:19:33,179 --> 01:19:38,770
worth trying

1836
01:19:34,779 --> 01:19:40,389
data and so he here asked what is the

1837
01:19:38,770 --> 01:19:44,710
training did so it's a very simple

1838
01:19:40,390 --> 01:19:47,010
machine learning but the trans dataset

1839
01:19:44,710 --> 01:19:48,850
is that he we basically the mirth

1840
01:19:47,010 --> 01:19:50,199
Observatory what's really going on is

1841
01:19:48,850 --> 01:19:51,370
that we are getting triggers all the

1842
01:19:50,199 --> 01:19:52,300
time so there's moments where the

1843
01:19:51,369 --> 01:19:54,039
telescope things

1844
01:19:52,300 --> 01:19:56,890
oh this start is fainter than it was

1845
01:19:54,039 --> 01:19:59,079
maybe I have a transit and so there are

1846
01:19:56,890 --> 01:20:01,750
thousands of those events in the data

1847
01:19:59,079 --> 01:20:03,909
and what he had to do was define the one

1848
01:20:01,750 --> 01:20:05,739
or the two the small number that were

1849
01:20:03,909 --> 01:20:08,260
not just triggers because of bad data

1850
01:20:05,739 --> 01:20:09,880
like to tell us what about the bit or

1851
01:20:08,260 --> 01:20:11,260
the star was a little off from its

1852
01:20:09,880 --> 01:20:12,609
normal position so I made the star up

1853

01:20:11,260 --> 01:20:14,770
here we think about it wasn't really a

1854
01:20:12,609 --> 01:20:18,549
painter from the very small number of

1855
01:20:14,770 --> 01:20:20,650
events this was a real effect and so

1856
01:20:18,550 --> 01:20:23,619
what he did was to train he went and

1857
01:20:20,649 --> 01:20:30,069
took the in Eclipse the transit data

1858
01:20:23,619 --> 01:20:32,619
from known planets and he said

1859
01:20:30,069 --> 01:20:35,380
cannulated that's that's actual good

1860
01:20:32,619 --> 01:20:36,789
transit data so he tricked so then he

1861
01:20:35,380 --> 01:20:38,619
said what are the characteristics of my

1862
01:20:36,789 --> 01:20:40,569
data and he trained it on that good data

1863
01:20:38,619 --> 01:20:42,250
then he said the news on the

1864
01:20:40,569 --> 01:20:44,590
uncharacterized day that he pulled out

1865
01:20:42,250 --> 01:20:46,149
this one phantom okay and when he did it

1866
01:20:44,590 --> 01:20:48,400
was really nice when he brought me the

1867
01:20:46,149 --> 01:20:49,599

transit I have to confess as you know

1868

01:20:48,399 --> 01:20:52,689

I've got to watch it as a professor you

1869

01:20:49,600 --> 01:20:57,190

get kind of overconfident and I said to

1870

01:20:52,689 --> 01:20:58,539

myself this is not this is not you know

1871

01:20:57,189 --> 01:21:00,429

all the guys finishing at what stage do

1872

01:20:58,539 --> 01:21:02,619

you and I I'm gonna you know I think I

1873

01:21:00,430 --> 01:21:04,570

think I just got some slack and maybe

1874

01:21:02,619 --> 01:21:06,399

right and he was right who's right and

1875

01:21:04,569 --> 01:21:07,299

then that really showed me that I should

1876

01:21:06,399 --> 01:21:17,289

not

1877

01:21:07,300 --> 01:21:22,350

and to possibly be considered that life

1878

01:21:17,289 --> 01:21:27,220

could exist a comet or asteroid exist

1879

01:21:22,350 --> 01:21:30,310

asteroid yeah great question so I think

1880

01:21:27,220 --> 01:21:31,750

that in general astrobiologists would

1881

01:21:30,310 --> 01:21:35,080

say they don't expect life to be

1882
01:21:31,750 --> 01:21:37,479
uncommon or an asteroid because we think

1883
01:21:35,079 --> 01:21:39,760
you have to have liquid water and the

1884
01:21:37,479 --> 01:21:41,709
reason is that you need a way for the

1885
01:21:39,760 --> 01:21:45,250
chemistry of life to proceed okay so if

1886
01:21:41,710 --> 01:21:46,659
you have a gas the interesting molecules

1887
01:21:45,250 --> 01:21:47,739
in the gas are too far apart so you

1888
01:21:46,659 --> 01:21:50,079
don't have a chemical connection very

1889
01:21:47,739 --> 01:21:52,090
quickly if it's a solid obviously things

1890
01:21:50,079 --> 01:21:53,739
are locked in the in the crystal lattice

1891
01:21:52,090 --> 01:21:59,949
the can move around so that's why we

1892
01:21:53,739 --> 01:22:02,050
really like liquids for for and so on in

1893
01:21:59,949 --> 01:22:03,849
the comets and asteroids we think

1894
01:22:02,050 --> 01:22:06,550
they're they don't have that everything

1895
01:22:03,850 --> 01:22:09,760
that's called the orbital comments of

1896
01:22:06,550 --> 01:22:11,920
course is a very very elliptical and so

1897
01:22:09,760 --> 01:22:13,090
they they they do change quite a bit

1898
01:22:11,920 --> 01:22:14,949
their distance but they still remain

1899
01:22:13,090 --> 01:22:28,930
quite solved so we so we don't really

1900
01:22:14,949 --> 01:22:32,380
think so taury

1901
01:22:28,930 --> 01:22:34,180
she's your Pied Piper to follow next

1902
01:22:32,380 --> 01:22:35,529
month Courtney McManus we'll be back to

1903
01:22:34,180 --> 01:22:37,869
our regular first Tuesday of the month

1904
01:22:35,529 --> 01:22:40,719
starting next month Courtney ik Manus

1905
01:22:37,869 --> 01:22:42,279
the view from Mission Control and please

1906
01:22:40,720 --> 01:22:43,610
join me in another warm round of

1907
01:22:42,279 --> 01:22:58,429
applause per game

1908
01:22:43,609 --> 01:22:58,429
[Applause]

1909
01:23:00,430 --> 01:23:05,369
[Laughter]

1910

01:23:02,988 --> 01:23:09,529
we'll have to see because the Great Red

1911
01:23:05,369 --> 01:23:09,529
Spot observation is in 21 minutes

1912
01:23:44,430 --> 01:23:46,490
you