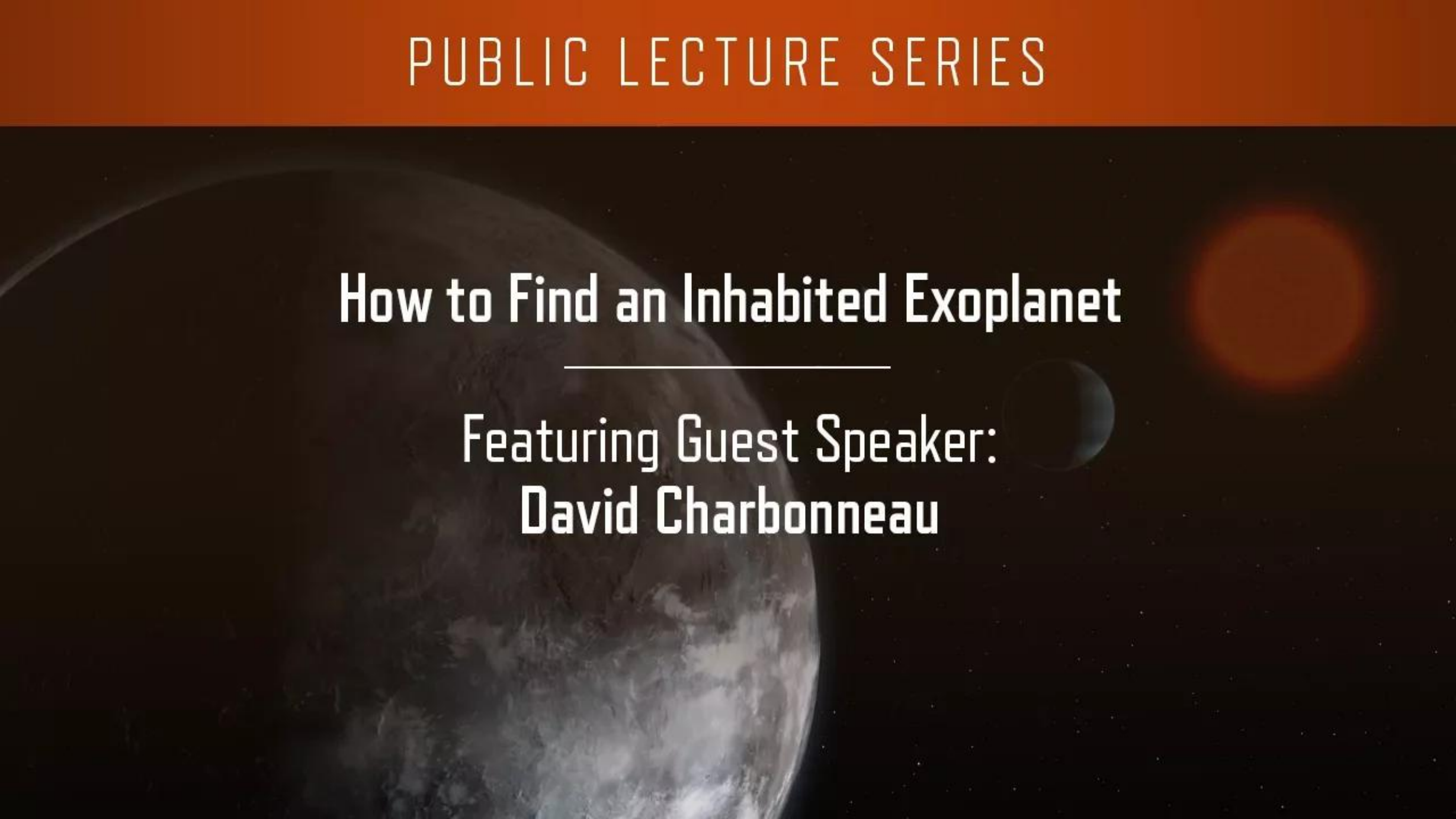
PUBLIC LECTURE SERIES

How to Find an Inhabited Exoplanet

Featuring Guest Speaker:

David Charbonneau



1
00:00:05,360 --> 00:00:02,929
whilst our Rs Papas and if you want to

2
00:00:07,820 --> 00:00:05,370
know about it well simply flip over we

3
00:00:09,709 --> 00:00:07,830
have a description of it along with

4
00:00:12,290 --> 00:00:09,719
pointers for where you can get even more

5
00:00:13,850 --> 00:00:12,300
information about it grab those on your

6
00:00:18,310 --> 00:00:13,860
way out

7
00:00:22,340 --> 00:00:18,320
tonight we have how to find an inhabited

8
00:00:24,590 --> 00:00:22,350
exoplanet and purposely intriguing title

9
00:00:28,279 --> 00:00:24,600
which I know is going to also be an

10
00:00:30,919 --> 00:00:28,289
intriguing talk tonight next month a

11
00:00:33,560 --> 00:00:30,929
view from Mission Operations a lot of

12
00:00:36,799 --> 00:00:33,570
things that go on in the background

13
00:00:39,380 --> 00:00:36,809

behind all of the science results that

14
00:00:41,720 --> 00:00:39,390
we per we present how we actually

15
00:00:45,290 --> 00:00:41,730
operate the missions Courtney McManus as

16
00:00:48,560 --> 00:00:45,300
has agreed to give a talk about this

17
00:00:50,720 --> 00:00:48,570
this very important topic in September

18
00:00:52,819 --> 00:00:50,730
Nolan Walborn he's spoken here a few

19
00:00:54,860 --> 00:00:52,829
times we'll be talking about active

20
00:00:57,979 --> 00:00:54,870
luminous blue variables in the Large

21
00:01:00,680 --> 00:00:57,989
Magellanic Cloud that's a mouthful right

22
00:01:02,569 --> 00:01:00,690
that there are variable stars there are

23
00:01:04,910 --> 00:01:02,579
blue stars there are luminous blue

24
00:01:07,039 --> 00:01:04,920
variables and they are even active and

25
00:01:09,740 --> 00:01:07,049
they actually tell you an awful lot

26
00:01:12,230 --> 00:01:09,750
Nolan promises that he will challenge

27
00:01:15,050 --> 00:01:12,240
you okay so bring your thinking caps in

28
00:01:18,230 --> 00:01:15,060
September when Nolan speaks and in

29
00:01:18,859 --> 00:01:18,240
October one you won't want to miss bring

30
00:01:22,130 --> 00:01:18,869
the kids

31
00:01:24,170 --> 00:01:22,140
Cassini's grand finale at Saturn Cassini

32
00:01:26,719 --> 00:01:24,180
has been orbiting Saturn for over a

33
00:01:29,539 --> 00:01:26,729
decade I forget when they got there do

34
00:01:32,450 --> 00:01:29,549
you remember when it got to like 2006 or

35
00:01:34,609 --> 00:01:32,460
something so it is just amazing what

36
00:01:37,249 --> 00:01:34,619
Cassini has found at Saturday its grand

37
00:01:38,510 --> 00:01:37,259
finale is in September and our own

38
00:01:41,420 --> 00:01:38,520

bonnie monkey from the office of public

39
00:01:43,940 --> 00:01:41,430
outreach who specializes in saturn will

40
00:01:46,190 --> 00:01:43,950
be giving the talk to tell you how it

41
00:01:47,510 --> 00:01:46,200
executed his grand finale she'd have to

42
00:01:49,910 --> 00:01:47,520
have a talk that's six hours long to

43
00:01:51,560 --> 00:01:49,920
cover everything in Cassini has done but

44
00:01:55,100 --> 00:01:51,570
she's so crammed as much as you can into

45
00:01:57,469 --> 00:01:55,110
a one-hour talk the details are on our

46
00:01:59,899 --> 00:01:57,479
website just use your favorite search

47
00:02:01,969 --> 00:01:59,909
engine for Hubble public talks and you

48
00:02:05,300 --> 00:02:01,979
should find this page with a list of our

49
00:02:08,479 --> 00:02:05,310
upcoming lectures and we you can watch

50
00:02:11,540 --> 00:02:08,489
live online the this is the link to our

51
00:02:13,699 --> 00:02:11,550
web casting also you can watch past

52
00:02:16,220 --> 00:02:13,709
lectures all the way back to 2

53
00:02:18,920 --> 00:02:16,230
and five twelve years of astronomical

54
00:02:22,160 --> 00:02:18,930
goodness for you to explore you can also

55
00:02:24,649 --> 00:02:22,170
sign up for our email list here and a

56
00:02:25,729 --> 00:02:24,659
lot of you have taken advantage of that

57
00:02:26,780 --> 00:02:25,739
so I'm glad that there are a lot of

58
00:02:29,809 --> 00:02:26,790
people getting informed about our

59
00:02:31,789 --> 00:02:29,819
lectures the announcements sign up at

60
00:02:33,890 --> 00:02:31,799
the website if you want other ways of

61
00:02:35,599 --> 00:02:33,900
getting it to you you can for those you

62
00:02:37,039 --> 00:02:35,609
here in the audience you want to walk

63
00:02:38,509 --> 00:02:37,049

down and write your email address and

64
00:02:41,179 --> 00:02:38,519
hand it to me I'll make sure you get on

65
00:02:44,349 --> 00:02:41,189
the list if you want to contact us and

66
00:02:48,979 --> 00:02:44,359
ask us comments or give us us questions

67
00:02:52,520 --> 00:02:48,989
public lecture STScI dot edu of course

68
00:02:54,649 --> 00:02:52,530
we have the usual social media I will

69
00:02:56,780 --> 00:02:54,659
have to update this page at the end of

70
00:02:59,000 --> 00:02:56,790
this month because that woman right

71
00:03:00,890 --> 00:02:59,010
there has got a whole new suite of

72
00:03:03,229 --> 00:03:00,900
social media pushes that we're doing

73
00:03:05,000 --> 00:03:03,239
this month and she'll update me and make

74
00:03:06,349 --> 00:03:05,010
sure I have that so next month is slide

75
00:03:08,360 --> 00:03:06,359
will be updated but we have the usable

76
00:03:10,429 --> 00:03:08,370
Facebook and Twitter and Google Plus and

77
00:03:12,979 --> 00:03:10,439
Pinterest and a few more that she's

78
00:03:14,599 --> 00:03:12,989
gonna tell me about this month I have my

79
00:03:16,699 --> 00:03:14,609
blog and Facebook and Google Plus and

80
00:03:18,979 --> 00:03:16,709
Twitter that I use every now and then

81
00:03:20,960 --> 00:03:18,989
but I'm usually too enthused with my

82
00:03:24,339 --> 00:03:20,970
work I had to spend much time on social

83
00:03:27,559 --> 00:03:24,349
media so don't expect a lot from

84
00:03:29,569 --> 00:03:27,569
Observatory tonight yes it will be here

85
00:03:31,610 --> 00:03:29,579
weather permitting it looked like it was

86
00:03:34,399 --> 00:03:31,620
clear when I came in so I hope it will

87
00:03:34,909 --> 00:03:34,409
still be clear arenal and Bradys will be

88
00:03:37,550 --> 00:03:34,919

here

89
00:03:39,589 --> 00:03:37,560
I'll have her come down front and you

90
00:03:42,559 --> 00:03:39,599
guys can go with her and go across the

91
00:03:44,689 --> 00:03:42,569
street you cannot be a laggard on this

92
00:03:46,129 --> 00:03:44,699
when arena takes a group across if

93
00:03:47,929 --> 00:03:46,139
you're not with the group you don't get

94
00:03:50,289 --> 00:03:47,939
in the doors are locked so the whole

95
00:03:52,550 --> 00:03:50,299
group has to go in as one so

96
00:03:53,839 --> 00:03:52,560
unfortunately that means sometimes you

97
00:03:55,849 --> 00:03:53,849
can't hang around and ask the speaker

98
00:03:58,640 --> 00:03:55,859
questions if you want to go do the

99
00:04:01,520 --> 00:03:58,650
observing across the street alright and

100
00:04:07,099 --> 00:04:01,530
now my section news from the universe

101
00:04:09,530 --> 00:04:07,109
for July 2017 first story the curious

102
00:04:11,780 --> 00:04:09,540
instant of the star in the night time

103
00:04:14,420 --> 00:04:11,790
now who recognizes what that's a

104
00:04:18,189 --> 00:04:14,430
reference to and as I know she does who

105
00:04:26,120 --> 00:04:23,420
yes it's from actually from Sherlock

106
00:04:28,159 --> 00:04:26,130
Holmes is where I took it from where

107
00:04:29,629 --> 00:04:28,169
detective Gregory astronaut's Holmes is

108
00:04:31,879 --> 00:04:29,639
there any other point to which you would

109
00:04:33,529 --> 00:04:31,889
wish to draw my attention and he replies

110
00:04:36,350 --> 00:04:33,539
to the Curious Incident of the dog in

111
00:04:37,100 --> 00:04:36,360
the night-time the dog did nothing in

112
00:04:40,909 --> 00:04:37,110
the nighttime

113
00:04:42,770 --> 00:04:40,919

that was the Curious Incident now it's

114
00:04:45,950 --> 00:04:42,780
come down through folklore as the dog

115
00:04:48,260 --> 00:04:45,960
that didn't bark here we're going to

116
00:04:51,439 --> 00:04:48,270
talk about a star in the night time and

117
00:04:54,439 --> 00:04:51,449
stars do other things besides barking so

118
00:04:57,020 --> 00:04:54,449
this is a picture in 1984 of a certain

119
00:05:00,550 --> 00:04:57,030
particular star taken at the angle

120
00:05:05,770 --> 00:05:00,560
Australian Observatory and that star in

121
00:05:09,830 --> 00:05:05,780
1987 looked like this this was supernova

122
00:05:12,710 --> 00:05:09,840
1987a and so very massive stars at the

123
00:05:15,379 --> 00:05:12,720
end of their lifetime explode as these

124
00:05:17,870 --> 00:05:15,389
giant supernova explosions and they

125
00:05:22,189 --> 00:05:17,880
become incredibly bright basically as

126
00:05:25,360 --> 00:05:22,199
bright as an entire galaxy ok so that's

127
00:05:28,460 --> 00:05:25,370
how we expect these super massive

128
00:05:30,320 --> 00:05:28,470
supergiant stars to end their life let

129
00:05:35,240 --> 00:05:30,330
me tell you the story of a different

130
00:05:37,010 --> 00:05:35,250
star this one now there is a supernova

131
00:05:38,960 --> 00:05:37,020
search that's being run out of the Ohio

132
00:05:40,250 --> 00:05:38,970
State University and they're using a

133
00:05:42,620 --> 00:05:40,260
ground-based telescope the large

134
00:05:45,020 --> 00:05:42,630
binocular telescope and in order to find

135
00:05:47,480 --> 00:05:45,030
supernovae because you don't know which

136
00:05:50,240 --> 00:05:47,490
stars gonna go supernova at any time you

137
00:05:52,760 --> 00:05:50,250
monitor lots of galaxies over many years

138
00:05:55,550 --> 00:05:52,770

and on average you'll see a few

139
00:05:56,629 --> 00:05:55,560
supernovae in each galaxy and while in

140
00:05:59,779 --> 00:05:56,639
some of the galaxies that you're

141
00:06:03,040 --> 00:05:59,789
monitoring well this will star hate here

142
00:06:06,080 --> 00:06:03,050
turns out to be a 25 solar mass star

143
00:06:10,490 --> 00:06:06,090
it's in the galaxies you what is it NGC

144
00:06:14,420 --> 00:06:10,500
69 46 and this star was observed

145
00:06:17,089 --> 00:06:14,430
brightened in the year 2009 but since

146
00:06:18,740 --> 00:06:17,099
then it is faded away now when I say it

147
00:06:21,290 --> 00:06:18,750
brightened in 2009 it didn't go

148
00:06:23,779 --> 00:06:21,300
supernova you saw that huge brightness a

149
00:06:25,820 --> 00:06:23,789
change there it did not bright enough to

150
00:06:29,330 --> 00:06:25,830
say it went supernova it brightened a

151
00:06:30,410 --> 00:06:29,340
bit but it did not brighten to a huge

152
00:06:31,790 --> 00:06:30,420
amount

153
00:06:34,030 --> 00:06:31,800
and then it faded away such the

154
00:06:36,830 --> 00:06:34,040
ground-based telescopes could not see it

155
00:06:38,870 --> 00:06:36,840
well they wondered what was going on was

156
00:06:41,090 --> 00:06:38,880
this star just enshrouded and dust and

157
00:06:43,490 --> 00:06:41,100
we couldn't see it or maybe it had faded

158
00:06:45,830 --> 00:06:43,500
away to such it was undetectable by

159
00:06:47,570 --> 00:06:45,840
ground-based so what do you do you call

160
00:06:52,150 --> 00:06:47,580
in the space telescopes for follow-up

161
00:06:56,150 --> 00:06:52,160
all right this is what Hubble saw

162
00:06:58,640 --> 00:06:56,160
nothing it was not that the star had

163
00:07:01,580 --> 00:06:58,650

just faded below observable level from

164
00:07:03,770 --> 00:07:01,590
the ground then they looked with the

165
00:07:06,170 --> 00:07:03,780
spitzer space telescope perhaps it was

166
00:07:08,420 --> 00:07:06,180
shrouded in dust and therefore obscured

167
00:07:10,400 --> 00:07:08,430
in optical bandpass but that would be

168
00:07:15,830 --> 00:07:10,410
invisible in the infrared bandpass of

169
00:07:18,230 --> 00:07:15,840
Spitzer Spitzer also saw nothing it's

170
00:07:21,320 --> 00:07:18,240
not visible an optical light it's not

171
00:07:26,660 --> 00:07:21,330
visible in infrared light what happened

172
00:07:30,170 --> 00:07:26,670
to this 25 solar mass star well the

173
00:07:34,160 --> 00:07:30,180
conclusion is this is not the dog that

174
00:07:38,320 --> 00:07:34,170
didn't bark this is the star that didn't

175
00:07:42,260 --> 00:07:38,330
explode this they both star they believe

176
00:07:45,200 --> 00:07:42,270
collapsed to a black hole without going

177
00:07:47,540 --> 00:07:45,210
through a supernova normally we believe

178
00:07:49,610 --> 00:07:47,550
that stars except that at the end of the

179
00:07:51,440 --> 00:07:49,620
star's light it collapses it explodes

180
00:07:54,650 --> 00:07:51,450
and the core collapses to either a

181
00:07:57,610 --> 00:07:54,660
neutron star or a black hole this is

182
00:08:01,520 --> 00:07:57,620
evidence that stars may collapse

183
00:08:05,240 --> 00:08:01,530
directly to a black hole without going

184
00:08:07,280 --> 00:08:05,250
through the supernova phase this had not

185
00:08:10,310 --> 00:08:07,290
been seen before this is the first one

186
00:08:13,190 --> 00:08:10,320
of what they call failed supernovas and

187
00:08:15,710 --> 00:08:13,200
in their survey they saw a six or seven

188
00:08:17,540 --> 00:08:15,720

other supernovae in the galaxies they

189
00:08:20,060 --> 00:08:17,550
were monitoring and that starts to give

190
00:08:22,940 --> 00:08:20,070
them some statistics about how many of

191
00:08:25,580 --> 00:08:22,950
these very massive stars might collapse

192
00:08:28,690 --> 00:08:25,590
directly to black holes without leaving

193
00:08:32,180 --> 00:08:28,700
the tell-tale explosion of a supernova

194
00:08:34,850 --> 00:08:32,190
so there's a new way for forming a black

195
00:08:37,190 --> 00:08:34,860
hole we believe that we you can form

196
00:08:40,219 --> 00:08:37,200
black holes from the standard model

197
00:08:41,690 --> 00:08:40,229
where you have an explosion and you get

198
00:08:43,820 --> 00:08:41,700
the supernova explosion and you get the

199
00:08:45,410 --> 00:08:43,830
black hole but here we

200
00:08:47,780 --> 00:08:45,420
evidence that you can get a super you

201
00:08:52,060 --> 00:08:47,790
can get a black hole without having a

202
00:08:56,949 --> 00:08:52,070
supernova explosion that's really cool

203
00:09:00,019 --> 00:08:56,959
now third story a stellar light weight

204
00:09:01,819 --> 00:09:00,029
so if you want to weigh a star you want

205
00:09:04,850 --> 00:09:01,829
to understand the mass of a star you

206
00:09:07,940 --> 00:09:04,860
have to figure out how much gravity That

207
00:09:10,100 --> 00:09:07,950
star has and the usual way to do it is

208
00:09:13,100 --> 00:09:10,110
if you've got a planet or another star

209
00:09:15,710 --> 00:09:13,110
orbiting around it the characteristics

210
00:09:17,420 --> 00:09:15,720
of that orbit will tell you the amount

211
00:09:20,269 --> 00:09:17,430
of gravity that is in the system and

212
00:09:23,420 --> 00:09:20,279
therefore the mass of the star this is a

213
00:09:27,319 --> 00:09:23,430

dynamical measurement of the mass of a

214
00:09:29,389 --> 00:09:27,329
star but if a star is isolated doesn't

215
00:09:33,190 --> 00:09:29,399
have anything orbiting around it how do

216
00:09:37,730 --> 00:09:33,200
you tell its mass generally you can't

217
00:09:41,449 --> 00:09:37,740
accept the mass of a star can also do

218
00:09:43,639 --> 00:09:41,459
something else we in deine steins

219
00:09:46,550 --> 00:09:43,649
relativity we think of the fabric of

220
00:09:49,699 --> 00:09:46,560
space-time okay and let's represent it

221
00:09:53,840 --> 00:09:49,709
here as this grid but the presence of a

222
00:09:57,860 --> 00:09:53,850
star creates a deformation in the grid

223
00:10:02,600 --> 00:09:57,870
of space-time light that passes through

224
00:10:04,819 --> 00:10:02,610
that deformation changes direction so

225
00:10:07,460 --> 00:10:04,829
and the amount of directional change is

226
00:10:11,030 --> 00:10:07,470
going to be proportional to the mass of

227
00:10:13,430 --> 00:10:11,040
That star so if you can measure that you

228
00:10:16,250 --> 00:10:13,440
can measure the mass of the star and

229
00:10:20,750 --> 00:10:16,260
this is what Hubble is trying to do for

230
00:10:23,780 --> 00:10:20,760
this star Stein 2:05 1b and actually I

231
00:10:26,660 --> 00:10:23,790
just lied to you it's not a star it's a

232
00:10:28,760 --> 00:10:26,670
white dwarf now you'll always hear being

233
00:10:30,860 --> 00:10:28,770
called a white dwarf star but a white

234
00:10:33,620 --> 00:10:30,870
dwarf isn't a star because there's no

235
00:10:36,110 --> 00:10:33,630
nuclear fusion going on in its core it's

236
00:10:38,480 --> 00:10:36,120
a dead star it's a stellar remnant all

237
00:10:40,670 --> 00:10:38,490
the nuclear fusion has ceased it's just

238
00:10:42,620 --> 00:10:40,680

a really really hot ball basically of

239
00:10:44,810 --> 00:10:42,630
carbon now you can sort of think it as a

240
00:10:46,730 --> 00:10:44,820
giant charcoal briquette that will burn

241
00:10:48,710 --> 00:10:46,740
for trillions of trillions of years you

242
00:10:55,160 --> 00:10:48,720
can have a really really long barbecue

243
00:10:56,879 --> 00:10:55,170
with this so Stein 2:05 1b you might

244
00:10:59,160 --> 00:10:56,889
think that it has a planet around it or

245
00:11:02,369 --> 00:10:59,170
another star nearby it but it doesn't

246
00:11:05,639 --> 00:11:02,379
this is actually passing in front of a

247
00:11:08,579 --> 00:11:05,649
star that's 5,000 light years away when

248
00:11:12,179 --> 00:11:08,589
there's sign - Oh fun bee is only 17

249
00:11:13,889 --> 00:11:12,189
light years away so stein 205 1 b being

250
00:11:16,199 --> 00:11:13,899
very close and this other star being

251
00:11:19,439 --> 00:11:16,209
very far away they move relative to one

252
00:11:22,919 --> 00:11:19,449
another in the sky and as styie no 205

253
00:11:24,900 --> 00:11:22,929
one b passes by that star we should be

254
00:11:28,259 --> 00:11:24,910
able to measure the gravitational

255
00:11:31,590 --> 00:11:28,269
lensing of the background star so here's

256
00:11:34,199 --> 00:11:31,600
the diagram this is the white dwarf okay

257
00:11:36,720 --> 00:11:34,209
here is Hubble's observed star position

258
00:11:38,460 --> 00:11:36,730
and here's where the star person really

259
00:11:40,889 --> 00:11:38,470
should be and we can measure that

260
00:11:44,519 --> 00:11:40,899
deflection we can then measure the mass

261
00:11:46,530 --> 00:11:44,529
of the star here's how here isn't a

262
00:11:49,829 --> 00:11:46,540
diagram attic this is an illustration of

263
00:11:54,449 --> 00:11:49,839

the idea that as the white dwarf passes

264
00:11:58,650 --> 00:11:54,459
by the position of that star will change

265
00:12:01,109 --> 00:11:58,660
okay now that's incredibly overstated

266
00:12:03,119 --> 00:12:01,119
alright that's an illustration of it

267
00:12:05,340 --> 00:12:03,129
just to give you the idea of it do you

268
00:12:07,799 --> 00:12:05,350
want to see the real data I'm happy to

269
00:12:14,909 --> 00:12:07,809
show you the real data this is the real

270
00:12:18,179 --> 00:12:14,919
data did you all see that motion of

271
00:12:21,659 --> 00:12:18,189
course you didn't okay because the

272
00:12:25,559 --> 00:12:21,669
motion of that background star is offset

273
00:12:27,720 --> 00:12:25,569
by two milli arcseconds to thousands of

274
00:12:29,460 --> 00:12:27,730
an arc second where an arc second is one

275
00:12:31,919 --> 00:12:29,470
sixtieth of an arc minute and an arc

276
00:12:33,629 --> 00:12:31,929
minute is one sixtieth of a degree okay

277
00:12:35,999 --> 00:12:33,639
so one thirty six hundredth of a degree

278
00:12:39,749 --> 00:12:36,009
and then to one thousandth of that

279
00:12:43,259 --> 00:12:39,759
that's a really small angle but Hubble

280
00:12:46,169 --> 00:12:43,269
was able to measure it and using this

281
00:12:48,239 --> 00:12:46,179
Hubble was able to measure the mass of

282
00:12:50,279 --> 00:12:48,249
the white dwarf star the result being

283
00:12:52,109 --> 00:12:50,289
about two thirds of the mass of the Sun

284
00:12:55,319 --> 00:12:52,119
which fits in with our theoretical

285
00:12:56,699 --> 00:12:55,329
expectations for the masses of white

286
00:12:58,769 --> 00:12:56,709
dwarfs and actually it fits written with

287
00:13:03,090 --> 00:12:58,779
our other observations of the masses of

288
00:13:06,900 --> 00:13:03,100

white dwarfs this actually is the second

289
00:13:08,350 --> 00:13:06,910
star for which it had been done when was

290
00:13:13,060 --> 00:13:08,360
it done the first time

291
00:13:16,780 --> 00:13:13,070
a hundred years ago during the 1919

292
00:13:19,480 --> 00:13:16,790
total solar eclipse just after general

293
00:13:22,150 --> 00:13:19,490
relativity was was put forth in the

294
00:13:24,340 --> 00:13:22,160
paper they recognized that they could

295
00:13:27,190 --> 00:13:24,350
see this gravitational lensing of

296
00:13:29,470 --> 00:13:27,200
different background stars during a

297
00:13:30,850 --> 00:13:29,480
solar eclipse so what they did is they

298
00:13:32,829 --> 00:13:30,860
measured you see all those stars I've

299
00:13:34,540 --> 00:13:32,839
got pointed out there they measured

300
00:13:37,300 --> 00:13:34,550
those stars well before the Eclipse

301
00:13:39,880 --> 00:13:37,310
where their positions were and then when

302
00:13:41,800 --> 00:13:39,890
the Sun underwent the total solar

303
00:13:43,300 --> 00:13:41,810
eclipse and the moon was blocking it

304
00:13:45,730 --> 00:13:43,310
they could actually see those stars

305
00:13:48,449 --> 00:13:45,740
passing through the gravitational field

306
00:13:51,400 --> 00:13:48,459
of the Sun they could measure the

307
00:13:55,690 --> 00:13:51,410
deflection of light to test general

308
00:13:59,710 --> 00:13:55,700
relativity and they did this in 1919 so

309
00:14:03,150 --> 00:13:59,720
Hubble is finally doing for external

310
00:14:05,530 --> 00:14:03,160
stars what was done for our own star in

311
00:14:06,160 --> 00:14:05,540
1919 and we have a new way to measure

312
00:14:11,009 --> 00:14:06,170
start

313
00:14:15,220 --> 00:14:11,019

Celer masses which also gives us a good

314
00:14:18,160 --> 00:14:15,230
entry into reminding you Hey where will

315
00:14:20,620 --> 00:14:18,170
you be when the light goes out just want

316
00:14:25,630 --> 00:14:20,630
to make sure you all remember that next

317
00:14:27,430 --> 00:14:25,640
month on August 21st 2017 we have the

318
00:14:29,980 --> 00:14:27,440
greatest total solar eclipse so far in

319
00:14:33,069 --> 00:14:29,990
my lifetime in the United States it

320
00:14:37,360 --> 00:14:33,079
passes from Oregon all the way down

321
00:14:39,610 --> 00:14:37,370
through South Carolina alright about two

322
00:14:41,650 --> 00:14:39,620
minutes to two minutes and 40 seconds

323
00:14:48,220 --> 00:14:41,660
duration if you're on this if you're on

324
00:14:49,990 --> 00:14:48,230
the centerline it's on a Monday make

325
00:14:52,000 --> 00:14:50,000
sure that there are all sorts of things

326
00:14:53,620 --> 00:14:52,010
if you can't get to the centerline you

327
00:14:56,009 --> 00:14:53,630
can see that the entire continental

328
00:15:00,250 --> 00:14:56,019
United States will have some level of

329
00:15:03,280 --> 00:15:00,260
the partial solar eclipse there are all

330
00:15:05,290 --> 00:15:03,290
sorts of cool tools online for example

331
00:15:07,600 --> 00:15:05,300
this one is an interactive map and if

332
00:15:11,139 --> 00:15:07,610
you click on Salem you find that Salem

333
00:15:13,949 --> 00:15:11,149
is in the path of totality it will have

334
00:15:16,180 --> 00:15:13,959
a 1 minute and 55 second total totality

335
00:15:17,410 --> 00:15:16,190
however if you don't leave here if you

336
00:15:19,960 --> 00:15:17,420
stay at the johns hopkins university

337
00:15:23,050 --> 00:15:19,970
campus in baltimore maryland you will

338
00:15:25,000 --> 00:15:23,060

only get an 80% obscure

339
00:15:27,129 --> 00:15:25,010
and here are the times of the Eclipse

340
00:15:30,819 --> 00:15:27,139
you can find all these incredible tools

341
00:15:33,220 --> 00:15:30,829
online I'm not gonna we gave a talk on

342
00:15:35,110 --> 00:15:33,230
this in January if you go to our web

343
00:15:38,680 --> 00:15:35,120
casting site and go back to our January

344
00:15:40,269 --> 00:15:38,690
1 you can find our talk on that although

345
00:15:42,759 --> 00:15:40,279
I'm sure there's a lot more cool stuff

346
00:15:45,250 --> 00:15:42,769
on the web now because everyone's hyping

347
00:15:49,269 --> 00:15:45,260
up for this I will only say one thing

348
00:15:52,620 --> 00:15:49,279
you must have certified solar viewing

349
00:15:55,240 --> 00:15:52,630
glasses I cannot say this enough ok

350
00:15:57,160 --> 00:15:55,250
sunglasses are not good enough ok a

351
00:15:58,840 --> 00:15:57,170
mylar balloon which some people think is

352
00:16:01,030 --> 00:15:58,850
good enough is not good enough

353
00:16:02,590 --> 00:16:01,040
what's your Uncle Joe from Montana tells

354
00:16:05,620 --> 00:16:02,600
you was good enough isn't good enough

355
00:16:08,139 --> 00:16:05,630
unless he says you need certified solar

356
00:16:10,030 --> 00:16:08,149
viewing glasses ok so please make sure

357
00:16:12,509 --> 00:16:10,040
that your if you're going to watch the

358
00:16:16,660 --> 00:16:12,519
solar eclipse you keep your eyes safe

359
00:16:28,810 --> 00:16:16,670
alright and that's our news for July you

360
00:16:30,400 --> 00:16:28,820
have a question here well 1919 the Maine

361
00:16:32,590 --> 00:16:30,410
alright so the question I've got a

362
00:16:34,689 --> 00:16:32,600
repeated for the online audience the

363
00:16:36,069 --> 00:16:34,699

mass of the Sun it measured in 1919 how

364
00:16:39,269 --> 00:16:36,079
does it compare to the mass we would

365
00:16:42,519 --> 00:16:39,279
measure today and the main point of the

366
00:16:45,130 --> 00:16:42,529
Eclipse expeditions in 1919 was actually

367
00:16:47,889 --> 00:16:45,140
to test whether those stars actually

368
00:16:49,630 --> 00:16:47,899
really moved whether general activity

369
00:16:52,210 --> 00:16:49,640
was correct because this was a

370
00:16:55,240 --> 00:16:52,220
mathematical theory that you know

371
00:16:57,040 --> 00:16:55,250
stretched the imagination a bit ahead

372
00:16:59,560 --> 00:16:57,050
and so the main point of it so I don't

373
00:17:02,019 --> 00:16:59,570
really know whether they measured the

374
00:17:03,910 --> 00:17:02,029
mass of the Sun that but I think they

375
00:17:05,829 --> 00:17:03,920
probably put in the mass of the Sun as

376
00:17:08,409 --> 00:17:05,839
one of their parameters to measure how

377
00:17:12,280 --> 00:17:08,419
much the stars should move in the light

378
00:17:15,100 --> 00:17:12,290
deflection equation we have obviously

379
00:17:16,230 --> 00:17:15,110
planets orbiting the Sun so we can

380
00:17:19,049 --> 00:17:16,240
measure the mass

381
00:17:21,299 --> 00:17:19,059
I'm pretty accurately using that I don't

382
00:17:23,939 --> 00:17:21,309
know if that light deflection actually

383
00:17:27,270 --> 00:17:23,949
would improve on that in any way but

384
00:17:31,620 --> 00:17:27,280
yeah it's a good question thank you yes

385
00:17:35,640 --> 00:17:31,630
first story about the the starter was 25

386
00:17:39,000 --> 00:17:35,650
solar masses is that rare for a star to

387
00:17:41,549 --> 00:17:39,010
be that big or so in the story of the

388
00:17:43,530 --> 00:17:41,559

star star that didn't explode is it

389
00:17:45,840 --> 00:17:43,540
unusual to have us 25 solar mass star

390
00:17:48,600 --> 00:17:45,850
yes okay

391
00:17:51,450 --> 00:17:48,610
the meek inherit the universe the tiny

392
00:17:53,669 --> 00:17:51,460
very small stars smaller than the Sun

393
00:17:56,730 --> 00:17:53,679
are the most numerous in the entire

394
00:17:58,650 --> 00:17:56,740
universe the red dwarf stars are really

395
00:18:00,299 --> 00:17:58,660
the most unit numerous as you get up to

396
00:18:04,140 --> 00:18:00,309
larger and larger stars they're much

397
00:18:07,740 --> 00:18:04,150
much rarer and so a 25 solar mass star

398
00:18:09,900 --> 00:18:07,750
is is a relatively rare star and I think

399
00:18:11,790 --> 00:18:09,910
the stars getting you have to get above

400
00:18:14,580 --> 00:18:11,800
at least eight solar masses to have it

401
00:18:19,200 --> 00:18:14,590
at a supernova and those are the O and

402
00:18:20,610 --> 00:18:19,210
the B stars those those are the you know

403
00:18:22,799 --> 00:18:20,620
few and far between those are the big

404
00:18:27,930 --> 00:18:22,809
monster stars inside the star clusters

405
00:18:31,230 --> 00:18:27,940
all right okay let's move on to our

406
00:18:34,530 --> 00:18:31,240
featured speaker I am extremely pleased

407
00:18:36,419 --> 00:18:34,540
to have Dave Charbonneau of the Harvard

408
00:18:41,520 --> 00:18:36,429
University here tonight he is a

409
00:18:44,640 --> 00:18:41,530
professor of astronomy he's a professor

410
00:18:47,360 --> 00:18:44,650
of astronomy at Harvard University and

411
00:18:50,310 --> 00:18:47,370
his research as you might guess is on

412
00:18:53,460 --> 00:18:50,320
exoplanets and you hear a lot of his

413
00:18:57,030 --> 00:18:53,470

stuff here tonight he has worked on the

414
00:18:58,919 --> 00:18:57,040
both the Kepler mission and he's working

415
00:19:02,370 --> 00:18:58,929
on the upcoming test mission the

416
00:19:09,470 --> 00:19:02,380
transiting extrasolar surveys extra

417
00:19:14,630 --> 00:19:12,350
when I'm talking to the public yes you

418
00:19:18,350 --> 00:19:14,640
guess you yes you went to exoplanet all

419
00:19:20,900 --> 00:19:18,360
right let's see he did his undergraduate

420
00:19:25,430 --> 00:19:20,910
work at the University of Toronto before

421
00:19:28,100 --> 00:19:25,440
doing his PhD at Harvard postdoc no

422
00:19:34,570 --> 00:19:28,110
postdoc at Caltech so he's hitting all

423
00:19:39,890 --> 00:19:36,560
the NASA medal for exceptional

424
00:19:41,750 --> 00:19:39,900
scientific achievement scientist of the

425
00:19:43,580 --> 00:19:41,760
year from Discovery magazine these

426
00:19:46,370 --> 00:19:43,590
members National Academy Sciences yada

427
00:19:48,560 --> 00:19:46,380
yada yada usual stuff that we have you

428
00:19:51,530 --> 00:19:48,570
know I only get you the best speakers

429
00:19:54,680 --> 00:19:51,540
okay but the most important thing is

430
00:19:57,380 --> 00:19:54,690
he's the father of four girls he is a

431
00:20:00,710 --> 00:19:57,390
hockey coach and he tells me he's

432
00:20:07,400 --> 00:20:00,720
probably the only male to be a Girl

433
00:20:09,200 --> 00:20:07,410
Scout leader one of the few rare males

434
00:20:13,760 --> 00:20:09,210
to be a Girl Scout leader

435
00:20:16,490 --> 00:20:13,770
so a definite Renaissance guy please

436
00:20:23,940 --> 00:20:16,500
welcome Dave Charbonneau

437
00:20:29,050 --> 00:20:26,950
well thanks for the really kind

438
00:20:30,640 --> 00:20:29,060

introduction so I'm really looking

439
00:20:33,100 --> 00:20:30,650
forward to this what I want to do is

440
00:20:35,260 --> 00:20:33,110
just tell you about what I think is the

441
00:20:37,990 --> 00:20:35,270
most exciting thing going on in all of

442
00:20:40,030 --> 00:20:38,000
science maybe I'm a little biased but

443
00:20:43,150 --> 00:20:40,040
this is a very very special moment to be

444
00:20:45,220 --> 00:20:43,160
alive and be interested in this question

445
00:20:51,010 --> 00:20:45,230
of whether or not we're the only

446
00:20:53,740 --> 00:20:51,020
inhabited planet out there okay so you

447
00:20:56,320 --> 00:20:53,750
know I'm sure you are all aware that if

448
00:20:58,570 --> 00:20:56,330
you if you if you take a telescope out

449
00:21:00,340 --> 00:20:58,580
to a dark point on the earth and you

450
00:21:02,260 --> 00:21:00,350
point it up at the night sky and you

451
00:21:04,720 --> 00:21:02,270
just take a long exposure you know it's

452
00:21:06,850 --> 00:21:04,730
just it's stars all the way down right

453
00:21:09,400 --> 00:21:06,860
so it's not just the stars that you see

454
00:21:10,690 --> 00:21:09,410
in the image but the fact that you know

455
00:21:12,820 --> 00:21:10,700
there's all these kind of unresolved

456
00:21:14,800 --> 00:21:12,830
stars I mean that if we add them all up

457
00:21:19,360 --> 00:21:14,810
there's something like 300 billion stars

458
00:21:21,250 --> 00:21:19,370
in the galaxy okay and often when I'm

459
00:21:24,010 --> 00:21:21,260
talking to folks about whether or not

460
00:21:25,360 --> 00:21:24,020
we're alone they say look you know we

461
00:21:27,850 --> 00:21:25,370
now know that there's planets around

462
00:21:29,860 --> 00:21:27,860
other stars there's 300 billion stars

463
00:21:31,240 --> 00:21:29,870

out there in our own galaxy there's you

464
00:21:33,820 --> 00:21:31,250
know hundreds of billions of other

465
00:21:38,410 --> 00:21:33,830
galaxies isn't it inevitable that

466
00:21:41,380 --> 00:21:38,420
there's life and I find that answer to

467
00:21:43,330 --> 00:21:41,390
be awful I find that to be really

468
00:21:45,850 --> 00:21:43,340
unsatisfying I don't want to know that

469
00:21:47,760 --> 00:21:45,860
there's a mathematical possibility that

470
00:21:51,100 --> 00:21:47,770
there's probably life I want to actually

471
00:21:53,230 --> 00:21:51,110
find the life and I want to see if it's

472
00:21:55,210 --> 00:21:53,240
got DNA and I want to see if it's

473
00:21:58,300 --> 00:21:55,220
multicellular maybe even if it's

474
00:21:59,740 --> 00:21:58,310
intelligent okay so so it's not enough

475
00:22:01,180 --> 00:21:59,750
to do the calculation we have to

476
00:22:05,050 --> 00:22:01,190
actually go I think and actually look

477
00:22:07,120 --> 00:22:05,060
for um what I do want to point out is

478
00:22:09,100 --> 00:22:07,130
that this is not a new idea okay we're

479
00:22:11,200 --> 00:22:09,110
not the first generation to really worry

480
00:22:14,200 --> 00:22:11,210
about these things if you go back

481
00:22:18,370 --> 00:22:14,210
through at least more than 2,000 years

482
00:22:20,110 --> 00:22:18,380
of human written thought you can find

483
00:22:21,700 --> 00:22:20,120
that people have been thinking about

484
00:22:25,150 --> 00:22:21,710
whether or not we're alone for a long

485
00:22:30,190 --> 00:22:25,160
time okay so so here we have Epicurus

486
00:22:32,590 --> 00:22:30,200
okay writing in 300 BC there is an

487
00:22:34,960 --> 00:22:32,600
infinite number of worlds some like this

488
00:22:35,440 --> 00:22:34,970

world and others unlike it some of these

489
00:22:37,240 --> 00:22:35,450
worlds

490
00:22:39,430 --> 00:22:37,250
contain the seeds out of which animals

491
00:22:41,080 --> 00:22:39,440
and plants arise and all the rest of the

492
00:22:43,389 --> 00:22:41,090
things that we see so they so the Greeks

493
00:22:46,060 --> 00:22:43,399
didn't even really know that the points

494
00:22:47,440 --> 00:22:46,070
of light in the night sky were stars and

495
00:22:49,360 --> 00:22:47,450
there might be planets around those

496
00:22:51,279 --> 00:22:49,370
stars but even without that knowledge

497
00:22:53,769 --> 00:22:51,289
they had this thought that there might

498
00:22:56,019 --> 00:22:53,779
be alien worlds and we would somehow

499
00:23:01,330 --> 00:22:56,029
come into contact with with these

500
00:23:05,230 --> 00:23:01,340
unknown places ok here you know much

501
00:23:06,340 --> 00:23:05,240
more modern only gosh you know 450 years

502
00:23:09,669 --> 00:23:06,350
ago

503
00:23:11,860 --> 00:23:09,679
we've got Giordano Bruno so he was a

504
00:23:14,320 --> 00:23:11,870
medieval scholar and he said there are

505
00:23:16,450 --> 00:23:14,330
countless suns and countless earths all

506
00:23:17,769 --> 00:23:16,460
rotating around their Suns in exactly

507
00:23:20,590 --> 00:23:17,779
the same way as the planets of our

508
00:23:23,379 --> 00:23:20,600
system the countless worlds are no worse

509
00:23:26,230 --> 00:23:23,389
and no less inhabited than our earth so

510
00:23:27,639 --> 00:23:26,240
so he now knew that the other that the

511
00:23:29,799 --> 00:23:27,649
points of light in the night sky really

512
00:23:30,970 --> 00:23:29,809
were stars he didn't know that there

513
00:23:32,740 --> 00:23:30,980

were planets but he thought well they're

514
00:23:35,019 --> 00:23:32,750
probably planets we just can't see them

515
00:23:39,159 --> 00:23:35,029
and he thought well maybe some of them

516
00:23:42,220 --> 00:23:39,169
have life what what's so special is that

517
00:23:44,110 --> 00:23:42,230
for thousands of years people have only

518
00:23:46,450 --> 00:23:44,120
been able to theorize they've been able

519
00:23:49,149 --> 00:23:46,460
to use their imaginations and say gee I

520
00:23:51,220 --> 00:23:49,159
wonder but we're all alive at this

521
00:23:53,320 --> 00:23:51,230
special moment in human history where we

522
00:23:55,960 --> 00:23:53,330
have the technological ability to

523
00:23:58,379 --> 00:23:55,970
actually go and answer that question ok

524
00:24:02,019 --> 00:23:58,389
so so this is a very very special time

525
00:24:02,889 --> 00:24:02,029
how are we gonna do it right how are we

526
00:24:04,090 --> 00:24:02,899
gonna do it how are we actually gonna

527
00:24:05,680 --> 00:24:04,100
find out I mean there's only one

528
00:24:11,830 --> 00:24:05,690
generation that gets to do it you only

529
00:24:13,930 --> 00:24:11,840
find out you're not alone once so so

530
00:24:15,669 --> 00:24:13,940
here's here's kind of one one idea maybe

531
00:24:18,190 --> 00:24:15,679
we should build spaceships right and and

532
00:24:22,149 --> 00:24:18,200
often when I'm talking to folks they say

533
00:24:23,379 --> 00:24:22,159
you know is that a possibility and you

534
00:24:25,330 --> 00:24:23,389
know I want to point out that of course

535
00:24:27,250 --> 00:24:25,340
that's not really the way that's not

536
00:24:31,509 --> 00:24:27,260
really a realistic possibility for

537
00:24:32,860 --> 00:24:31,519
discovering life on other planets there

538
00:24:34,360 --> 00:24:32,870

aren't people thinking about what it

539
00:24:36,730 --> 00:24:34,370
would take to send probes to other stars

540
00:24:38,200 --> 00:24:36,740
and that's that's very very exciting but

541
00:24:39,759 --> 00:24:38,210
it's not the way the first discoveries

542
00:24:41,799 --> 00:24:39,769
are going to be made and it's a really

543
00:24:44,110 --> 00:24:41,809
difficult challenge ok so if you take

544
00:24:46,419 --> 00:24:44,120
the fastest spacecraft that we've ever

545
00:24:48,970 --> 00:24:46,429
made and you pointed it directly at the

546
00:24:50,500 --> 00:24:48,980
closest star and you fired the engines

547
00:24:53,800 --> 00:24:50,510
you're still talking something like ten

548
00:24:58,060 --> 00:24:53,810
thousand years ten thousand years to get

549
00:24:59,620 --> 00:24:58,070
there okay so I am impatient I've got

550
00:25:01,660 --> 00:24:59,630
things that I gotta go coach my hockey

551
00:25:06,280 --> 00:25:01,670
team so I got I can't I can't wait that

552
00:25:07,540 --> 00:25:06,290
long so here's another idea right the

553
00:25:11,590 --> 00:25:07,550
search for extraterrestrial intelligence

554
00:25:14,470 --> 00:25:11,600
so we should listen for radio signals or

555
00:25:17,290 --> 00:25:14,480
for laser signals from intelligent life

556
00:25:20,440 --> 00:25:17,300
that's trying to communicate with us now

557
00:25:23,830 --> 00:25:20,450
I am really glad that people are trying

558
00:25:26,170 --> 00:25:23,840
to do this but I don't think it's the

559
00:25:28,240 --> 00:25:26,180
way to make the first discovery and the

560
00:25:30,040 --> 00:25:28,250
reason is it has a lot of assumptions

561
00:25:32,530 --> 00:25:30,050
right it's not enough that there's life

562
00:25:35,050 --> 00:25:32,540
out there the life has to be interested

563
00:25:38,710 --> 00:25:35,060

in technology it has to be interested in

564
00:25:41,410 --> 00:25:38,720
radio telescopes or lasers and it has to

565
00:25:45,310 --> 00:25:41,420
want to communicate okay maybe that's

566
00:25:47,140 --> 00:25:45,320
just unfortunately a human desire so the

567
00:25:48,280 --> 00:25:47,150
more I really think about SETI I think

568
00:25:50,740 --> 00:25:48,290
well we're really kind of looking for

569
00:25:53,050 --> 00:25:50,750
ourselves now I'd hate to I'd hate to

570
00:25:56,110 --> 00:25:53,060
miss it and gosh if they find something

571
00:25:58,810 --> 00:25:56,120
I'll be the first you know celebrate it

572
00:26:00,310 --> 00:25:58,820
but it's those additional assumptions

573
00:26:02,230 --> 00:26:00,320
that make me a little bit nervous and so

574
00:26:03,850 --> 00:26:02,240
what we're trying to do as astronomers

575
00:26:06,700 --> 00:26:03,860
is we're trying to come up with a much

576
00:26:08,920 --> 00:26:06,710
broader net something a very robust idea

577
00:26:10,570 --> 00:26:08,930
that's going to go and find life even if

578
00:26:13,870 --> 00:26:10,580
the life is is not interested in

579
00:26:18,640 --> 00:26:13,880
actually being found okay all right so

580
00:26:22,150 --> 00:26:18,650
what's that idea well to put it in

581
00:26:24,460 --> 00:26:22,160
perspective the difficulty is of course

582
00:26:26,440 --> 00:26:24,470
we first have to find the likely places

583
00:26:29,500 --> 00:26:26,450
for life and we think those are planets

584
00:26:31,870 --> 00:26:29,510
all right so so just to remind you how

585
00:26:34,000 --> 00:26:31,880
hard it is to find planets it's only

586
00:26:35,370 --> 00:26:34,010
about 20 years ago that we found the

587
00:26:38,740 --> 00:26:35,380
first planet orbiting another star

588
00:26:40,030 --> 00:26:38,750

sun-like star and to put that in

589
00:26:42,670 --> 00:26:40,040
perspective let me show you the earth

590
00:26:45,520 --> 00:26:42,680
okay everything you know and love all

591
00:26:47,650 --> 00:26:45,530
the history of humans and all of our

592
00:26:50,080 --> 00:26:47,660
wonderful art and theater and and

593
00:26:52,840 --> 00:26:50,090
thought throughout generations it's all

594
00:26:55,000 --> 00:26:52,850
that blue marble and of course if you

595
00:26:57,010 --> 00:26:55,010
put it in perspective next to even

596
00:26:58,690 --> 00:26:57,020
another planet in the solar system it

597
00:27:01,210 --> 00:26:58,700
looks kind of small right there's

598
00:27:02,499 --> 00:27:01,220
Jupiter and of course if I keep the

599
00:27:05,649 --> 00:27:02,509
scale everything here is drawn

600
00:27:09,879 --> 00:27:05,659
the scale and I now put the Sun up on

601
00:27:11,379 --> 00:27:09,889
here okay then then you can see that the

602
00:27:13,869 --> 00:27:11,389
earth really doesn't amount to very much

603
00:27:17,680 --> 00:27:13,879
so very very precious for us but really

604
00:27:21,069 --> 00:27:17,690
not a big player in the solar system so

605
00:27:23,109 --> 00:27:21,079
that's why progress was so slow progress

606
00:27:24,819 --> 00:27:23,119
was slow because planets are small and

607
00:27:26,379 --> 00:27:24,829
they don't put out much light so

608
00:27:28,379 --> 00:27:26,389
compared to the stars they orbit they're

609
00:27:31,259 --> 00:27:28,389
simply overwhelmed and we don't see them

610
00:27:33,609 --> 00:27:31,269
so how are we gonna find those planets

611
00:27:34,060 --> 00:27:33,619
well I actually I showed you the answer

612
00:27:37,419 --> 00:27:34,070
right away

613
00:27:40,930 --> 00:27:37,429

did you see it they just you know so of

614
00:27:42,159 --> 00:27:40,940
course at the end of the title is that's

615
00:27:45,369 --> 00:27:42,169
not a that's I hope you weren't that's

616
00:27:47,049 --> 00:27:45,379
not a period that's an actual image

617
00:27:48,909 --> 00:27:47,059
that's a real image this is not

618
00:27:53,739 --> 00:27:48,919
something I did in Photoshop that's a

619
00:27:56,619 --> 00:27:53,749
real image taken in 2012 when of course

620
00:27:59,859 --> 00:27:56,629
Venus went in front of the Sun and did

621
00:28:02,589 --> 00:27:59,869
anybody here see that yes

622
00:28:04,239 --> 00:28:02,599
did anybody decide that you needed a two

623
00:28:08,469 --> 00:28:04,249
week family vacation in Hawaii to see

624
00:28:11,859 --> 00:28:08,479
the whole thing yes okay good

625
00:28:15,069 --> 00:28:11,869
so so that's that's Venus going in front

626
00:28:16,569 --> 00:28:15,079
of the Sun and that's how we're gonna

627
00:28:18,699 --> 00:28:16,579
find these planets that idea of a

628
00:28:20,589 --> 00:28:18,709
transit so they as the planets are gonna

629
00:28:22,119 --> 00:28:20,599
go in front of their stars they're gonna

630
00:28:23,680 --> 00:28:22,129
make their presence known because

631
00:28:25,899 --> 00:28:23,690
they're gonna block some of the light

632
00:28:27,879 --> 00:28:25,909
from the star so all of a sudden the

633
00:28:29,469 --> 00:28:27,889
star goes from being an adversary that's

634
00:28:31,659 --> 00:28:29,479
really bright thing blocking our view of

635
00:28:33,639 --> 00:28:31,669
a faint thing to an ally the star's

636
00:28:37,029 --> 00:28:33,649
light is now what's going to betray the

637
00:28:39,669 --> 00:28:37,039
presence of those planets now if we zoom

638
00:28:41,229 --> 00:28:39,679

in on the planet and we look very

639
00:28:43,629 --> 00:28:41,239
carefully we see something very very

640
00:28:44,949 --> 00:28:43,639
intriguing and Tom I don't know if it's

641
00:28:47,430 --> 00:28:44,959
possible just to bring the lights down a

642
00:28:52,449 --> 00:28:47,440
little bit for this one slide please

643
00:28:54,809 --> 00:28:52,459
okay so in 17 in the 1760s a Russian

644
00:28:57,430 --> 00:28:54,819
scientist by the name of Lomonosov was

645
00:28:59,529 --> 00:28:57,440
observing a transit of Venus these are

646
00:29:01,930 --> 00:28:59,539
very rare he was observing a transit of

647
00:29:02,769 --> 00:29:01,940
Venus and he noticed this is Venus now

648
00:29:05,379 --> 00:29:02,779
okay

649
00:29:06,999 --> 00:29:05,389
the Sun is enormous at the scale the Sun

650
00:29:08,619 --> 00:29:07,009
would go down several stories right so

651
00:29:11,680 --> 00:29:08,629
we're just zoomed in the planet and what

652
00:29:14,379 --> 00:29:11,690
he noticed was that the part of Venus

653
00:29:16,660 --> 00:29:14,389
that wasn't yet in front of the Sun was

654
00:29:20,790 --> 00:29:16,670
still illuminated you see

655
00:29:23,770 --> 00:29:20,800
there's that light arc and he said oh oh

656
00:29:26,770 --> 00:29:23,780
I bet you that's refraction that's the

657
00:29:29,700 --> 00:29:26,780
bending of light and so if light is

658
00:29:33,910 --> 00:29:29,710
bending there must be an atmosphere and

659
00:29:35,500 --> 00:29:33,920
so he deduced that Venus had an

660
00:29:37,030 --> 00:29:35,510
atmosphere that other planets had

661
00:29:38,440 --> 00:29:37,040
atmospheres it wasn't just a property of

662
00:29:43,840 --> 00:29:38,450
the earth and he was right it's an

663
00:29:45,940 --> 00:29:43,850

amazing induction that he made from a

664
00:29:48,220 --> 00:29:45,950
very large distance never actually going

665
00:29:49,900 --> 00:29:48,230
to the planet directly using this

666
00:29:52,270 --> 00:29:49,910
geometry he was able to infer that

667
00:29:58,180 --> 00:29:52,280
planets and atmospheres that is how

668
00:30:00,250 --> 00:29:58,190
we're gonna make progress okay so so so

669
00:30:02,950 --> 00:30:00,260
here are really kind of the goals that I

670
00:30:04,630 --> 00:30:02,960
want to tackle today really I want to I

671
00:30:07,270 --> 00:30:04,640
wanna do three things I want to describe

672
00:30:08,530 --> 00:30:07,280
the methods by which we find and

673
00:30:10,570 --> 00:30:08,540
characterize these planets and I think

674
00:30:11,410 --> 00:30:10,580
I've already kind of played my hand here

675
00:30:15,190 --> 00:30:11,420
which is it's going to be through

676
00:30:16,360 --> 00:30:15,200
transits I want to describe our current

677
00:30:18,550 --> 00:30:16,370
state of knowledge of earth-like

678
00:30:21,490 --> 00:30:18,560
exoplanets okay so what do we actually

679
00:30:23,860 --> 00:30:21,500
know about planets that are similar to

680
00:30:26,110 --> 00:30:23,870
the earth and then I really want to

681
00:30:28,360 --> 00:30:26,120
describe a kind of a first opportunity

682
00:30:30,130 --> 00:30:28,370
for going in detecting life okay so

683
00:30:31,540 --> 00:30:30,140
there's many many ideas astronomers I'm

684
00:30:33,340 --> 00:30:31,550
actually I'm here because there's

685
00:30:36,640 --> 00:30:33,350
there's a conference right now going on

686
00:30:37,720 --> 00:30:36,650
about about how we might use a future

687
00:30:39,520 --> 00:30:37,730
great observatory which I'm going to

688
00:30:41,170 --> 00:30:39,530

tell you about so astronomers are

689
00:30:43,750 --> 00:30:41,180
thinking hard about this issue and this

690
00:30:45,400 --> 00:30:43,760
is this is this is my thoughts on how

691
00:30:47,320 --> 00:30:45,410
we're actually our first opportunity

692
00:30:49,950 --> 00:30:47,330
might not work but it's the first time

693
00:30:52,210 --> 00:30:49,960
we have a genuine shot at this thing

694
00:30:53,620 --> 00:30:52,220
okay so just to remind you how we

695
00:30:55,570 --> 00:30:53,630
actually do go and find those planets

696
00:30:58,840 --> 00:30:55,580
there's of course the Doppler wobbles so

697
00:31:02,350 --> 00:30:58,850
the idea is the star is not fixed but

698
00:31:04,120 --> 00:31:02,360
the planet and the star dosey doe around

699
00:31:06,070 --> 00:31:04,130
each other sort of like sort of picture

700
00:31:08,260 --> 00:31:06,080
them is like to dance partners but but

701
00:31:10,570 --> 00:31:08,270
one dance partner weighs like you know

702
00:31:13,240 --> 00:31:10,580
300 thousand times more than another

703
00:31:14,560 --> 00:31:13,250
dance partner okay but if you looked at

704
00:31:15,700 --> 00:31:14,570
the big dance partner you would still

705
00:31:17,410 --> 00:31:15,710
see that they were kind of you know

706
00:31:19,870 --> 00:31:17,420
wobbling around and you didn't further

707
00:31:20,950 --> 00:31:19,880
there was another another body there so

708
00:31:22,120 --> 00:31:20,960
that's the Doppler method that's

709
00:31:24,370 --> 00:31:22,130
important because that gives us the

710
00:31:26,020 --> 00:31:24,380
planet's mass then the transit method

711
00:31:27,250 --> 00:31:26,030
I've already described that that that's

712
00:31:29,440 --> 00:31:27,260
the idea where the planet goes in front

713
00:31:30,430 --> 00:31:29,450

of its star and the fraction of light

714
00:31:32,470 --> 00:31:30,440
that it blocks

715
00:31:33,999 --> 00:31:32,480
if it blocks a lot of light it must be a

716
00:31:36,220 --> 00:31:34,009
big planet if it doesn't block very much

717
00:31:37,840 --> 00:31:36,230
light it must be a small planet and so

718
00:31:39,789 --> 00:31:37,850
if you can put these ideas together if

719
00:31:42,070 --> 00:31:39,799
you have a planet and you can measure

720
00:31:45,009 --> 00:31:42,080
its mass and you can measure its size

721
00:31:46,899 --> 00:31:45,019
then you can you can calculate a density

722
00:31:48,909 --> 00:31:46,909
and so without ever having been to the

723
00:31:51,970 --> 00:31:48,919
planet we can figure out is it a rocky

724
00:31:53,440 --> 00:31:51,980
planet or is it a gas giant planet we

725
00:31:54,700 --> 00:31:53,450
don't think gas giants planets are going

726
00:31:56,799 --> 00:31:54,710
to be good places for life we think we

727
00:32:00,779 --> 00:31:56,809
have to find rocky planets with a thin

728
00:32:04,060 --> 00:32:00,789
ocean so we're looking for rocky planets

729
00:32:06,519 --> 00:32:04,070
the other exciting thing about transits

730
00:32:10,419 --> 00:32:06,529
is that they allow us to go after the

731
00:32:12,580 --> 00:32:10,429
atmosphere ok so as the planet passes in

732
00:32:14,799 --> 00:32:12,590
front of the star some of the light from

733
00:32:18,999 --> 00:32:14,809
the star is going to pass through this

734
00:32:21,759 --> 00:32:19,009
little onion skin and imprinted on that

735
00:32:23,470 --> 00:32:21,769
star light which then travels through

736
00:32:25,659 --> 00:32:23,480
space and we capture with our telescopes

737
00:32:27,639 --> 00:32:25,669
imprinted on That star light is the

738
00:32:29,680 --> 00:32:27,649

chemical fingerprint of whatever atoms

739
00:32:33,970 --> 00:32:29,690
or molecules are present in the

740
00:32:35,139 --> 00:32:33,980
atmosphere ok so so we're never gonna

741
00:32:37,029 --> 00:32:35,149
see these planets we're not going to

742
00:32:39,279 --> 00:32:37,039
take a picture of them there's not gonna

743
00:32:41,200 --> 00:32:39,289
be any photographs but we can figure out

744
00:32:43,029 --> 00:32:41,210
their size we can figure out their mass

745
00:32:44,980 --> 00:32:43,039
we can figure out what their composition

746
00:32:46,960 --> 00:32:44,990
is by their density we can even study

747
00:32:48,850 --> 00:32:46,970
what the Ramah spheres are made of all

748
00:32:51,730 --> 00:32:48,860
by kind of clever thinking about how to

749
00:32:54,220 --> 00:32:51,740
make the star and a lie and this field

750
00:32:56,499 --> 00:32:54,230
has really taken off okay so in 2001

751
00:33:00,119 --> 00:32:56,509
there was one such planet

752
00:33:05,759 --> 00:33:00,129
figured out how to study its atmosphere

753
00:33:08,860 --> 00:33:05,769
in 2017 there are more than 5000 such

754
00:33:11,350 --> 00:33:08,870
worlds and we've studied the atmospheres

755
00:33:17,950 --> 00:33:11,360
for a little over probably a hundred of

756
00:33:20,019 --> 00:33:17,960
them I thought about many ways to try to

757
00:33:22,119 --> 00:33:20,029
express the following idea and here I

758
00:33:24,879 --> 00:33:22,129
really have to give credit to Zack Berta

759
00:33:26,499 --> 00:33:24,889
Thompson who's a professor at the

760
00:33:29,259 --> 00:33:26,509
University of Colorado who I see has

761
00:33:34,330 --> 00:33:29,269
joined us Zack was also my student at

762
00:33:37,060 --> 00:33:34,340
Harvard and he he captured it in a

763
00:33:38,740 --> 00:33:37,070

nutshell through an image the idea is

764
00:33:40,690 --> 00:33:38,750
that there's something really special

765
00:33:44,019 --> 00:33:40,700
about the earth right if you were an

766
00:33:44,259 --> 00:33:44,029
alien looking at all the planets of the

767
00:33:46,779 --> 00:33:44,269
soul

768
00:33:48,099 --> 00:33:46,789
system you would see that there's

769
00:33:50,349 --> 00:33:48,109
something really different about the

770
00:33:52,810 --> 00:33:50,359
earth the earth has been transformed by

771
00:33:55,329 --> 00:33:52,820
biological activity the continents are

772
00:33:58,089 --> 00:33:55,339
green right they should be brown if it's

773
00:34:00,489 --> 00:33:58,099
just rock okay like Mars but they're

774
00:34:02,799 --> 00:34:00,499
green and sometimes they change color

775
00:34:04,659 --> 00:34:02,809
because the vegetation grows and and

776
00:34:07,389 --> 00:34:04,669
disappears in the fall and comes back in

777
00:34:10,029 --> 00:34:07,399
the spring and importantly the air on

778
00:34:12,339 --> 00:34:10,039
that planet is full of oxygen now you

779
00:34:13,750 --> 00:34:12,349
would know that oxygen likes to react

780
00:34:16,210 --> 00:34:13,760
with things there shouldn't be a lot of

781
00:34:18,669 --> 00:34:16,220
oxygen but yet here's this planet with

782
00:34:20,950 --> 00:34:18,679
twenty twenty-one percent oxygen in its

783
00:34:23,980 --> 00:34:20,960
atmosphere driven by biological activity

784
00:34:26,349 --> 00:34:23,990
so that's the idea it's not radio

785
00:34:29,379 --> 00:34:26,359
signals it's not spaceships it's that

786
00:34:32,829 --> 00:34:29,389
the inevitable chemistry of life the the

787
00:34:34,690 --> 00:34:32,839
waste products of life really change the

788
00:34:36,399 --> 00:34:34,700

appearance of a planet life has

789
00:34:39,099 --> 00:34:36,409
radically transformed the way the earth

790
00:34:41,409 --> 00:34:39,109
looks and the way it smells and the

791
00:34:42,879 --> 00:34:41,419
things in its atmosphere and those are

792
00:34:45,010 --> 00:34:42,889
the things that we look for remotely

793
00:34:46,299 --> 00:34:45,020
with our powerful telescopes whether or

794
00:34:51,159 --> 00:34:46,309
not life has any interest in

795
00:34:53,349 --> 00:34:51,169
communicating okay so now connect that

796
00:34:55,599 --> 00:34:53,359
idea to the possible what you know

797
00:34:57,690 --> 00:34:55,609
there's there's the ideas of what's out

798
00:35:01,450 --> 00:34:57,700
there and then there's what can I do

799
00:35:05,440 --> 00:35:01,460
this is the opportunity the James Webb

800
00:35:08,680 --> 00:35:05,450
Space Telescope okay so here we are you

801
00:35:10,599 --> 00:35:08,690
know at that at the at the at the place

802
00:35:12,460 --> 00:35:10,609
where I'm here for this to and after

803
00:35:15,700 --> 00:35:12,470
meeting talking about how to use James

804
00:35:19,120 --> 00:35:15,710
Webb to study planets and here we are

805
00:35:22,690 --> 00:35:19,130
only about a year away from launch James

806
00:35:25,660 --> 00:35:22,700
Webb is the successor both in terms of

807
00:35:27,190 --> 00:35:25,670
hardware and in terms of ideas from the

808
00:35:29,440 --> 00:35:27,200
Hubble Space Telescope and the Spitzer

809
00:35:31,660 --> 00:35:29,450
Space Telescope but of course it's an

810
00:35:35,620 --> 00:35:31,670
enormous ly much much larger and much

811
00:35:37,660 --> 00:35:35,630
more powerful Observatory as as many of

812
00:35:40,839 --> 00:35:37,670
you probably know it was as it's a it's

813
00:35:43,150 --> 00:35:40,849

a local kid okay it was assembled at the

814
00:35:44,470 --> 00:35:43,160
Goddard Space Flight Center and some of

815
00:35:46,390 --> 00:35:44,480
you maybe even got a chance to actually

816
00:35:47,170 --> 00:35:46,400
see it being assembled and it is

817
00:35:49,299 --> 00:35:47,180
enormous

818
00:35:51,970 --> 00:35:49,309
okay it's six and a half meters in size

819
00:35:54,880 --> 00:35:51,980
okay these are these are normal size to

820
00:35:57,609 --> 00:35:54,890
humans you're working on working on the

821
00:35:58,120 --> 00:35:57,619
telescope okay and these are the

822
00:36:00,430 --> 00:35:58,130
individual

823
00:36:02,230 --> 00:36:00,440
all mirrors some of which have covers on

824
00:36:05,230 --> 00:36:02,240
them and some of them which don't and

825
00:36:08,079 --> 00:36:05,240
they have that kind of gold look if you

826
00:36:10,599 --> 00:36:08,089
didn't get a chance to see James Webb

827
00:36:13,420 --> 00:36:10,609
I'm a Ford I'm sad to say it's it's it's

828
00:36:14,859 --> 00:36:13,430
gone now it's moved to Texas and the

829
00:36:15,999 --> 00:36:14,869
reason is that there's a whole bunch of

830
00:36:18,099 --> 00:36:16,009
testing that you have to go through

831
00:36:24,700 --> 00:36:18,109
before you get to go to space okay and

832
00:36:29,380 --> 00:36:24,710
so now it's gone to Texas to I use this

833
00:36:31,180 --> 00:36:29,390
enormous cryogenic testing chamber and

834
00:36:33,700 --> 00:36:31,190
they're going to put the James Webb

835
00:36:36,670 --> 00:36:33,710
Space Telescope in there cool it down

836
00:36:38,499 --> 00:36:36,680
over many months I believe and do

837
00:36:41,769 --> 00:36:38,509
various tests and make sure that

838
00:36:43,539 --> 00:36:41,779

everything performs exactly as it should

839
00:36:46,569 --> 00:36:43,549
so that it was out in the coldness of

840
00:36:48,670 --> 00:36:46,579
space there are no surprises James Webb

841
00:36:50,230 --> 00:36:48,680
will be so far from the earth there was

842
00:36:51,160 --> 00:36:50,240
no chance to go and service it the way

843
00:36:53,440 --> 00:36:51,170
we did with the Hubble Space Telescope

844
00:36:55,450 --> 00:36:53,450
it is farther from the earth it will be

845
00:36:57,039 --> 00:36:55,460
farther from the earth then any human

846
00:37:00,430 --> 00:36:57,049
has ever been right the farthest people

847
00:37:02,319 --> 00:37:00,440
have been is the moon you might worry by

848
00:37:08,980 --> 00:37:02,329
the way is it gonna fit and I want to

849
00:37:11,559 --> 00:37:08,990
point out it does barely fit okay but of

850
00:37:12,970 --> 00:37:11,569
course NASA was very good with precision

851
00:37:13,990 --> 00:37:12,980
so they knew they knew going down there

852
00:37:16,329 --> 00:37:14,000
was going to be a tight fit but a

853
00:37:18,039 --> 00:37:16,339
possible one okay so the idea is James

854
00:37:19,839 --> 00:37:18,049
Webb very special opportunity much more

855
00:37:21,730 --> 00:37:19,849
powerful telescope very good infrared

856
00:37:23,620 --> 00:37:21,740
telescope much bigger than anything

857
00:37:24,999 --> 00:37:23,630
that's been put out in space maybe it

858
00:37:27,819 --> 00:37:25,009
can do something for exoplanet

859
00:37:29,620 --> 00:37:27,829
atmospheres I want to introduce another

860
00:37:31,390 --> 00:37:29,630
telescope that you might not be so

861
00:37:33,549 --> 00:37:31,400
familiar with which is the giant

862
00:37:38,019 --> 00:37:33,559
Magellan telescope giant Magellan

863
00:37:40,630 --> 00:37:38,029

telescope is enormous okay it at the

864
00:37:42,549 --> 00:37:40,640
time that it is constructed we think

865
00:37:44,470 --> 00:37:42,559
it's going to be finished around 2023

866
00:37:47,529 --> 00:37:44,480
it's going to be the largest optical

867
00:37:49,599 --> 00:37:47,539
telescope ever built but it's on the

868
00:37:51,519 --> 00:37:49,609
ground okay James Webb is six and a half

869
00:37:52,960 --> 00:37:51,529
meters that's the biggest thing we know

870
00:37:54,370 --> 00:37:52,970
how to get up into space right now it's

871
00:37:56,410 --> 00:37:54,380
obviously very expensive very heavy to

872
00:37:58,420 --> 00:37:56,420
get things up into space this is a much

873
00:38:00,759 --> 00:37:58,430
much bigger telescope but it's going to

874
00:38:02,589 --> 00:38:00,769
be located in Chile okay so it has to

875
00:38:07,089 --> 00:38:02,599
look up through the Earth's atmosphere

876
00:38:08,440 --> 00:38:07,099
to make these measurements just just to

877
00:38:09,970 --> 00:38:08,450
just to make sure that you all

878
00:38:11,320 --> 00:38:09,980
understand how truly enormous this

879
00:38:14,590 --> 00:38:11,330
telescope is it

880
00:38:15,300 --> 00:38:14,600
composed of one two three four five six

881
00:38:19,090 --> 00:38:15,310
seven

882
00:38:25,630 --> 00:38:19,100
giant mirrors each one of these mirrors

883
00:38:28,600 --> 00:38:25,640
is about 25 feet 25 feet in diameter so

884
00:38:32,290 --> 00:38:28,610
the James Webb Space Telescope it's its

885
00:38:35,920 --> 00:38:32,300
entire mirror is smaller than one of

886
00:38:37,330 --> 00:38:35,930
these mirrors okay so there's a person

887
00:38:40,120 --> 00:38:37,340
remember we had people dangling down

888
00:38:42,280 --> 00:38:40,130

before okay look how big a person is now

889
00:38:44,860 --> 00:38:42,290
compared to this entire thing in fact if

890
00:38:46,120 --> 00:38:44,870
you take this middle mirror which has

891
00:38:47,200 --> 00:38:46,130
got a hole in it because when it's all

892
00:38:49,150 --> 00:38:47,210
assembled that's where the light goes

893
00:38:50,800 --> 00:38:49,160
through to be studied if you take that

894
00:38:53,410 --> 00:38:50,810
middle mirror there it is it's not

895
00:38:56,290 --> 00:38:53,420
polished yet but all these people are

896
00:38:57,790 --> 00:38:56,300
sitting on the mirror blank okay before

897
00:39:00,940 --> 00:38:57,800
we go through the actual polishing which

898
00:39:03,670 --> 00:39:00,950
is all being done in Arizona so we've

899
00:39:05,800 --> 00:39:03,680
got the James Webb Space Telescope which

900
00:39:07,900 --> 00:39:05,810
is undergoing testing ready to launch in

901
00:39:10,720 --> 00:39:07,910
2018 going to be up in space giant

902
00:39:12,760 --> 00:39:10,730
Magellan telescope we you know are still

903
00:39:14,410 --> 00:39:12,770
figuring out how to pay for it but we

904
00:39:15,700 --> 00:39:14,420
started construction that's a real

905
00:39:18,790 --> 00:39:15,710
challenge it is not a federally funded

906
00:39:21,820 --> 00:39:18,800
project okay it is a very interesting

907
00:39:23,230 --> 00:39:21,830
collaboration of us partners and the

908
00:39:25,300 --> 00:39:23,240
National Science Foundation's of many

909
00:39:26,560 --> 00:39:25,310
other countries but it's not fully

910
00:39:27,070 --> 00:39:26,570
funded that is the main challenge with

911
00:39:29,500 --> 00:39:27,080
the GMT

912
00:39:33,100 --> 00:39:29,510
but confident that we'll get this thing

913
00:39:35,140 --> 00:39:33,110

together in 2023 so so if I put these

914
00:39:36,940 --> 00:39:35,150
together right we've got these two

915
00:39:38,680 --> 00:39:36,950
really unprecedented observatories the

916
00:39:40,750 --> 00:39:38,690
giant Magellan telescope and the James

917
00:39:44,320 --> 00:39:40,760
Webb Space Telescope they will have the

918
00:39:47,530 --> 00:39:44,330
power to access the atmospheres perhaps

919
00:39:49,210 --> 00:39:47,540
of earth-like planets so what is the

920
00:39:50,520 --> 00:39:49,220
challenge given that these telescopes

921
00:39:53,470 --> 00:39:50,530
are getting built

922
00:39:57,010 --> 00:39:53,480
okay the challenge is we don't yet know

923
00:39:58,780 --> 00:39:57,020
where to point them so so it may sound

924
00:40:01,570 --> 00:39:58,790
shocking but we actually haven't found

925
00:40:05,710 --> 00:40:01,580
the planets orbiting the very closest

926
00:40:07,180 --> 00:40:05,720
stars to us right so so for four we

927
00:40:09,880 --> 00:40:07,190
actually have found a lot of planets

928
00:40:11,770 --> 00:40:09,890
that are at somewhat larger distances

929
00:40:13,390 --> 00:40:11,780
out in the galaxy but we haven't

930
00:40:14,560 --> 00:40:13,400
actually figured out which of the very

931
00:40:16,960 --> 00:40:14,570
closest stars which were the most

932
00:40:19,540 --> 00:40:16,970
accessible to telescopes actually have

933
00:40:23,020 --> 00:40:19,550
that the planets that we seek so how do

934
00:40:24,970 --> 00:40:23,030
we how do we remedy that okay

935
00:40:29,050 --> 00:40:24,980
so again to remind you the challenge

936
00:40:31,420 --> 00:40:29,060
here is a picture of the Sun okay and

937
00:40:33,880 --> 00:40:31,430
can anybody see the earth-like planet in

938
00:40:35,380 --> 00:40:33,890

front of the Sun dropped one in there

939
00:40:37,030 --> 00:40:35,390
just a mimic it okay it's not these are

940
00:40:40,540 --> 00:40:37,040
some these are star spots they're bigger

941
00:40:45,130 --> 00:40:40,550
than the earth often but it's right over

942
00:40:47,859 --> 00:40:45,140
here okay so that's roughly how big the

943
00:40:50,830 --> 00:40:47,869
earth would look going in front of a

944
00:40:53,080 --> 00:40:50,840
sun-like star viewed from the distance

945
00:40:54,820 --> 00:40:53,090
of another star so that's really really

946
00:40:56,980 --> 00:40:54,830
hard to discover that's really really

947
00:41:01,570 --> 00:40:56,990
hard to find such a small thing going in

948
00:41:02,950 --> 00:41:01,580
front of such a big thing so NASA knew

949
00:41:05,140 --> 00:41:02,960
how to tackle that that was the Kepler

950
00:41:06,880 --> 00:41:05,150
mission right I hope you've all heard of

951
00:41:09,400 --> 00:41:06,890
the Kepler mission the Kepler mission

952
00:41:11,320 --> 00:41:09,410
launched in 2009 operated for four years

953
00:41:13,420 --> 00:41:11,330
it's now still operating but in a

954
00:41:15,550 --> 00:41:13,430
different way because of a hardware

955
00:41:17,260 --> 00:41:15,560
failure that that prevented it from

956
00:41:18,730 --> 00:41:17,270
gathering data the way it had been

957
00:41:20,140 --> 00:41:18,740
gathering data for four years and that's

958
00:41:22,420 --> 00:41:20,150
called the k2 mission which I won't

959
00:41:24,970 --> 00:41:22,430
focus on here but during these four

960
00:41:28,900 --> 00:41:24,980
years it studied a hundred and fifty

961
00:41:31,810 --> 00:41:28,910
thousand stars and the purpose was to

962
00:41:34,870 --> 00:41:31,820
figure out how common planets were

963
00:41:37,030 --> 00:41:34,880

around stars in general so with 150,000

964
00:41:39,220 --> 00:41:37,040
stars it can actually do statistics okay

965
00:41:41,140 --> 00:41:39,230
now it found all sorts of different

966
00:41:44,230 --> 00:41:41,150
kinds of planets it found small planets

967
00:41:45,790 --> 00:41:44,240
big planets wild architectures there

968
00:41:47,830 --> 00:41:45,800
were there are planetary systems where

969
00:41:49,330 --> 00:41:47,840
you have a gas giant and a rocky planet

970
00:41:51,040 --> 00:41:49,340
and then a gas giant and then a rocky

971
00:41:52,980 --> 00:41:51,050
planet and then a gas giant completely

972
00:41:57,490 --> 00:41:52,990
unlike the solar system where things are

973
00:41:59,170 --> 00:41:57,500
nicely divided but there's one there's

974
00:42:03,730 --> 00:41:59,180
one result in particular that I want to

975
00:42:06,040 --> 00:42:03,740
focus on of course what what I'm

976
00:42:06,849 --> 00:42:06,050
interested in if we want to answer this

977
00:42:11,800 --> 00:42:06,859
question of whether or not we're alone

978
00:42:13,960 --> 00:42:11,810
is how common our earth-like planets so

979
00:42:16,480 --> 00:42:13,970
to be earth-like you have to be rocky

980
00:42:18,490 --> 00:42:16,490
you have to be sir science and you also

981
00:42:21,820 --> 00:42:18,500
have to be the right temperature right

982
00:42:26,010 --> 00:42:21,830
so if I take rocky planet and I put it

983
00:42:29,980 --> 00:42:26,020
too close to a star then the water will

984
00:42:32,410 --> 00:42:29,990
boil and it'll be it'll be gaseous if I

985
00:42:34,900 --> 00:42:32,420
move it too far from the star it's good

986
00:42:37,450 --> 00:42:34,910
good for hockey but bad for life which

987
00:42:38,440 --> 00:42:37,460
is it's all frozen so you have to be in

988
00:42:42,220 --> 00:42:38,450

kind of this

989
00:42:43,810 --> 00:42:42,230
this Goldilocks zone so of all the

990
00:42:47,650 --> 00:42:43,820
hundred and fifty thousand stars that

991
00:42:48,790 --> 00:42:47,660
Kepler studied you know most the time we

992
00:42:50,380 --> 00:42:48,800
didn't see planets because they just

993
00:42:52,329 --> 00:42:50,390
didn't happen to be lying a longer line

994
00:42:55,000 --> 00:42:52,339
of sight but there was still enough that

995
00:42:58,930 --> 00:42:55,010
that we could do statistics and I really

996
00:43:01,390 --> 00:42:58,940
am delighted to say that we now know how

997
00:43:04,030 --> 00:43:01,400
common earth-like planets are in the

998
00:43:06,760 --> 00:43:04,040
galaxy we actually know how common is it

999
00:43:10,089 --> 00:43:06,770
that the typical star in the galaxy has

1000
00:43:14,349 --> 00:43:10,099
a planet that's the same size and the

1001
00:43:16,210 --> 00:43:14,359
same temperature as the earth and what

1002
00:43:18,310 --> 00:43:16,220
I'm particularly proud of is that that

1003
00:43:19,599 --> 00:43:18,320
result so there was an enormous amount

1004
00:43:20,650 --> 00:43:19,609
of work that went into the Kepler

1005
00:43:22,690 --> 00:43:20,660
mission okay it was hundreds of

1006
00:43:24,010 --> 00:43:22,700
scientists and engineers they produced

1007
00:43:25,990 --> 00:43:24,020
the state of the data was used for many

1008
00:43:27,550 --> 00:43:26,000
different studies but the particular

1009
00:43:29,620 --> 00:43:27,560
question of the statistics of earth-like

1010
00:43:31,599 --> 00:43:29,630
planets that was figured out by Courtney

1011
00:43:33,970 --> 00:43:31,609
adressing Courtney was a graduate

1012
00:43:35,500 --> 00:43:33,980
student working with me at Harvard and

1013
00:43:36,849 --> 00:43:35,510

she was the first person ever know how

1014
00:43:39,250 --> 00:43:36,859
common they were so it could have been

1015
00:43:40,690 --> 00:43:39,260
one in a million it could have been the

1016
00:43:41,770 --> 00:43:40,700
Star Trek universe where every star has

1017
00:43:44,770 --> 00:43:41,780
an earth-like planet

1018
00:43:53,099 --> 00:43:44,780
Courtley found out the answer is one in

1019
00:43:56,380 --> 00:43:53,109
four okay so so one in four stars has a

1020
00:43:58,390 --> 00:43:56,390
has a has an earth-like planet which is

1021
00:44:00,370 --> 00:43:58,400
fantastic news if you want to go and

1022
00:44:01,690 --> 00:44:00,380
follow them up because if it had been

1023
00:44:03,849 --> 00:44:01,700
one in a million let's say one in a

1024
00:44:05,380 --> 00:44:03,859
million stars had had such a planet then

1025
00:44:07,900 --> 00:44:05,390
that would mean the closest one to us

1026
00:44:10,210 --> 00:44:07,910
would still be so far away that it would

1027
00:44:11,950 --> 00:44:10,220
be beyond our ability to study it with

1028
00:44:13,359 --> 00:44:11,960
things like the James Webb Space

1029
00:44:15,940 --> 00:44:13,369
Telescope and the giant Magellan

1030
00:44:17,770 --> 00:44:15,950
telescope but this now gives us hope

1031
00:44:25,030 --> 00:44:17,780
this means that even the closest stars

1032
00:44:26,980 --> 00:44:25,040
might perhaps have such a planet so how

1033
00:44:28,599 --> 00:44:26,990
do we actually go and find the planet we

1034
00:44:30,819 --> 00:44:28,609
want to study well we can't use the ones

1035
00:44:32,770 --> 00:44:30,829
that Kepler found Kepler was looking at

1036
00:44:35,559 --> 00:44:32,780
150,000 stars but the stars were all

1037
00:44:37,329 --> 00:44:35,569
quite far away if we want to study the

1038
00:44:39,790 --> 00:44:37,339

atmosphere of a planet we need the star

1039
00:44:42,250 --> 00:44:39,800
to have have two features first the star

1040
00:44:43,720 --> 00:44:42,260
has to be very very close buying okay if

1041
00:44:44,800 --> 00:44:43,730
the star is close to us obviously it's a

1042
00:44:47,620 --> 00:44:44,810
lot brighter we get a lot more

1043
00:44:50,349 --> 00:44:47,630
information from it more quickly and we

1044
00:44:52,270 --> 00:44:50,359
also care about how big the star is

1045
00:44:56,240 --> 00:44:52,280
compared to the plan

1046
00:44:57,920 --> 00:44:56,250
if I can shrink the star then the

1047
00:44:59,570 --> 00:44:57,930
planet's atmosphere blocks

1048
00:45:01,490 --> 00:44:59,580
proportionately more light

1049
00:45:03,020 --> 00:45:01,500
okay the atmosphere doesn't change I'm

1050
00:45:05,270 --> 00:45:03,030
not changing the size of the earth but

1051
00:45:06,770 --> 00:45:05,280
if I can shrink the star then a relative

1052
00:45:08,840 --> 00:45:06,780
to the star the atmosphere starts to

1053
00:45:10,640 --> 00:45:08,850
look very big and it makes my

1054
00:45:12,380 --> 00:45:10,650
measurement easier so it's a very

1055
00:45:15,350 --> 00:45:12,390
opportunistic thing okay

1056
00:45:17,120 --> 00:45:15,360
I I simply want to find closeby stars

1057
00:45:18,710 --> 00:45:17,130
and I want them to be as small as I can

1058
00:45:19,820 --> 00:45:18,720
make them and that gives me the best

1059
00:45:26,930 --> 00:45:19,830
chance for going and setting the

1060
00:45:30,230 --> 00:45:26,940
atmospheres of those planets as it turns

1061
00:45:32,840 --> 00:45:30,240
out I was I was told a big lie in high

1062
00:45:35,060 --> 00:45:32,850
school by my science teacher did any of

1063
00:45:37,340 --> 00:45:35,070

you get the same I was told the Sun was

1064
00:45:38,770 --> 00:45:37,350
an average star heard this all the time

1065
00:45:41,570 --> 00:45:38,780
in high school Sun is an average star

1066
00:45:45,200 --> 00:45:41,580
big lie the Sun is not an average star

1067
00:45:46,850 --> 00:45:45,210
the Sun is much much bigger and more

1068
00:45:48,890 --> 00:45:46,860
massive and puts out a lot more light

1069
00:45:52,190 --> 00:45:48,900
than the typical star the typical star

1070
00:45:55,730 --> 00:45:52,200
is what we call a red dwarf star it's

1071
00:45:59,570 --> 00:45:55,740
about 1/4 of the size of the Sun it's

1072
00:46:01,460 --> 00:45:59,580
about 1/4 the mass of the Sun and it

1073
00:46:04,580 --> 00:46:01,470
puts out about one one thousandth the

1074
00:46:07,250 --> 00:46:04,590
amount of light ok so so if you know the

1075
00:46:09,170 --> 00:46:07,260
Sun is like a big thousand watt light

1076
00:46:12,410 --> 00:46:09,180
bulb this is this is a little Christmas

1077
00:46:14,630 --> 00:46:12,420
tree light ok but that's that's the

1078
00:46:16,820 --> 00:46:14,640
dominant mode of star formation in the

1079
00:46:20,900 --> 00:46:16,830
galaxy sun-like stars are actually quite

1080
00:46:22,490 --> 00:46:20,910
quite rare great news right great news

1081
00:46:24,170 --> 00:46:22,500
if you want to go and find earth-like

1082
00:46:28,700 --> 00:46:24,180
planets because I just told you I want

1083
00:46:31,150 --> 00:46:28,710
to make the star small that also has the

1084
00:46:34,670 --> 00:46:31,160
benefit of shrinking the habitable zone

1085
00:46:37,370 --> 00:46:34,680
so the idea is you know you want to find

1086
00:46:38,750 --> 00:46:37,380
the distance around the star at which

1087
00:46:41,060 --> 00:46:38,760
your planet is going to have the right

1088
00:46:44,540 --> 00:46:41,070

temperature if the star is very very

1089
00:46:46,940 --> 00:46:44,550
bright you have to move far away but if

1090
00:46:49,100 --> 00:46:46,950
the star puts out very little light then

1091
00:46:51,050 --> 00:46:49,110
then the planets want to kind of huddle

1092
00:46:53,750 --> 00:46:51,060
in close to just have the right

1093
00:46:55,970 --> 00:46:53,760
temperature once again the benefit of

1094
00:46:57,620 --> 00:46:55,980
that is if they're in close they go

1095
00:46:59,030 --> 00:46:57,630
around much more frequently so instead

1096
00:47:00,950 --> 00:46:59,040
of having to wait for a signal that I

1097
00:47:02,660 --> 00:47:00,960
see once a year right if an alien was

1098
00:47:04,710 --> 00:47:02,670
studying us they would only get to see

1099
00:47:06,450 --> 00:47:04,720
us go in front of the Sun once a year

1100
00:47:10,770 --> 00:47:06,460
now they might go in front of the Sun

1101
00:47:13,170 --> 00:47:10,780
maybe once every 15 or 20 days okay so

1102
00:47:14,790 --> 00:47:13,180
small stars are the most common but they

1103
00:47:16,050 --> 00:47:14,800
also are exactly what we're looking for

1104
00:47:17,400 --> 00:47:16,060
it makes it a lot easier to study the

1105
00:47:23,580 --> 00:47:17,410
atmosphere because the signal is bigger

1106
00:47:25,650 --> 00:47:23,590
and it's more frequent if I draw a

1107
00:47:27,810 --> 00:47:25,660
bubble if I were to go out in space and

1108
00:47:30,300 --> 00:47:27,820
draw a giant bubble just around the

1109
00:47:33,599 --> 00:47:30,310
nearby stars so let's go out to say

1110
00:47:35,910 --> 00:47:33,609
about 30 light-years okay and I count up

1111
00:47:38,370 --> 00:47:35,920
all the stars in that bubble then here's

1112
00:47:40,859 --> 00:47:38,380
what you get okay so there are no oh

1113
00:47:43,200 --> 00:47:40,869

stars no B stars these are the really

1114
00:47:44,970 --> 00:47:43,210
really massive stars there's a small

1115
00:47:46,890 --> 00:47:44,980
number of a and F stars and there's

1116
00:47:49,380 --> 00:47:46,900
about 20 sun-like stars what astronomers

1117
00:47:52,080 --> 00:47:49,390
called G stars so after 30 light years

1118
00:47:55,470 --> 00:47:52,090
we're talking about 20 g-type stars in

1119
00:47:58,800 --> 00:47:55,480
that same volume of space how many of

1120
00:48:04,349 --> 00:47:58,810
these red dwarf stars are there okay

1121
00:48:05,820 --> 00:48:04,359
there's 246 okay so in in in the same

1122
00:48:08,730 --> 00:48:05,830
amount of space where you have 20 of

1123
00:48:11,730 --> 00:48:08,740
these sun-like stars you've got 246 of

1124
00:48:14,730 --> 00:48:11,740
these M dwarfs so they owe number us 12

1125
00:48:17,070 --> 00:48:14,740
to 1 so if you're interested in life on

1126
00:48:18,690 --> 00:48:17,080
other planets red dwarf stars are great

1127
00:48:20,790 --> 00:48:18,700
because it's easier to find that life

1128
00:48:22,829 --> 00:48:20,800
but they're also great because they just

1129
00:48:25,320 --> 00:48:22,839
outnumber us twelve to one I mean if if

1130
00:48:26,550 --> 00:48:25,330
if planets form around those kinds of

1131
00:48:28,200 --> 00:48:26,560
stars the same way they form around

1132
00:48:30,300 --> 00:48:28,210
sun-like stars it's kind of inevitable

1133
00:48:31,500 --> 00:48:30,310
that the closest one to us is going to

1134
00:48:33,359 --> 00:48:31,510
be around an M dwarf just because

1135
00:48:37,920 --> 00:48:33,369
they're so common these little red dwarf

1136
00:48:40,740 --> 00:48:37,930
stars so with that idea in mind I set

1137
00:48:44,640 --> 00:48:40,750
out a number of years ago now about nine

1138
00:48:46,020 --> 00:48:44,650

years to build a special project called

1139
00:48:50,490 --> 00:48:46,030
the mirth project which was going to

1140
00:48:53,160 --> 00:48:50,500
focus on finding planets that are small

1141
00:48:56,099 --> 00:48:53,170
like the earth and going in front of the

1142
00:48:57,300 --> 00:48:56,109
very closest small red dwarf stars so

1143
00:48:59,670 --> 00:48:57,310
because we were trying to find

1144
00:49:02,300 --> 00:48:59,680
earth-like planets in front of m-type

1145
00:49:05,190 --> 00:49:02,310
stars we called it the mirth project and

1146
00:49:06,900 --> 00:49:05,200
here is what we came up with the idea

1147
00:49:09,120 --> 00:49:06,910
was we didn't need very big telescopes

1148
00:49:10,620 --> 00:49:09,130
because the Stars were very nearby but

1149
00:49:13,050 --> 00:49:10,630
we needed a lot of telescopes because

1150
00:49:14,609 --> 00:49:13,060
the stars were all over the sky so we

1151
00:49:16,770 --> 00:49:14,619
had a list of the very closest few

1152
00:49:18,020 --> 00:49:16,780
thousand stars but some one was over

1153
00:49:19,670 --> 00:49:18,030
here one was over here

1154
00:49:20,990 --> 00:49:19,680
was over here so we needed different

1155
00:49:22,610 --> 00:49:21,000
telescopes to look at them all at the

1156
00:49:27,500 --> 00:49:22,620
same time we couldn't get by with one

1157
00:49:29,150 --> 00:49:27,510
big telescope we wanted to see stars in

1158
00:49:32,240 --> 00:49:29,160
both the Northern Hemisphere and the

1159
00:49:34,370 --> 00:49:32,250
southern hemisphere and so in the North

1160
00:49:38,600 --> 00:49:34,380
we're located in Arizona and then much

1161
00:49:41,120 --> 00:49:38,610
more recently just about two years two

1162
00:49:42,800 --> 00:49:41,130
and a half years ago we began operating

1163
00:49:45,080 --> 00:49:42,810

in in Chile

1164
00:49:46,250 --> 00:49:45,090
okay and that gives us access to both

1165
00:49:49,640 --> 00:49:46,260
the Northern Hemisphere and the southern

1166
00:49:51,440 --> 00:49:49,650
hemisphere and every night these

1167
00:49:53,840 --> 00:49:51,450
telescopes go about their business they

1168
00:49:55,880 --> 00:49:53,850
are frantically surveying all the nearby

1169
00:49:57,020 --> 00:49:55,890
stars and I want to show you what that

1170
00:49:58,820 --> 00:49:57,030
looks like and again if we could just

1171
00:49:59,930 --> 00:49:58,830
Tom if we could just bring down the

1172
00:50:09,140 --> 00:49:59,940
light a little bit face for the next

1173
00:50:10,730 --> 00:50:09,150
image okay so here's a time-lapse of the

1174
00:50:12,470 --> 00:50:10,740
observatory in action so you can see all

1175
00:50:14,630 --> 00:50:12,480
these different telescopes as the stars

1176
00:50:17,630 --> 00:50:14,640
scroll overhead but this particular

1177
00:50:19,610 --> 00:50:17,640
telescope I'm plotting its data and it's

1178
00:50:20,780 --> 00:50:19,620
studying one star and nothing much is

1179
00:50:24,170 --> 00:50:20,790
happening until it gets to this

1180
00:50:26,660 --> 00:50:24,180
observation right here boom it slow

1181
00:50:29,150 --> 00:50:26,670
the telescope realizes that in real time

1182
00:50:32,030 --> 00:50:29,160
and it changes the way it was gathering

1183
00:50:33,980 --> 00:50:32,040
data it notices the Stars fainter than

1184
00:50:36,800 --> 00:50:33,990
it had been earlier in the evening and

1185
00:50:38,510 --> 00:50:36,810
so it follows that star until it notices

1186
00:50:41,440 --> 00:50:38,520
that it brightens up again and then it

1187
00:50:44,720 --> 00:50:41,450
goes back to its survey observations

1188
00:50:47,150 --> 00:50:44,730

this is great for family life I'm it's

1189
00:50:51,860 --> 00:50:47,160
fully robotic I'm home with the kids I'm

1190
00:50:54,680 --> 00:50:51,870
making dinner and and lo and behold of

1191
00:50:56,810 --> 00:50:54,690
course then we find out the next morning

1192
00:50:58,700 --> 00:50:56,820
that mirth is found a planet okay so

1193
00:51:00,770 --> 00:50:58,710
that's what that signal looks like it's

1194
00:51:02,480 --> 00:51:00,780
blocking only a few parts in a thousand

1195
00:51:04,490 --> 00:51:02,490
of the light from the star but that's

1196
00:51:09,200 --> 00:51:04,500
our first hint that there is this rocky

1197
00:51:12,170 --> 00:51:09,210
world okay and and this discovery was

1198
00:51:17,950 --> 00:51:12,180
led by Zak who I just mentioned earlier

1199
00:51:22,250 --> 00:51:17,960
in the talk okay so that was a discovery

1200
00:51:26,450 --> 00:51:22,260
of a nearby rocky world and then more

1201
00:51:27,860 --> 00:51:26,460
recently just recently we we found the

1202
00:51:31,430 --> 00:51:27,870
one that we're really looking for so

1203
00:51:35,900 --> 00:51:31,440
that's what I want to tell you about so

1204
00:51:39,170 --> 00:51:35,910
so in September of 2014 our Observatory

1205
00:51:40,339 --> 00:51:39,180
mirth found a dip a dip of one of the

1206
00:51:41,690 --> 00:51:40,349
stars that we've been surveying so is

1207
00:51:44,210 --> 00:51:41,700
this anonymous star it's got this

1208
00:51:45,710 --> 00:51:44,220
catalog name LHS 11:40 so even though

1209
00:51:47,809 --> 00:51:45,720
it's a very nearby star it's just got

1210
00:51:49,490 --> 00:51:47,819
this completely anonymous name but we

1211
00:51:52,490 --> 00:51:49,500
didn't we didn't really think very much

1212
00:51:54,349 --> 00:51:52,500
of it ok and then a student Jason

1213
00:51:57,799 --> 00:51:54,359

Dittman went back and reanalyzed the

1214
00:51:59,690 --> 00:51:57,809
data using a very clever software that

1215
00:52:01,160 --> 00:51:59,700
he wrote a machine learning software if

1216
00:52:02,630 --> 00:52:01,170
you're into that kind of thing and he

1217
00:52:04,279 --> 00:52:02,640
found that those data were were

1218
00:52:07,819 --> 00:52:04,289
persuasive he thought we should go and

1219
00:52:10,789 --> 00:52:07,829
and try to and try to do some follow up

1220
00:52:12,529 --> 00:52:10,799
so we began to do Doppler monitoring so

1221
00:52:14,329 --> 00:52:12,539
instead of waiting for another transit

1222
00:52:15,829 --> 00:52:14,339
to occur we thought well you know if the

1223
00:52:17,120 --> 00:52:15,839
planets actually out in the habitable

1224
00:52:18,829 --> 00:52:17,130
zone we're not going to see another

1225
00:52:21,349 --> 00:52:18,839
Eclipse we're just gonna see one those

1226
00:52:23,180 --> 00:52:21,359
are pretty rare so instead what Jason

1227
00:52:24,559 --> 00:52:23,190
had us doing was to actually start to

1228
00:52:27,500 --> 00:52:24,569
measure the wobble of the star and sure

1229
00:52:30,650 --> 00:52:27,510
enough the star wobbled okay and it took

1230
00:52:32,870 --> 00:52:30,660
about 25 days to complete its wobble and

1231
00:52:34,760 --> 00:52:32,880
then based on that wobble we were able

1232
00:52:37,430 --> 00:52:34,770
to predict when the other eclipses would

1233
00:52:39,319 --> 00:52:37,440
occur you can see that it took about two

1234
00:52:40,130 --> 00:52:39,329
years for us to sort that out and then

1235
00:52:43,010 --> 00:52:40,140
we measured them

1236
00:52:49,130 --> 00:52:43,020
September 1st September 25th October

1237
00:52:51,200 --> 00:52:49,140
20th based on the wobble of the star

1238
00:52:54,049 --> 00:52:51,210

we're able to figure out how heavy the

1239
00:52:58,690 --> 00:52:54,059
planet was and we measured the mass and

1240
00:53:03,589 --> 00:53:02,000
the period of the planet though was very

1241
00:53:05,480 --> 00:53:03,599
long compared to most of the other

1242
00:53:07,849 --> 00:53:05,490
planets that we've been studying the the

1243
00:53:11,000 --> 00:53:07,859
planet takes about 25 days to go around

1244
00:53:12,650 --> 00:53:11,010
its star remember what I told you

1245
00:53:14,630 --> 00:53:12,660
earlier that means that for this red

1246
00:53:18,250 --> 00:53:14,640
dwarf star it's nice and cool it's not

1247
00:53:20,269 --> 00:53:18,260
too hot and in fact at 25 days it is

1248
00:53:23,359 --> 00:53:20,279
probably the same temperature as the

1249
00:53:25,609 --> 00:53:23,369
earth ok so it gets about half the light

1250
00:53:28,490 --> 00:53:25,619
from its star that the earth gets from

1251
00:53:30,170 --> 00:53:28,500
the Sun not 20 or 30 times not a hundred

1252
00:53:32,120 --> 00:53:30,180
times the way so many planets do with

1253
00:53:36,920 --> 00:53:32,130
superhot planets this one was actually

1254
00:53:38,539 --> 00:53:36,930
nice and cool and importantly of course

1255
00:53:40,789 --> 00:53:38,549
because we have the transit we could

1256
00:53:43,039 --> 00:53:40,799
measure the size of the planet so we

1257
00:53:44,750 --> 00:53:43,049
measured the size to be about 40% larger

1258
00:53:46,819 --> 00:53:44,760
than the earth and so it looked like we

1259
00:53:48,200 --> 00:53:46,829
truly had what we've been looking for is

1260
00:53:51,470 --> 00:53:48,210
a planet that had the right temperature

1261
00:53:53,480 --> 00:53:51,480
but was definitely rocky ok it was

1262
00:53:55,490 --> 00:53:53,490
bigger than the earth ok was not 1 times

1263
00:53:56,960 --> 00:53:55,500

the Earth's Earth's mass it was 6 times

1264
00:54:01,130 --> 00:53:56,970
the Earth's mass so it was a super earth

1265
00:54:04,279 --> 00:54:01,140
but a rocky world around this star LHS

1266
00:54:06,500 --> 00:54:04,289
11:40 and we announced that in April so

1267
00:54:07,910 --> 00:54:06,510
just this this discovery finally came

1268
00:54:09,500 --> 00:54:07,920
together and published it very very

1269
00:54:10,880 --> 00:54:09,510
recently so if I'd been here last year

1270
00:54:15,799 --> 00:54:10,890
wouldn't been able to tell you anything

1271
00:54:17,870 --> 00:54:15,809
about this ok so so what's so exciting

1272
00:54:19,940 --> 00:54:17,880
is how quickly this field is moving so

1273
00:54:23,120 --> 00:54:19,950
if I had given this talk a year ago I

1274
00:54:26,150 --> 00:54:23,130
would have said if we could find such

1275
00:54:27,950 --> 00:54:26,160
planets then we will use the James Webb

1276
00:54:30,049 --> 00:54:27,960
Space Telescope and the giant Magellan

1277
00:54:31,490 --> 00:54:30,059
telescope to study their atmospheres but

1278
00:54:33,650 --> 00:54:31,500
I don't have to say the if anymore

1279
00:54:36,260 --> 00:54:33,660
now I can say we have found those

1280
00:54:38,269 --> 00:54:36,270
planets we hope to find even better ones

1281
00:54:42,710 --> 00:54:38,279
closer ones but we have found the first

1282
00:54:44,210 --> 00:54:42,720
targets for these kinds of studies the

1283
00:54:47,809 --> 00:54:44,220
one I just told you about that's the one

1284
00:54:49,250 --> 00:54:47,819
that I got to be part of la just 1140

1285
00:54:52,670 --> 00:54:49,260
but of course I'm sure you've heard

1286
00:54:56,510 --> 00:54:52,680
about Trappist same idea right Trappist

1287
00:54:57,950 --> 00:54:56,520
is a small nearby red dwarf star but it

1288
00:55:01,160 --> 00:54:57,960

doesn't have just one planet it's got

1289
00:55:06,470 --> 00:55:01,170
seven of them ok roughly the same

1290
00:55:08,329 --> 00:55:06,480
distance from us as LHS 11:40 now all

1291
00:55:10,819 --> 00:55:08,339
all the systems are different in their

1292
00:55:12,440 --> 00:55:10,829
own way I would say 11:40 what's special

1293
00:55:13,880 --> 00:55:12,450
about that is we know the mass of the

1294
00:55:16,339 --> 00:55:13,890
planet so we know that the planet is

1295
00:55:18,890 --> 00:55:16,349
definitely rocky a real requirement for

1296
00:55:20,180 --> 00:55:18,900
life but it's only one planet as far as

1297
00:55:20,569 --> 00:55:20,190
we know although we hope others will be

1298
00:55:22,519 --> 00:55:20,579
found

1299
00:55:23,960 --> 00:55:22,529
Trappist one there are seven worlds

1300
00:55:25,039 --> 00:55:23,970
which means we've got kind of seven

1301
00:55:27,170 --> 00:55:25,049
chances to go and study their

1302
00:55:28,940 --> 00:55:27,180
atmospheres but actually it's very hard

1303
00:55:30,529 --> 00:55:28,950
to get the masses for Travis one so we

1304
00:55:34,849 --> 00:55:30,539
don't truly know yet that their rocky

1305
00:55:38,299 --> 00:55:34,859
time will tell and then Proxima

1306
00:55:41,779 --> 00:55:38,309
so about nine months ago Proxima was

1307
00:55:43,430 --> 00:55:41,789
announced to have a planet as well in

1308
00:55:45,470 --> 00:55:43,440
the habitable zone Proxima is the very

1309
00:55:47,900 --> 00:55:45,480
closest star to us but it doesn't

1310
00:55:49,400 --> 00:55:47,910
transit so we can't quite use the

1311
00:55:51,440 --> 00:55:49,410
methods I've been talking about but now

1312
00:55:53,839 --> 00:55:51,450
we have three nearby stars all very

1313
00:55:55,880 --> 00:55:53,849

close to us that have what we think are

1314
00:55:57,200 --> 00:55:55,890
potentially habitable worlds so a really

1315
00:56:02,000 --> 00:55:57,210
fundamental change from even

1316
00:56:04,730 --> 00:56:02,010
months ago okay so how are we gonna put

1317
00:56:07,660 --> 00:56:04,740
this all together so I I think what I

1318
00:56:09,350 --> 00:56:07,670
want to emphasize is the the

1319
00:56:10,250 --> 00:56:09,360
complementarity of these two great

1320
00:56:13,640 --> 00:56:10,260
observatories

1321
00:56:16,280 --> 00:56:13,650
okay so if we just use the giant

1322
00:56:18,830 --> 00:56:16,290
Magellan telescope or if we just used

1323
00:56:20,930 --> 00:56:18,840
the James Webb Space Telescope I don't

1324
00:56:22,100 --> 00:56:20,940
think no matter how good the data was I

1325
00:56:23,900 --> 00:56:22,110
don't think we'd be able to conclude

1326
00:56:27,710 --> 00:56:23,910
that there was life on one of these

1327
00:56:32,510 --> 00:56:27,720
planets okay and the and and and here's

1328
00:56:34,460 --> 00:56:32,520
why what we want to do with the GMT is

1329
00:56:35,930 --> 00:56:34,470
we want to go and detect oxygen it

1330
00:56:38,120 --> 00:56:35,940
studies the right wavelengths of light

1331
00:56:41,270 --> 00:56:38,130
so that we can actually detect molecular

1332
00:56:43,240 --> 00:56:41,280
oxygen which is the kind of the giveaway

1333
00:56:45,320 --> 00:56:43,250
that there's life right life

1334
00:56:47,240 --> 00:56:45,330
photosynthetic life makes oxygen the

1335
00:56:50,660 --> 00:56:47,250
oxygen accumulates in the atmosphere the

1336
00:56:52,640 --> 00:56:50,670
oxygen is entirely due to life on the

1337
00:56:54,580 --> 00:56:52,650
earth and so that would tell us that

1338
00:56:57,110 --> 00:56:54,590

there really was life on the planet

1339
00:56:59,180 --> 00:56:57,120
however if all we have is oxygen that

1340
00:57:00,200 --> 00:56:59,190
doesn't work because of course

1341
00:57:01,310 --> 00:57:00,210
astronomers have been thinking about

1342
00:57:03,380 --> 00:57:01,320
this problem and they said well you know

1343
00:57:06,170 --> 00:57:03,390
on the earth the oxygen is all made by

1344
00:57:08,000 --> 00:57:06,180
life but they can concoct schemes where

1345
00:57:10,430 --> 00:57:08,010
an other planets the oxygen would not be

1346
00:57:12,230 --> 00:57:10,440
due to life the oxygen would be due to

1347
00:57:14,900 --> 00:57:12,240
for example ultraviolet light from the

1348
00:57:16,640 --> 00:57:14,910
star hitting water and breaking the

1349
00:57:18,680 --> 00:57:16,650
water up into its hydrogen and it's

1350
00:57:21,020 --> 00:57:18,690
oxygen and maybe that's how you make

1351
00:57:25,850 --> 00:57:21,030
oxygen so if you just saw oxygen you

1352
00:57:27,710 --> 00:57:25,860
could be fooled that's why you need the

1353
00:57:30,080 --> 00:57:27,720
James Webb Space Telescope what James

1354
00:57:32,390 --> 00:57:30,090
Webb can do is it can detect all sorts

1355
00:57:34,640 --> 00:57:32,400
of other molecules that will distinguish

1356
00:57:36,800 --> 00:57:34,650
between those two scenarios whether the

1357
00:57:41,560 --> 00:57:36,810
oxygen is made by life or whether the

1358
00:57:48,800 --> 00:57:47,090
photolysis process so putting them both

1359
00:57:51,440 --> 00:57:48,810
together I think we actually can go and

1360
00:57:54,200 --> 00:57:51,450
and interpret the data correctly so

1361
00:57:57,770 --> 00:57:54,210
perhaps they can do it together GMT is

1362
00:57:59,210 --> 00:57:57,780
able to detect molecular oxygen James

1363
00:58:00,350 --> 00:57:59,220

Webb really can't do that because of the

1364
00:58:03,620 --> 00:58:00,360
wavelength it just doesn't study the

1365
00:58:06,110 --> 00:58:03,630
right wavelengths to do that but by the

1366
00:58:08,000 --> 00:58:06,120
same token GMT can't gather the

1367
00:58:09,470 --> 00:58:08,010
ancillary information that will really

1368
00:58:09,900 --> 00:58:09,480
allow us to interpret the oxygen

1369
00:58:12,480 --> 00:58:09,910
detector

1370
00:58:13,740 --> 00:58:12,490
and James Webb Space Telescope is going

1371
00:58:16,490 --> 00:58:13,750
to be awesome at doing that it's got

1372
00:58:19,770 --> 00:58:16,500
infrared sensitivity it can detect water

1373
00:58:22,020 --> 00:58:19,780
carbon dioxide carbon monoxide methane

1374
00:58:24,710 --> 00:58:22,030
all the things that put that oxygen in

1375
00:58:31,890 --> 00:58:29,160
okay so so you know big picture I really

1376
00:58:33,210 --> 00:58:31,900
think that that's our first opportunity

1377
00:58:37,049 --> 00:58:33,220
to go and find life on other planets

1378
00:58:38,789 --> 00:58:37,059
with these new observatories I think we

1379
00:58:40,410 --> 00:58:38,799
really have a shot at this it's the

1380
00:58:42,150 --> 00:58:40,420
first time humanity's been able to make

1381
00:58:43,470 --> 00:58:42,160
that claim I might be wrong there might

1382
00:58:44,880 --> 00:58:43,480
be lots of reasons why there's no life

1383
00:58:46,829 --> 00:58:44,890
around planets orbiting and Dwarfs I'm

1384
00:58:48,000 --> 00:58:46,839
happy to talk about that but it's the

1385
00:58:50,520 --> 00:58:48,010
first time we can take a shot at this

1386
00:58:52,109 --> 00:58:50,530
thing and the point I want to leave you

1387
00:58:54,750 --> 00:58:52,119
with is that the impact really will

1388
00:58:56,789 --> 00:58:54,760

extend well beyond astronomy and I think

1389
00:58:59,490 --> 00:58:56,799
even science I think when I talked to

1390
00:59:01,650 --> 00:58:59,500
people I think knowing whether or not

1391
00:59:04,799 --> 00:59:01,660
we're it whether there's other inhabited

1392
00:59:06,900 --> 00:59:04,809
worlds and what that relationship of

1393
00:59:08,849 --> 00:59:06,910
life is relative to life on the earth I

1394
00:59:11,250 --> 00:59:08,859
think speaks very deeply to people

1395
00:59:16,079 --> 00:59:11,260
beyond just just the astronomical

1396
00:59:17,789 --> 00:59:16,089
questions that it will answer so in in

1397
00:59:21,299 --> 00:59:17,799
preparing a public talk about a year ago

1398
00:59:24,660 --> 00:59:21,309
I I wrote some of my students and I said

1399
00:59:26,760 --> 00:59:24,670
you know I'm trying to convey the

1400
00:59:28,230 --> 00:59:26,770
importance of telescopes for this work

1401
00:59:30,839 --> 00:59:28,240
you know I said this is like for me a

1402
00:59:32,339 --> 00:59:30,849
telescope is like telescope is like that

1403
00:59:33,809 --> 00:59:32,349
spaceship it allows me to kind of go to

1404
00:59:37,650 --> 00:59:33,819
other worlds see the local conditions

1405
00:59:38,849 --> 00:59:37,660
discover life but of course over you

1406
00:59:40,980 --> 00:59:38,859
know without having to overcome this

1407
00:59:43,170 --> 00:59:40,990
this technological miracle of actual

1408
00:59:44,460 --> 00:59:43,180
we're actually traveling to other stars

1409
00:59:47,670 --> 00:59:44,470
I can just go there kind of with my

1410
00:59:49,260 --> 00:59:47,680
telescopes what what do what do these

1411
00:59:50,579 --> 00:59:49,270
giant telescopes mean to you and so my

1412
00:59:53,339 --> 00:59:50,589
students wrote back and I just wanted to

1413
00:59:55,890 --> 00:59:53,349

share one quote this is from Hannah

1414
00:59:59,400 --> 00:59:55,900
diamond Lowe Hannah was in the first

1415
01:00:00,930 --> 00:59:59,410
year of her PhD working with me and I

1416
01:00:02,430 --> 01:00:00,940
loved what she wrote she said spending

1417
01:00:03,870 --> 01:00:02,440
time at one of the biggest telescopes in

1418
01:00:05,460 --> 01:00:03,880
the world has given me a grand

1419
01:00:07,380 --> 01:00:05,470
perspective on the accomplishments of

1420
01:00:08,910 --> 01:00:07,390
humanity from this vantage point

1421
01:00:11,039 --> 01:00:08,920
detecting signs of extraterrestrial life

1422
01:00:14,010 --> 01:00:11,049
seems well within our reach so I love

1423
01:00:16,640 --> 01:00:14,020
the fact that you know for me this just

1424
01:00:18,390 --> 01:00:16,650
all seems like this incredible

1425
01:00:21,809 --> 01:00:18,400
opportunity that I would have never

1426
01:00:22,970 --> 01:00:21,819
foreseen when I was doing my PhD which

1427
01:00:25,780 --> 01:00:22,980
was

1428
01:00:28,070 --> 01:00:25,790
fifteen 20 years ago for Hana it seems

1429
01:00:29,599 --> 01:00:28,080
like it's really something that's on the

1430
01:00:31,609 --> 01:00:29,609
table we could really go and actually

1431
01:00:32,630 --> 01:00:31,619
make these discoveries and that's that's

1432
01:00:34,060 --> 01:00:32,640
a picture of Hana in front of the

1433
01:00:39,109 --> 01:00:34,070
Magellan Observatory where she was

1434
01:00:40,880 --> 01:00:39,119
gathering data and Hannah is here at the

1435
01:00:43,220 --> 01:00:40,890
conference and she's giving a scientific

1436
01:00:45,140 --> 01:00:43,230
presentation on her results tomorrow but

1437
01:00:48,020 --> 01:00:45,150
I we haven't discovered life yet just

1438
01:00:49,880 --> 01:00:48,030

just you know okay I want to thank the

1439
01:00:51,400 --> 01:00:49,890
funding agencies that really made this

1440
01:00:53,240 --> 01:00:51,410
all possible it's really nice

1441
01:00:54,490 --> 01:00:53,250
collaboration between the federal

1442
01:00:56,210 --> 01:00:54,500
funding agencies and the private

1443
01:00:58,370 --> 01:00:56,220
foundations the National Science

1444
01:01:00,410 --> 01:00:58,380
Foundation NASA the David and Lucile

1445
01:01:02,599 --> 01:01:00,420
Packard Foundation and the John

1446
01:01:05,810 --> 01:01:02,609
Templeton Foundation and then most

1447
01:01:09,080 --> 01:01:05,820
importantly these folks who do all the

1448
01:01:11,270 --> 01:01:09,090
work Zak Berta Thompson Jason Ditman

1449
01:01:14,000 --> 01:01:11,280
Courtney dressing Rafael Heywood

1450
01:01:17,210 --> 01:01:14,010
Jonathan Irwin Mercedes Lopez Morales

1451
01:01:19,640 --> 01:01:17,220
Elizabeth Newton Joey Rodriguez and and

1452
01:01:21,920 --> 01:01:19,650
Jennifer winters I've showed you all of

1453
01:01:23,510 --> 01:01:21,930
their results all put together in this

1454
01:01:27,260 --> 01:01:23,520
picture of the progress that we're

1455
01:01:31,099 --> 01:01:27,270
trying to make on this big question okay

1456
01:01:33,109 --> 01:01:31,109
so so this is my final slide but I want

1457
01:01:37,040 --> 01:01:33,119
to make sure that when in the morning

1458
01:01:38,690 --> 01:01:37,050
you're talking to family friends you

1459
01:01:40,790 --> 01:01:38,700
wake up and tweet or whatever this is

1460
01:01:42,859 --> 01:01:40,800
what you should be talking about okay

1461
01:01:44,060 --> 01:01:42,869
all right these are the real takeaways

1462
01:01:47,750 --> 01:01:44,070
that you've got it you've got to go home

1463
01:01:50,150 --> 01:01:47,760

with one red dwarf stars are the most

1464
01:01:52,490 --> 01:01:50,160
common star in the galaxy and there's at

1465
01:01:56,240 --> 01:01:52,500
least one habitable planet for every

1466
01:01:59,270 --> 01:01:56,250
four of them okay a fundamental advance

1467
01:02:00,830 --> 01:01:59,280
in our understanding that is hot off the

1468
01:02:05,359 --> 01:02:00,840
presses that that result is only a

1469
01:02:07,340 --> 01:02:05,369
couple years old okay - we have begun to

1470
01:02:09,740 --> 01:02:07,350
find the closest transiting earths okay

1471
01:02:12,050 --> 01:02:09,750
though those results are only a couple

1472
01:02:13,310 --> 01:02:12,060
months old and we are planning to study

1473
01:02:15,200 --> 01:02:13,320
their atmospheres with the next

1474
01:02:18,590 --> 01:02:15,210
generation of power telescopes powerful

1475
01:02:20,210 --> 01:02:18,600
telescopes and then and then finally the

1476
01:02:22,430 --> 01:02:20,220
search for atmospheric biomarkers such

1477
01:02:23,990 --> 01:02:22,440
as oxygen I think really is humanity's

1478
01:02:25,070 --> 01:02:24,000
first attempt to answer this great

1479
01:02:28,610 --> 01:02:25,080
question of whether or not we're alone

1480
01:02:31,480 --> 01:02:28,620
and that's the end of my talk thank you

1481
01:02:41,030 --> 01:02:31,490
[Applause]

1482
01:02:56,109 --> 01:02:43,780
[Music]

1483
01:02:59,420 --> 01:02:56,119
okay if you looked at Earth's atmosphere

1484
01:03:02,059 --> 01:02:59,430
during times of extreme climates such as

1485
01:03:04,339 --> 01:03:02,069
the I say you know what earth have

1486
01:03:07,069 --> 01:03:04,349
appeared habitable because it strikes me

1487
01:03:10,160 --> 01:03:07,079
you're looking at these planets in a

1488
01:03:13,250 --> 01:03:10,170

very narrow time in their existence and

1489
01:03:49,579 --> 01:03:13,260
that doesn't tell you what the future

1490
01:03:52,220 --> 01:03:49,589
may have yeah so so that's right so the

1491
01:03:54,020 --> 01:03:52,230
the recent ice ages so you know the

1492
01:03:56,690 --> 01:03:54,030
recent ice ages are tens of thousands of

1493
01:03:57,650 --> 01:03:56,700
years ago the oxygen content of the

1494
01:03:58,849 --> 01:03:57,660
Earth's atmosphere didn't change

1495
01:04:00,440 --> 01:03:58,859
significantly there was still plenty of

1496
01:04:02,720 --> 01:04:00,450
oxygen which is a signal kind of measure

1497
01:04:05,150 --> 01:04:02,730
but to broaden your point a little bit

1498
01:04:06,230 --> 01:04:05,160
the earth has definitely changed over

1499
01:04:09,140 --> 01:04:06,240
four-and-a-half billion years

1500
01:04:11,450 --> 01:04:09,150
when it started out it took billions of

1501
01:04:13,370 --> 01:04:11,460
years for the oxygen to build up to the

1502
01:04:15,829 --> 01:04:13,380
point where it was something astronomers

1503
01:04:18,650 --> 01:04:15,839
could ever detect remotely okay so for a

1504
01:04:21,230 --> 01:04:18,660
very long time even after there was a

1505
01:04:23,480 --> 01:04:21,240
photosynthetic bacteria they were made

1506
01:04:25,700 --> 01:04:23,490
of oxygen the oxygen was probably going

1507
01:04:28,700 --> 01:04:25,710
and reacting chemically with exposed

1508
01:04:31,359 --> 01:04:28,710
rock on the surface so that's right so I

1509
01:04:34,099 --> 01:04:31,369
what I'm talking about is trying to find

1510
01:04:37,130 --> 01:04:34,109
evidence for life as the earth has

1511
01:04:39,109 --> 01:04:37,140
appeared for roughly the past half of

1512
01:04:41,900 --> 01:04:39,119
its existence but not for all four and a

1513
01:04:43,549 --> 01:04:41,910

half billion years I would love to come

1514
01:04:45,589 --> 01:04:43,559
up with an idea with the tool

1515
01:04:48,019 --> 01:04:45,599
with even broader net and allow me to

1516
01:04:49,459 --> 01:04:48,029
look for life that we're taking all the

1517
01:04:52,160 --> 01:04:49,469
way back to when life first appeared on

1518
01:04:54,259 --> 01:04:52,170
the earth but I just I don't know how to

1519
01:04:56,390 --> 01:04:54,269
master that from afar time so this is

1520
01:05:03,529 --> 01:04:56,400
this is what I've got to present as a

1521
01:05:05,660 --> 01:05:03,539
tool for planets going up orbiting the

1522
01:05:09,439 --> 01:05:05,670
red dwarfs with a magnetic field be as

1523
01:05:12,049 --> 01:05:09,449
important as it would around the larger

1524
01:05:13,849 --> 01:05:12,059
star or side so the question is for

1525
01:05:16,309 --> 01:05:13,859
planets orbiting a red dwarf with the

1526
01:05:18,429 --> 01:05:16,319
magnetic field be as important as it

1527
01:05:21,289 --> 01:05:18,439
might be for a larger star like the song

1528
01:05:26,120 --> 01:05:21,299
yes do you mean the magnetic field of

1529
01:05:28,849 --> 01:05:26,130
the star protecting it from yes so a big

1530
01:05:31,459 --> 01:05:28,859
question is since these planets are in

1531
01:05:33,170 --> 01:05:31,469
close to their stars can they hold on to

1532
01:05:35,630 --> 01:05:33,180
their atmospheres if the star has a

1533
01:05:37,099 --> 01:05:35,640
strong seller win for example would it

1534
01:05:39,410 --> 01:05:37,109
simply remove the atmosphere of the

1535
01:05:42,289 --> 01:05:39,420
planet and then obviously be habitable

1536
01:05:45,439 --> 01:05:42,299
so yes I think that it is a requirement

1537
01:05:51,529 --> 01:05:45,449
of planets to be habitable have a go

1538
01:05:54,499 --> 01:05:51,539

here and field narrows to Mars probably

1539
01:05:56,120 --> 01:05:54,509
lost its atmosphere because it is cooled

1540
01:05:58,160 --> 01:05:56,130
all the way through so it no longer has

1541
01:06:00,259 --> 01:05:58,170
a molten core that means it doesn't have

1542
01:06:02,089 --> 01:06:00,269
this coherent magnetic field and over

1543
01:06:03,709 --> 01:06:02,099
time the solar wind is able to strip

1544
01:06:06,140 --> 01:06:03,719
away the atmosphere of Mars it also was

1545
01:06:08,959 --> 01:06:06,150
lower surface gravity so it's easier to

1546
01:06:10,999 --> 01:06:08,969
let that gas go for the out of interest

1547
01:06:11,299 --> 01:06:11,009
for the planet that we've that I was

1548
01:06:13,880 --> 01:06:11,309
talking about

1549
01:06:16,189 --> 01:06:13,890
LHS 11:40 it's more massive than the

1550
01:06:18,499 --> 01:06:16,199
earth so almost certainly its core has

1551
01:06:20,059 --> 01:06:18,509
not solidified so it's it's got a better

1552
01:06:22,099 --> 01:06:20,069
chance of keeping magnetic field and

1553
01:06:23,719 --> 01:06:22,109
also the stronger surface gravity would

1554
01:06:29,949 --> 01:06:23,729
allow it to protect its atmosphere just

1555
01:06:34,599 --> 01:06:33,169
you mentioned that in 2001 there was one

1556
01:06:38,660 --> 01:06:34,609
extra planet now now we know a

1557
01:06:41,239 --> 01:06:38,670
considerably more you envision that

1558
01:06:44,529 --> 01:06:41,249
exponential growth and understanding to

1559
01:06:47,250 --> 01:06:44,539
continue about this in this field like

1560
01:06:49,200 --> 01:06:47,260
we got

1561
01:06:53,730 --> 01:06:49,210
transiting exoplanets in the past two

1562
01:06:55,350 --> 01:06:53,740
decades how long does that so I'd like

1563
01:06:57,570 --> 01:06:55,360

to wait and the question was to

1564
01:07:01,170 --> 01:06:57,580
anticipate the same exponential growth

1565
01:07:03,690 --> 01:07:01,180
and understanding and and I would say I

1566
01:07:07,020 --> 01:07:03,700
don't expect the same exponential growth

1567
01:07:10,890 --> 01:07:07,030
in number but in understanding I do so

1568
01:07:15,180 --> 01:07:10,900
so what you know that most of you come

1569
01:07:22,410 --> 01:07:15,190
from one NASA mission okay there are

1570
01:07:26,070 --> 01:07:22,420
other missions coming up the NASA test

1571
01:07:28,950 --> 01:07:26,080
mission should launch in spring of next

1572
01:07:32,580 --> 01:07:28,960
year we expect that to find hundreds or

1573
01:07:34,410 --> 01:07:32,590
maybe a thousand planets and then

1574
01:07:36,690 --> 01:07:34,420
there's a European mission called Plato

1575
01:07:39,210 --> 01:07:36,700
that should also find you know of order

1576
01:07:41,100 --> 01:07:39,220
thousands of planets so we will continue

1577
01:07:43,230 --> 01:07:41,110
to increase the numbers but it's not

1578
01:07:44,760 --> 01:07:43,240
going to be exponential okay the way

1579
01:07:47,550 --> 01:07:44,770
that Kepler Kepler really took us from

1580
01:07:49,140 --> 01:07:47,560
kind of hundreds to 5,000 but the point

1581
01:07:50,580 --> 01:07:49,150
is we're finding planets that are closer

1582
01:07:52,560 --> 01:07:50,590
to our understanding I don't think we

1583
01:07:54,060 --> 01:07:52,570
need a lot more planets to do I mean

1584
01:07:56,250 --> 01:07:54,070
we'd love to have them but I think now

1585
01:07:57,810 --> 01:07:56,260
the issue is moving from statistics to

1586
01:08:00,780 --> 01:07:57,820
actually a detailed understanding of the

1587
01:08:02,550 --> 01:08:00,790
properties and compositions by finding

1588
01:08:17,269 --> 01:08:02,560

the nearby examples of the planets the

1589
01:08:17,279 --> 01:08:35,679
[Applause]

1590
01:08:42,990 --> 01:08:40,680
[Music]

1591
01:08:47,340 --> 01:08:43,000
because I show these curves for things

1592
01:08:49,499 --> 01:08:47,350
that I know how to recognize and so so

1593
01:08:50,670 --> 01:08:49,509
why you know I think what we've done is

1594
01:08:53,940 --> 01:08:50,680
we've come up with a plan where we can

1595
01:08:55,590 --> 01:08:53,950
say ah okay oxygen and the combination

1596
01:08:58,380 --> 01:08:55,600
of their molecules on a planet that has

1597
01:09:01,079 --> 01:08:58,390
a certain temperature I would be able to

1598
01:09:03,180 --> 01:09:01,089
really conclude that that was due to

1599
01:09:05,820 --> 01:09:03,190
life but you're right there could be

1600
01:09:08,160 --> 01:09:05,830
life that is more than what we call

1601
01:09:09,749 --> 01:09:08,170
extremophiles here on earth

1602
01:09:11,820 --> 01:09:09,759
there certainly is lots of life that

1603
01:09:13,229 --> 01:09:11,830
doesn't make oxygen and of course we can

1604
01:09:14,970 --> 01:09:13,239
imagine other kind of life that doesn't

1605
01:09:18,780 --> 01:09:14,980
exist on the earth but maybe would work

1606
01:09:20,490 --> 01:09:18,790
chemically and and yeah I think we would

1607
01:09:23,010 --> 01:09:20,500
I think we would easily miss that so

1608
01:09:25,979 --> 01:09:23,020
what I presented here is an idea to

1609
01:09:27,360 --> 01:09:25,989
recognize life that is that is pretty

1610
01:09:28,800 --> 01:09:27,370
similar to what we find in the earth

1611
01:09:31,170 --> 01:09:28,810
that certainly life that's been around

1612
01:09:32,700 --> 01:09:31,180
for billions of years of the earth

1613
01:09:34,710 --> 01:09:32,710

because I have the ground truth of the

1614
01:09:36,479 --> 01:09:34,720
earth I've known and recognized it and I

1615
01:09:39,180 --> 01:09:36,489
hope that kind of mining students are

1616
01:09:41,610 --> 01:09:39,190
going to come up with even broader tests

1617
01:09:45,780 --> 01:09:41,620
Twitter to broaden that and think of

1618
01:09:46,950 --> 01:09:45,790
ways to find life that we can't

1619
01:09:54,090 --> 01:09:46,960
currently figure out how to recognize

1620
01:09:57,270 --> 01:09:54,100
but I don't are there any atmospheric

1621
01:09:59,910 --> 01:09:57,280
markers that are created only by living

1622
01:10:10,229 --> 01:09:59,920
organisms there any atmosphere of Mars

1623
01:10:16,390 --> 01:10:14,229
there are definitely a lot I would say I

1624
01:10:17,770 --> 01:10:16,400
would say you know certain kind of

1625
01:10:21,390 --> 01:10:17,780
industrial pollutants and things like

1626
01:10:28,600 --> 01:10:21,400
that I think that any interesting

1627
01:10:29,890 --> 01:10:28,610
biomarker of oxygen is so you know

1628
01:10:30,940 --> 01:10:29,900
methane methane on the earth is a

1629
01:10:32,560 --> 01:10:30,950
biomarker methane

1630
01:10:34,060 --> 01:10:32,570
although methane in the Earth's

1631
01:10:35,770 --> 01:10:34,070
atmosphere if you just said if there

1632
01:10:37,990 --> 01:10:35,780
wasn't my and I just did a chemical

1633
01:10:39,580 --> 01:10:38,000
calculation how much methane should

1634
01:10:40,900 --> 01:10:39,590
there being hereit's atmosphere and the

1635
01:10:54,090 --> 01:10:40,910
answer is there should be less than one

1636
01:10:56,890 --> 01:10:54,100
molecule of methane in the entire okay

1637
01:10:58,810 --> 01:10:56,900
so that's another kind of bible it's a

1638
01:11:01,060 --> 01:10:58,820

very phrase guess it's much much less

1639
01:11:03,820 --> 01:11:01,070
abundant than oxygen so I would say that

1640
01:11:05,770 --> 01:11:03,830
yes I can think of those gases but but

1641
01:11:07,330 --> 01:11:05,780
all the ones that I can think about that

1642
01:11:09,490 --> 01:11:07,340
are actually detectable astronomically

1643
01:11:11,470 --> 01:11:09,500
but very large quantities things I know

1644
01:11:14,080 --> 01:11:11,480
how to go ahead measure they all are

1645
01:11:27,670 --> 01:11:14,090
pretty simple molecules that that

1646
01:11:30,430 --> 01:11:27,680
certainly could be produce yeah for

1647
01:11:31,510 --> 01:11:30,440
those that are looking for life in the

1648
01:11:35,200 --> 01:11:31,520
solar system

1649
01:11:38,830 --> 01:11:35,210
they are looking not at the planets but

1650
01:11:41,220 --> 01:11:38,840
at moons of planets like Europa No

1651
01:11:44,800 --> 01:11:41,230
is there any chance you'd be able to

1652
01:11:58,630 --> 01:11:44,810
detect moves around some of these

1653
01:12:00,820 --> 01:11:58,640
exoplanets the reasons is because we

1654
01:12:02,950 --> 01:12:00,830
need planets that have the right

1655
01:12:04,930 --> 01:12:02,960
temperature and the way the earth of

1656
01:12:06,490 --> 01:12:04,940
course maintains temperatures

1657
01:12:08,140 --> 01:12:06,500
radiation from the Sun but another way

1658
01:12:09,760 --> 01:12:08,150
to defeat your planet is to have an

1659
01:12:11,320 --> 01:12:09,770
orbiting gas giant and to be tidally

1660
01:12:14,030 --> 01:12:11,330
stretched and that's stretching and

1661
01:12:15,620 --> 01:12:14,040
pulling the friction heats the planet

1662
01:12:18,440 --> 01:12:15,630
so for example there are there are

1663
01:12:20,150 --> 01:12:18,450

planets of Sadler's or moons of Saturn

1664
01:12:23,230 --> 01:12:20,160
and Jupiter that that are much warmer

1665
01:12:28,280 --> 01:12:23,240
than they should we do that tidal energy

1666
01:12:32,090 --> 01:12:28,290
so yes there is a very healthy interest

1667
01:12:35,330 --> 01:12:32,100
in finding moons orbiting exoplanets and

1668
01:12:36,350 --> 01:12:35,340
people work very hard and nobody has

1669
01:12:37,490 --> 01:12:36,360
found a single one

1670
01:12:40,370 --> 01:12:37,500
please ever found a moving around

1671
01:12:41,930 --> 01:12:40,380
another refinery other star I think this

1672
01:12:43,220 --> 01:12:41,940
a new planet that we just found out with

1673
01:12:44,690 --> 01:12:43,230
just level 40 that would be a good

1674
01:12:46,370 --> 01:12:44,700
candidate for a movement so we're going

1675
01:12:49,310 --> 01:12:46,380
to go hunting but we haven't gotten data

1676
01:12:51,290 --> 01:12:49,320
yet people are searching through the

1677
01:12:52,190 --> 01:12:51,300
Kepler data hadn't been able to find can

1678
01:12:53,990 --> 01:12:52,200
you think that there's always a moment

1679
01:12:56,210 --> 01:12:54,000
that can improve that you know we're not

1680
01:12:57,890 --> 01:12:56,220
going to get more copy data from the

1681
01:12:59,900 --> 01:12:57,900
original mission but we can improve the

1682
01:13:09,920 --> 01:12:59,910
quality of the data by smarter data

1683
01:13:12,440 --> 01:13:09,930
analysis you have to wait to the second

1684
01:13:15,590 --> 01:13:12,450
half of her history to get oxygen in the

1685
01:13:18,170 --> 01:13:15,600
air but you the thing you're really

1686
01:13:28,910 --> 01:13:18,180
looking for is water and you can't even

1687
01:13:30,890 --> 01:13:28,920
detect water in the atmosphere that

1688
01:13:33,680 --> 01:13:30,900

great great question so the Russian ones

1689
01:13:35,330 --> 01:13:33,690
you know oxygen is a fairly recent

1690
01:13:37,430 --> 01:13:35,340
phenomenon meaning half of the Earth's

1691
01:13:38,900 --> 01:13:37,440
history maybe a little bit less water

1692
01:13:40,580 --> 01:13:38,910
has always been around

1693
01:13:44,330 --> 01:13:40,590
so yes I'm proud to say we're really

1694
01:13:46,940 --> 01:13:44,340
good at was hectic water water has a big

1695
01:13:49,070 --> 01:13:46,950
signature for astronomers it blocks a

1696
01:13:50,480 --> 01:13:49,080
lot of light in fact it's a terrible

1697
01:13:51,680 --> 01:13:50,490
paint-connect when you do is stronger

1698
01:13:53,000 --> 01:13:51,690
from the ground you have to look out

1699
01:13:54,470 --> 01:13:53,010
through the Earth's atmosphere and

1700
01:13:57,550 --> 01:13:54,480
there's all these parts of the Earth's

1701
01:13:59,500 --> 01:13:57,560
atmosphere that are blocked by water and

1702
01:14:00,910 --> 01:13:59,510
forever wavelengths when you're under

1703
01:14:02,620 --> 01:14:00,920
space you don't agree with that and

1704
01:14:04,570 --> 01:14:02,630
you're looking at other planets so yes

1705
01:14:06,660 --> 01:14:04,580
water has been intended on management

1706
01:14:10,060 --> 01:14:06,670
that's orbiting other stars

1707
01:14:12,010 --> 01:14:10,070
not yet down for long paths because

1708
01:14:12,970 --> 01:14:12,020
that's a more challenging nest egg one

1709
01:14:22,720 --> 01:14:12,980
of the first things that people are

1710
01:14:25,000 --> 01:14:22,730
going to do with the James what do you

1711
01:14:36,060 --> 01:14:25,010
think are the chances of finding life in

1712
01:14:42,430 --> 01:14:38,790
[Music]

1713
01:14:43,620 --> 01:14:42,440

open-minded I truly don't know if the

1714
01:14:49,690 --> 01:14:43,630
answer is going to be there is life

1715
01:14:58,510 --> 01:14:49,700
outside sources or in it or not so I you

1716
01:15:00,430 --> 01:14:58,520
know there really could be life I think

1717
01:15:02,320 --> 01:15:00,440
we have to go I think I think the only

1718
01:15:04,000 --> 01:15:02,330
way to answer is you've got to go and I

1719
01:15:06,330 --> 01:15:04,010
think we have to send probes out to

1720
01:15:08,380 --> 01:15:06,340
those bodies to do a lot of interesting

1721
01:15:10,630 --> 01:15:08,390
planetary science and also actually go

1722
01:15:13,570 --> 01:15:10,640
and look for life I hope that's not a

1723
01:15:15,580 --> 01:15:13,580
deeply unsatisfying answer to you but

1724
01:15:18,010 --> 01:15:15,590
that's honestly how I feel I really I

1725
01:15:19,870 --> 01:15:18,020
really think that we could find we are

1726
01:15:22,210 --> 01:15:19,880
truly alone to the best of our ability

1727
01:15:23,530 --> 01:15:22,220
to study or we could find out that in a

1728
01:15:25,840 --> 01:15:23,540
moment we can finally get to another

1729
01:15:27,340 --> 01:15:25,850
planet or moon whether it's in this

1730
01:15:28,720 --> 01:15:27,350
whole system or out that kind of

1731
01:15:29,920 --> 01:15:28,730
remotely had the right temperature

1732
01:15:34,450 --> 01:15:29,930
chemistry we're going to find life and

1733
01:15:44,750 --> 01:15:36,770
we should all see we've never done

1734
01:15:46,760 --> 01:15:44,760
experiment so to put things I've never

1735
01:15:54,709 --> 01:15:46,770
wanted to leave Jake Gyllenhaal's scope

1736
01:15:57,050 --> 01:15:54,719
its back in will it be in ultraviolet no

1737
01:15:58,070 --> 01:15:57,060
invoicing won't to look at all for all

1738
01:16:00,590 --> 01:15:58,080

the wavelengths to really have to go to

1739
01:16:02,950 --> 01:16:00,600
space Fortson from us all product

1740
01:16:08,959 --> 01:16:02,960
radiation is mostly blocked by our

1741
01:16:10,820 --> 01:16:08,969
sphere and instead really the preeminent

1742
01:16:13,640 --> 01:16:10,830
Observatory for ultraviolet observations

1743
01:16:25,370 --> 01:16:13,650
as the hospitals yeah so PMT really can

1744
01:16:27,830 --> 01:16:25,380
and if you look at this yeah so oxygen

1745
01:16:31,790 --> 01:16:27,840
has a very strong spectroscopic a

1746
01:16:35,600 --> 01:16:31,800
feature in kind of the red optical so so

1747
01:16:37,340 --> 01:16:35,610
a wavelength light that's very favorable

1748
01:16:39,590 --> 01:16:37,350
and in fact we look after yourselves

1749
01:16:41,330 --> 01:16:39,600
here it's very prominent and that's and

1750
01:16:43,070 --> 01:16:41,340
there's a trick actually how you how you

1751
01:16:44,810 --> 01:16:43,080
studied with the GMT you actually have

1752
01:16:46,430 --> 01:16:44,820
to get so much light you can do in a

1753
01:16:48,500 --> 01:16:46,440
very high resolution and the lines that

1754
01:16:50,870 --> 01:16:48,510
are due to oxygen move out of phase with

1755
01:16:53,209 --> 01:16:50,880
the lines review the alien oxygen

1756
01:16:57,729 --> 01:16:53,219
because of the relative speed of the

1757
01:16:59,600 --> 01:16:57,739
that star does so so the oxygen is

1758
01:17:01,610 --> 01:16:59,610
something you would do in visible light

1759
01:17:05,570 --> 01:17:01,620
with the ground-based telescope but

1760
01:17:07,390 --> 01:17:05,580
things like water methane carbon dioxide

1761
01:17:09,110 --> 01:17:07,400
carbon dioxide preserves mostly

1762
01:17:12,320 --> 01:17:09,120
exception those are mostly things have

1763
01:17:14,450 --> 01:17:12,330

all begun to space with alright so we

1764
01:17:22,070 --> 01:17:14,460
have a question from the internet when

1765
01:17:23,510 --> 01:17:22,080
you study a star system yeah great

1766
01:17:26,360 --> 01:17:23,520
question do we have a good investment

1767
01:17:31,879 --> 01:17:26,370
agency start so for Emma four stars for

1768
01:17:34,010 --> 01:17:31,889
these red dwarf stars so they basically

1769
01:17:37,669 --> 01:17:34,020
once they form they do not show their

1770
01:17:38,359 --> 01:17:37,679
age so so if you meet a red dwarf star

1771
01:17:42,350 --> 01:17:38,369
you

1772
01:17:44,990 --> 01:17:42,360
if it is 1 million years old or if it is

1773
01:17:46,609 --> 01:17:45,000
12 billion years old and the fact many

1774
01:17:48,439 --> 01:17:46,619
that will continue to live long in the

1775
01:17:50,930 --> 01:17:48,449
future so some red dwarf stars will live

1776
01:17:53,600 --> 01:17:50,940
for hundreds of billions of years they

1777
01:17:54,290 --> 01:17:53,610
have very little hydrogen in the core if

1778
01:17:59,750 --> 01:17:54,300
they burn it

1779
01:18:01,010 --> 01:17:59,760
that they they really don't have changed

1780
01:18:02,979 --> 01:18:01,020
of course for the sign and changes

1781
01:18:05,899 --> 01:18:02,989
because it's eating on the hydrogen ring

1782
01:18:08,810 --> 01:18:05,909
but but we do have a way to get their

1783
01:18:11,209 --> 01:18:08,820
ages now which is that we've learned

1784
01:18:14,600 --> 01:18:11,219
that over time the stars spin down and

1785
01:18:16,490 --> 01:18:14,610
one thing that I'm very proud of data

1786
01:18:17,930 --> 01:18:16,500
coming from the mirth Observatory was

1787
01:18:19,520 --> 01:18:17,940
we're able to get rotation here it's how

1788
01:18:21,620 --> 01:18:19,530

these spin periods for this various

1789
01:18:23,540 --> 01:18:21,630
regular stars and we think that that's a

1790
01:18:25,310 --> 01:18:23,550
proxy for age and so we can tell which

1791
01:18:27,020 --> 01:18:25,320
among them are the oldest stars which

1792
01:18:29,359 --> 01:18:27,030
are the younger stars and that was work

1793
01:18:30,800 --> 01:18:29,369
that by another PhD student Elizabeth

1794
01:18:32,810 --> 01:18:30,810
Newton

1795
01:18:34,550 --> 01:18:32,820
there's a another way to get the ages of

1796
01:18:36,080 --> 01:18:34,560
stars and that's after seismologist so

1797
01:18:38,060 --> 01:18:36,090
if you have really good data stars

1798
01:18:39,560 --> 01:18:38,070
actually pulsated and those are sound

1799
01:18:41,089 --> 01:18:39,570
waves most sound waves go all the way

1800
01:18:42,649 --> 01:18:41,099
through the star and they tell you about

1801
01:18:44,510 --> 01:18:42,659
what's going on in the core of the star

1802
01:18:46,700 --> 01:18:44,520
which is something that changes with age

1803
01:18:48,140 --> 01:18:46,710
and so as the seismology is a really

1804
01:18:50,450 --> 01:18:48,150
great way to do it for something stars

1805
01:19:00,919 --> 01:18:50,460
but unfortunately it doesn't work but

1806
01:19:02,839 --> 01:19:00,929
his works he wore the machine learning

1807
01:19:05,810 --> 01:19:02,849
model like what kind of type would oh

1808
01:19:11,030 --> 01:19:05,820
isn't how is it but look what was a

1809
01:19:12,620 --> 01:19:11,040
trade flip was a trade Oh birth

1810
01:19:15,229 --> 01:19:12,630
telescopes and the machine learning

1811
01:19:16,399 --> 01:19:15,239
didn't to be able to identify things

1812
01:19:18,979 --> 01:19:16,409
yeah okay great

1813
01:19:22,180 --> 01:19:18,989

that's what sir Jason I Devon was EHS

1814
01:19:25,669 --> 01:19:22,190
didn't work with me and he had basically

1815
01:19:27,169 --> 01:19:25,679
like I think one thing and Christians

1816
01:19:29,930 --> 01:19:27,179
because he just had learn about this on

1817
01:19:31,189 --> 01:19:29,940
its own and he he'll tell me who said I

1818
01:19:33,169 --> 01:19:31,199
had a hammer I'm looking for a nail

1819
01:19:34,770 --> 01:19:33,179
answer he said I'm gonna try this on and

1820
01:19:38,760 --> 01:19:34,780
worth trying

1821
01:19:40,380 --> 01:19:38,770
data and so he here asked what is the

1822
01:19:44,700 --> 01:19:40,390
training did so it's a very simple

1823
01:19:47,000 --> 01:19:44,710
machine learning but the trans dataset

1824
01:19:48,840 --> 01:19:47,010
is that he we basically the mirth

1825
01:19:50,190 --> 01:19:48,850
Observatory what's really going on is

1826
01:19:51,360 --> 01:19:50,200
that we are getting triggers all the

1827
01:19:52,290 --> 01:19:51,370
time so there's moments where the

1828
01:19:54,030 --> 01:19:52,300
telescope things

1829
01:19:56,880 --> 01:19:54,040
oh this start is fainter than it was

1830
01:19:59,070 --> 01:19:56,890
maybe I have a transit and so there are

1831
01:20:01,740 --> 01:19:59,080
thousands of those events in the data

1832
01:20:03,900 --> 01:20:01,750
and what he had to do was define the one

1833
01:20:05,730 --> 01:20:03,910
or the two the small number that were

1834
01:20:08,250 --> 01:20:05,740
not just triggers because of bad data

1835
01:20:09,870 --> 01:20:08,260
like to tell us what about the bit or

1836
01:20:11,250 --> 01:20:09,880
the star was a little off from its

1837
01:20:12,600 --> 01:20:11,260
normal position so I made the star up

1838
01:20:14,760 --> 01:20:12,610

here we think about it wasn't really a

1839
01:20:18,540 --> 01:20:14,770
painter from the very small number of

1840
01:20:20,640 --> 01:20:18,550
events this was a real effect and so

1841
01:20:23,610 --> 01:20:20,650
what he did was to train he went and

1842
01:20:30,060 --> 01:20:23,620
took the in Eclipse the transit data

1843
01:20:32,610 --> 01:20:30,070
from known planets and he said

1844
01:20:35,370 --> 01:20:32,620
cannulated that's that's actual good

1845
01:20:36,780 --> 01:20:35,380
transit data so he tricked so then he

1846
01:20:38,610 --> 01:20:36,790
said what are the characteristics of my

1847
01:20:40,560 --> 01:20:38,620
data and he trained it on that good data

1848
01:20:42,240 --> 01:20:40,570
then he said the news on the

1849
01:20:44,580 --> 01:20:42,250
uncharacterized day that he pulled out

1850
01:20:46,140 --> 01:20:44,590
this one phantom okay and when he did it

1851
01:20:48,390 --> 01:20:46,150
was really nice when he brought me the

1852
01:20:49,590 --> 01:20:48,400
transit I have to confess as you know

1853
01:20:52,680 --> 01:20:49,600
I've got to watch it as a professor you

1854
01:20:57,180 --> 01:20:52,690
get kind of overconfident and I said to

1855
01:20:58,530 --> 01:20:57,190
myself this is not this is not you know

1856
01:21:00,420 --> 01:20:58,540
all the guys finishing at what stage do

1857
01:21:02,610 --> 01:21:00,430
you and I I'm gonna you know I think I

1858
01:21:04,560 --> 01:21:02,620
think I just got some slack and maybe

1859
01:21:06,390 --> 01:21:04,570
right and he was right who's right and

1860
01:21:07,290 --> 01:21:06,400
then that really showed me that I should

1861
01:21:17,280 --> 01:21:07,300
not

1862
01:21:22,340 --> 01:21:17,290
and to possibly be considered that life

1863
01:21:27,210 --> 01:21:22,350

could exist a comet or asteroid exist

1864
01:21:30,300 --> 01:21:27,220
asteroid yeah great question so I think

1865
01:21:31,740 --> 01:21:30,310
that in general astrobiologists would

1866
01:21:35,070 --> 01:21:31,750
say they don't expect life to be

1867
01:21:37,470 --> 01:21:35,080
uncommon or an asteroid because we think

1868
01:21:39,750 --> 01:21:37,480
you have to have liquid water and the

1869
01:21:41,700 --> 01:21:39,760
reason is that you need a way for the

1870
01:21:45,240 --> 01:21:41,710
chemistry of life to proceed okay so if

1871
01:21:46,650 --> 01:21:45,250
you have a gas the interesting molecules

1872
01:21:47,730 --> 01:21:46,660
in the gas are too far apart so you

1873
01:21:50,070 --> 01:21:47,740
don't have a chemical connection very

1874
01:21:52,080 --> 01:21:50,080
quickly if it's a solid obviously things

1875
01:21:53,730 --> 01:21:52,090
are locked in the in the crystal lattice

1876
01:21:59,940 --> 01:21:53,740
the can move around so that's why we

1877
01:22:02,040 --> 01:21:59,950
really like liquids for for and so on in

1878
01:22:03,840 --> 01:22:02,050
the comets and asteroids we think

1879
01:22:06,540 --> 01:22:03,850
they're they don't have that everything

1880
01:22:09,750 --> 01:22:06,550
that's called the orbital comments of

1881
01:22:11,910 --> 01:22:09,760
course is a very very elliptical and so

1882
01:22:13,080 --> 01:22:11,920
they they they do change quite a bit

1883
01:22:14,940 --> 01:22:13,090
their distance but they still remain

1884
01:22:28,920 --> 01:22:14,950
quite solved so we so we don't really

1885
01:22:32,370 --> 01:22:28,930
think so taury

1886
01:22:34,170 --> 01:22:32,380
she's your Pied Piper to follow next

1887
01:22:35,520 --> 01:22:34,180
month Courtney McManus we'll be back to

1888
01:22:37,860 --> 01:22:35,530

our regular first Tuesday of the month

1889
01:22:40,710 --> 01:22:37,870
starting next month Courtney ik Manus

1890
01:22:42,270 --> 01:22:40,720
the view from Mission Control and please

1891
01:22:43,600 --> 01:22:42,280
join me in another warm round of

1892
01:23:00,420 --> 01:22:43,610
applause per game

1893
01:23:05,360 --> 01:23:02,979
[Laughter]