PUBLIC LECTURE SERIES

Exoplanets: A Search for New Worlds

Featuring Guest Speaker: Nestor Espinoza

1
00:00:04,249 --> 00:00:01,459
they can have their electronics on

2
00:00:06,880 --> 00:00:04,259
however loud they want all right there's

3
00:00:10,209 --> 00:00:06,890
my remote great tonight

4
00:00:12,020 --> 00:00:10,219
mr. Espinoza will be here to talk about

5
00:00:14,539 --> 00:00:12,030
eventually after we get through with all

6
00:00:18,500 --> 00:00:14,549
the technical difficulties exoplanets a

7
00:00:20,150 --> 00:00:18,510
search for new worlds and we're gonna be

8
00:00:22,790 --> 00:00:20,160
hearing a lot about exoplanets over the

9
00:00:24,980 --> 00:00:22,800
next bunch of years because Janos T is

10
00:00:26,929 --> 00:00:24,990
gonna really do some great stuff and we

11
00:00:29,000 --> 00:00:26,939
are hiring a bunch of exoplanets experts

12
00:00:30,700 --> 00:00:29,010
and Nestor's a brand new one that we

13
00:00:34,370 --> 00:00:30,710

just brought on board

14
00:00:37,580 --> 00:00:34,380
next month April 7th we will be talking

15
00:00:43,779 --> 00:00:37,590
about 30 years of the hubble space

16
00:00:50,840 --> 00:00:48,500
and there are six speakers I believe

17
00:00:52,790 --> 00:00:50,850
that we'll be talking next month I just

18
00:00:54,860 --> 00:00:52,800
got the list I didn't want to put it all

19
00:00:56,900 --> 00:00:54,870
up there so I just call it an all-star

20
00:00:59,689 --> 00:00:56,910
cast of folks will tell you about

21
00:01:02,959 --> 00:00:59,699
Hubble's 30 years and the projects that

22
00:01:07,190 --> 00:01:02,969
we are doing to celebrate it in May we

23
00:01:09,859 --> 00:01:07,200
have our infamous TBA to be announced

24
00:01:11,750 --> 00:01:09,869
June oh my gosh I forgot to fill out

25
00:01:14,899 --> 00:01:11,760
June I have a person for June and I

26
00:01:16,550 --> 00:01:14,909
didn't put it down I'm sorry that was my

27
00:01:18,170 --> 00:01:16,560
fault this afternoon I just going

28
00:01:19,520 --> 00:01:18,180
through the slides quickly I couldn't

29
00:01:22,460 --> 00:01:19,530
wait to get to the stuff about baitul

30
00:01:24,620 --> 00:01:22,470
juice and so I meant to come back and

31
00:01:26,060 --> 00:01:24,630
fill this one in yeah there is a speaker

32
00:01:28,880 --> 00:01:26,070
already for June I already have a

33
00:01:32,020 --> 00:01:28,890
speaker for June I just don't have it in

34
00:01:34,609 --> 00:01:32,030
my head sorry about that

35
00:01:38,480 --> 00:01:34,619
even astrophysicists make mistakes

36
00:01:39,710 --> 00:01:38,490
sometimes right as you all are here know

37
00:01:42,859 --> 00:01:39,720
the building is undergoing

38
00:01:46,249 --> 00:01:42,869

reconstruction the lobby redesign is

39
00:01:48,020 --> 00:01:46,259
getting there however it's not going to

40
00:01:49,880 --> 00:01:48,030
be done for the April public lecture so

41
00:01:51,980 --> 00:01:49,890
just like we had to come in through the

42
00:01:53,090 --> 00:01:51,990
alternate entrance tonight you will have

43
00:01:55,910 --> 00:01:53,100
to come through the alternate entrance

44
00:01:59,060 --> 00:01:55,920
in April I confirm that with building

45
00:02:00,469 --> 00:01:59,070
folks today everyone followed the signs

46
00:02:02,530 --> 00:02:00,479
very nicely the last two months I'm

47
00:02:05,600 --> 00:02:02,540
assuming there was no problem this month

48
00:02:08,029 --> 00:02:05,610
and again if you need wheelchair access

49
00:02:10,910 --> 00:02:08,039
please contact us and we will make

50
00:02:13,130 --> 00:02:10,920
arrangements for that all right our

51
00:02:16,340 --> 00:02:13,140
website for the public

52
00:02:19,430 --> 00:02:16,350
series is nice and simple stsci edu /

53
00:02:22,910 --> 00:02:19,440
public - lectures and you can find links

54
00:02:25,820 --> 00:02:22,920
to the webcasts you can find the not the

55
00:02:29,390 --> 00:02:25,830
place to sign up for our public lecture

56
00:02:32,000 --> 00:02:29,400
announcements you can find a list of the

57
00:02:34,070 --> 00:02:32,010
upcoming lectures unfortunately

58
00:02:35,720 --> 00:02:34,080
featuring the TBA speaker to be

59
00:02:39,160 --> 00:02:35,730
announced stuff that appears there every

60
00:02:41,840 --> 00:02:39,170
now and then sorry as well as

61
00:02:43,460 --> 00:02:41,850
information about previous lectures the

62
00:02:45,890 --> 00:02:43,470
previous lectures give you the

63
00:02:48,440 --> 00:02:45,900

description when it was done as well as

64
00:02:52,340 --> 00:02:48,450
links to the STScI webcast up top and

65
00:02:54,979 --> 00:02:52,350
the YouTube webcast down bottom you can

66
00:02:59,300 --> 00:02:54,989
go back and watch our webcast going all

67
00:03:01,280 --> 00:02:59,310
the way back to 2005 okay you know what

68
00:03:03,890 --> 00:03:01,290
that means we've been doing webcasts for

69
00:03:06,350 --> 00:03:03,900
half of Hubble's lifetime okay Hubble

70
00:03:08,990 --> 00:03:06,360
has been up 30 years for 15 years we've

71
00:03:10,640 --> 00:03:09,000
been doing these webcasts okay so we

72
00:03:13,009 --> 00:03:10,650
can't cover the early years but we can

73
00:03:16,640 --> 00:03:13,019
certainly cover the latter half of

74
00:03:18,199 --> 00:03:16,650
Hubble's life on our webcasts okay the

75
00:03:21,800 --> 00:03:18,209
email announcements sign up at the

76
00:03:22,970 --> 00:03:21,810
website if you can't handle that and you

77
00:03:24,050 --> 00:03:22,980
just want to write it down on a piece of

78
00:03:27,229 --> 00:03:24,060
paper and hand it to me at the end of

79
00:03:28,759 --> 00:03:27,239
lecture please do so if you have

80
00:03:33,199 --> 00:03:28,769
comments or questions you can send them

81
00:03:36,680 --> 00:03:33,209
to public lecture at STScI dot edu and I

82
00:03:39,050 --> 00:03:36,690
will make sure that gets answered social

83
00:03:42,680 --> 00:03:39,060
media if you like Facebook or Twitter or

84
00:03:44,360 --> 00:03:42,690
YouTube or Instagram we have accounts

85
00:03:46,880 --> 00:03:44,370
for the Hubble Space Telescope for the

86
00:03:48,560 --> 00:03:46,890
James Webb Space Telescope and some

87
00:03:52,280 --> 00:03:48,570
accounts for the Space Telescope Science

88
00:03:54,830 --> 00:03:52,290

Institute as well myself I'm just on

89
00:03:59,090 --> 00:03:54,840
Facebook and Twitter every now and then

90
00:04:02,569 --> 00:03:59,100
I'm not continuously on it ah the

91
00:04:04,729 --> 00:04:02,579
observatory tonight they did schedule it

92
00:04:07,490 --> 00:04:04,739
they got it everything already but when

93
00:04:10,039 --> 00:04:07,500
I was out at 7:15 there were clouds and

94
00:04:11,539 --> 00:04:10,049
it was raining so I'm assuming nobody

95
00:04:11,810 --> 00:04:11,549
will show up to take you across the

96
00:04:13,460 --> 00:04:11,820
street

97
00:04:14,810 --> 00:04:13,470
I will check remind me to check at the

98
00:04:17,630 --> 00:04:14,820
end to see if somebody if it's cleared

99
00:04:19,490 --> 00:04:17,640
up for some by some miracle and somebody

100
00:04:21,860 --> 00:04:19,500
is ready to kekua cross street if you

101
00:04:23,450 --> 00:04:21,870
cannot if they don't happen just

102
00:04:25,279 --> 00:04:23,460
remember on Friday evenings they have

103
00:04:26,750 --> 00:04:25,289
open houses you go to MD that Space

104
00:04:28,850 --> 00:04:26,760
Grant o RG

105
00:04:31,280 --> 00:04:28,860
check this webpage the observatory

106
00:04:34,580 --> 00:04:31,290
status in that box there will tell you

107
00:04:38,900 --> 00:04:34,590
all about whether they're open on Friday

108
00:04:43,670 --> 00:04:38,910
evenings great okay now our news from

109
00:04:47,360 --> 00:04:43,680
the universe for March 2001 team our top

110
00:04:51,020 --> 00:04:47,370
story tonight baitul juice dimming it's

111
00:04:53,170 --> 00:04:51,030
not cool man alright you'll understand

112
00:04:55,940 --> 00:04:53,180
what that means in just a second so

113
00:04:58,910 --> 00:04:55,950

battle juice is the shoulder of Orion

114
00:05:00,530 --> 00:04:58,920
the upper left in this picture on the

115
00:05:03,530 --> 00:05:00,540
right there that's star with a little

116
00:05:07,910 --> 00:05:03,540
four arrows around it that is baitul

117
00:05:10,040 --> 00:05:07,920
juice it is a red supergiant star what

118
00:05:13,190 --> 00:05:10,050
does supergiant mean well that's shown

119
00:05:15,320 --> 00:05:13,200
in this image on the left here that is

120
00:05:18,380 --> 00:05:15,330
an image from Hubble Hubble was actually

121
00:05:21,350 --> 00:05:18,390
able to resolve the star into a bunch of

122
00:05:23,750 --> 00:05:21,360
pixels maybe like 10 pixels across and

123
00:05:26,840 --> 00:05:23,760
you can see the size of the star you can

124
00:05:29,300 --> 00:05:26,850
see the size of Earth's orbit and the

125
00:05:32,540 --> 00:05:29,310
size of Jupiter's orbit baitul juices a

126
00:05:34,630 --> 00:05:32,550
thousand times bigger than our Sun and

127
00:05:39,590 --> 00:05:34,640
if it were where our son is

128
00:05:42,590 --> 00:05:39,600
Mercury Venus Earth Mars the asteroid

129
00:05:47,510 --> 00:05:42,600
belt and Jupiter would all be orbiting

130
00:05:50,720 --> 00:05:47,520
in side of baitul juice okay so that's a

131
00:05:52,630 --> 00:05:50,730
big star alright and so it's very famous

132
00:05:56,990 --> 00:05:52,640
it's only seven hundred light years away

133
00:05:58,970 --> 00:05:57,000
so it's been studied a lot so fatal

134
00:06:01,160 --> 00:05:58,980
juice as seen in twenty-two thousand

135
00:06:05,420 --> 00:06:01,170
eighteen has an average visible

136
00:06:08,510 --> 00:06:05,430
magnitude in V band of about 0.5 you'll

137
00:06:11,360 --> 00:06:08,520
notice that the numbers go backwards on

138
00:06:13,040 --> 00:06:11,370

magnitude okay they get smaller as they

139
00:06:16,160 --> 00:06:13,050
go up that's one of the crazy things

140
00:06:18,380 --> 00:06:16,170
about astronomy a lower number is a

141
00:06:20,900 --> 00:06:18,390
higher magnitude a star the first

142
00:06:23,750 --> 00:06:20,910
magnitude is brighter than a star of the

143
00:06:26,180 --> 00:06:23,760
second magnitude okay so baitul juice

144
00:06:30,980 --> 00:06:26,190
from our point of view is a magnitude of

145
00:06:34,040 --> 00:06:30,990
0.5 generally but if you watched in 2019

146
00:06:36,560 --> 00:06:34,050
you would see that it dipped and then

147
00:06:39,160 --> 00:06:36,570
rose back up what does that tell you

148
00:06:40,660 --> 00:06:39,170
that tells you that baitul juice is a

149
00:06:43,450 --> 00:06:40,670
variable star

150
00:06:47,950 --> 00:06:43,460
very it varies on a regular timescale

151
00:06:51,310 --> 00:06:47,960
about 452 days I'm told baile juice has

152
00:06:53,620 --> 00:06:51,320
probably several pulsation modes and the

153
00:06:56,050 --> 00:06:53,630
maximum the major one is about 450 - a

154
00:06:58,480 --> 00:06:56,060
pulsation mode where it gets fainter and

155
00:07:01,240 --> 00:06:58,490
brighter and fainter and brighter they

156
00:07:04,360 --> 00:07:01,250
actually call it a semi-regular variable

157
00:07:05,290 --> 00:07:04,370
star and I'm not exactly sure of it

158
00:07:08,740 --> 00:07:05,300
because I'm not a variable star

159
00:07:10,990 --> 00:07:08,750
specialist but it is an SR V see

160
00:07:17,440 --> 00:07:11,000
according to the semi variable regular

161
00:07:20,980 --> 00:07:17,450
star folks okay now in 2008 2019 fatal

162
00:07:24,310 --> 00:07:20,990
juice did something different it went

163
00:07:27,100 --> 00:07:24,320

from two the bright one you see on the

164
00:07:29,500 --> 00:07:27,110
left to the much fainter one you see on

165
00:07:31,090 --> 00:07:29,510
the right okay these two images are

166
00:07:33,490 --> 00:07:31,100
scaled can we take down off the house

167
00:07:37,210 --> 00:07:33,500
lights a bit guys so you can see that

168
00:07:41,710 --> 00:07:39,280
there we go so these two images were

169
00:07:43,570 --> 00:07:41,720
scaled by this guy Brian autumn to try

170
00:07:45,970 --> 00:07:43,580
and get the exact same brightness of the

171
00:07:47,680 --> 00:07:45,980
background stars so you could see the

172
00:07:50,620 --> 00:07:47,690
difference in battle use and you can see

173
00:07:52,180 --> 00:07:50,630
that in 2019 it's much dimmer than it is

174
00:07:54,490 --> 00:07:52,190
in February 2016

175
00:07:56,890 --> 00:07:54,500
matter of fact bail juice was dropping

176
00:08:01,150 --> 00:07:56,900
below half its usual brightness in

177
00:08:05,080 --> 00:08:01,160
December of 2019 so people were watching

178
00:08:07,180 --> 00:08:05,090
it and they got this plot right so on

179
00:08:09,730 --> 00:08:07,190
the far right you can see that in late

180
00:08:12,730 --> 00:08:09,740
2000 19 and into 20 into the early 2020

181
00:08:14,890 --> 00:08:12,740
bailed used drop it went from you know

182
00:08:17,110 --> 00:08:14,900
it usually goes between about zero and

183
00:08:20,440 --> 00:08:17,120
one magnitude it went down to one and

184
00:08:22,210 --> 00:08:20,450
one point five okay each magnitude is

185
00:08:26,020 --> 00:08:22,220
about a factor of two and a half in

186
00:08:28,570 --> 00:08:26,030
brightness so beta juice dropped to 40%

187
00:08:29,830 --> 00:08:28,580
of its usual brightness this is the

188
00:08:32,529 --> 00:08:29,840

stories you were hearing like is

189
00:08:34,409 --> 00:08:32,539
Betelgeuse gonna explode

190
00:08:36,969 --> 00:08:34,419
no it's probably not gonna explode okay

191
00:08:39,790 --> 00:08:36,979
it will explode I promise you it'll

192
00:08:41,500 --> 00:08:39,800
explode in the next 10 million years but

193
00:08:43,570 --> 00:08:41,510
probably not gonna explode during our

194
00:08:45,280 --> 00:08:43,580
lifetime we will not I guarantee you

195
00:08:46,750 --> 00:08:45,290
we're not gonna be that lucky to see

196
00:08:49,120 --> 00:08:46,760
baitul use explode that would be an

197
00:08:52,840 --> 00:08:49,130
amazing sight if we could see it but

198
00:08:57,160 --> 00:08:52,850
unfortunately I can't exceed enough to

199
00:08:58,660 --> 00:08:57,170
see that so what's going on how are you

200
00:09:00,820 --> 00:08:58,670
gonna figure out what's really going on

201
00:09:02,770 --> 00:09:00,830
you're not just going to measure the

202
00:09:05,230 --> 00:09:02,780
brightness of the star you're gonna

203
00:09:07,540 --> 00:09:05,240
measure its spectrum and a paper was

204
00:09:10,030 --> 00:09:07,550
just recently published by Emily

205
00:09:13,240 --> 00:09:10,040
Levesque and mr. Massey I forget his

206
00:09:16,180 --> 00:09:13,250
first name and they got spectrum of

207
00:09:18,670 --> 00:09:16,190
baitul juice and they compared the

208
00:09:21,630 --> 00:09:18,680
spectra of baitul juice from 2004 which

209
00:09:22,840 --> 00:09:21,640
is shown in red here to the spectrum in

210
00:09:25,270 --> 00:09:22,850
2020

211
00:09:27,100 --> 00:09:25,280
now there's an offset between the two of

212
00:09:28,810 --> 00:09:27,110
them and we'll get to that later but

213
00:09:31,480 --> 00:09:28,820

what they were really interested in is

214
00:09:33,280 --> 00:09:31,490
trying to measure the temperature the

215
00:09:34,690 --> 00:09:33,290
surface temperature of baitul juice and

216
00:09:36,670 --> 00:09:34,700
to measure the surface temperature

217
00:09:38,829 --> 00:09:36,680
you're looking at those absorption lines

218
00:09:41,020 --> 00:09:38,839
that the jags that go down those are the

219
00:09:43,900 --> 00:09:41,030
absorption lines and in particular the

220
00:09:47,110 --> 00:09:43,910
titanium oxide absorption lines are a

221
00:09:49,030 --> 00:09:47,120
strong indicator of temperature the more

222
00:09:50,420 --> 00:09:49,040
titanium oxide that's forms in the

223
00:09:53,420 --> 00:09:50,430
atmosphere of

224
00:09:56,150 --> 00:09:53,430
a red supergiant star the cooler it's

225
00:09:57,530 --> 00:09:56,160
temperature is and they found that yes

226
00:09:59,780 --> 00:09:57,540
there's a difference in the titanium

227
00:10:01,820 --> 00:09:59,790
oxide absorption lines but it's not a

228
00:10:05,300 --> 00:10:01,830
huge one they estimate the temperature

229
00:10:08,990 --> 00:10:05,310
in 2004 was three thousand six hundred

230
00:10:10,460 --> 00:10:09,000
and fifty degrees Kelvin and in 2020 was

231
00:10:14,120 --> 00:10:10,470
three thousand six hundred degrees

232
00:10:17,120 --> 00:10:14,130
Kelvin so a 50 degree Kelvin difference

233
00:10:20,930 --> 00:10:17,130
and unfortunately the ever bar the

234
00:10:23,480 --> 00:10:20,940
method is 25 degrees Kelvin so really

235
00:10:26,329 --> 00:10:23,490
not much temperature difference so the

236
00:10:29,690 --> 00:10:26,339
the idea that baitul juice was cooler

237
00:10:32,600 --> 00:10:29,700
and therefore emitting less light is not

238
00:10:35,240 --> 00:10:32,610

the reason for beta juice dimming okay

239
00:10:38,900 --> 00:10:35,250
this is why baitul juice dimming is not

240
00:10:42,230 --> 00:10:38,910
cool it's not that it's cooler that it's

241
00:10:45,530 --> 00:10:42,240
dimming okay I told you I'd get around

242
00:10:48,860 --> 00:10:45,540
to explaining my silly puns so what else

243
00:10:51,050 --> 00:10:48,870
could be going on all right well if you

244
00:10:53,960 --> 00:10:51,060
look at a different look at it it gives

245
00:10:57,680 --> 00:10:53,970
you a clue so here on the green is the

246
00:11:00,980 --> 00:10:57,690
visible light but up here in the magenta

247
00:11:03,800 --> 00:11:00,990
and the gray are two bands of infrared

248
00:11:07,699 --> 00:11:03,810
the J and the H bands in the infrared

249
00:11:12,040 --> 00:11:07,709
and you can see back in 2018 and 2019

250
00:11:15,500 --> 00:11:12,050
and now in 2020 they're all the same

251
00:11:18,170 --> 00:11:15,510
fatal juice is not changing in the

252
00:11:20,090 --> 00:11:18,180
infrared which by the way is where most

253
00:11:22,850 --> 00:11:20,100
of its light actually comes out it's a

254
00:11:25,730 --> 00:11:22,860
red supergiant it emits huge amounts of

255
00:11:28,579 --> 00:11:25,740
light in the infrared most of that light

256
00:11:31,130 --> 00:11:28,589
is not changing so what's going on

257
00:11:33,290 --> 00:11:31,140
something is blocking the visible light

258
00:11:34,880 --> 00:11:33,300
all right so it's like yellow you're

259
00:11:37,040 --> 00:11:34,890
blocking the light hey well that's an

260
00:11:40,760 --> 00:11:37,050
idea maybe there's a cloud of something

261
00:11:42,800 --> 00:11:40,770
in the way a cloud of dust and we

262
00:11:45,170 --> 00:11:42,810
compare these images which are taken by

263
00:11:47,870 --> 00:11:45,180

the European Southern Observatory in

264
00:11:49,430 --> 00:11:47,880
January 2019 they happen to have that

265
00:11:52,100 --> 00:11:49,440
image hanging around they took another

266
00:11:54,860 --> 00:11:52,110
one in December 2019 and you can see

267
00:11:57,290 --> 00:11:54,870
that it does look a bit gray this is

268
00:12:00,170 --> 00:11:57,300
another instrument that was able to

269
00:12:02,660 --> 00:12:00,180
resolve fatal juice into more than just

270
00:12:03,360 --> 00:12:02,670
a point of light so we can see that it

271
00:12:06,390 --> 00:12:03,370
looks or

272
00:12:08,579 --> 00:12:06,400
maybe there is a dust cloud there and if

273
00:12:11,940 --> 00:12:08,589
you go back to the idiot that you go

274
00:12:14,010 --> 00:12:11,950
back to the spectra you can see there is

275
00:12:16,769 --> 00:12:14,020
that decrement between there and that

276
00:12:18,750 --> 00:12:16,779
decrement exists all the way across the

277
00:12:21,329 --> 00:12:18,760
visible light and it gets a little bit

278
00:12:24,540 --> 00:12:21,339
less in the blue region which is kind of

279
00:12:26,550 --> 00:12:24,550
what you would expect for dust now it

280
00:12:28,890 --> 00:12:26,560
doesn't work if it's small grain dust

281
00:12:30,960 --> 00:12:28,900
they tell me but the large grain dust

282
00:12:33,860 --> 00:12:30,970
that these supergiant stars can blow off

283
00:12:36,930 --> 00:12:33,870
these supergiant stars blow off that

284
00:12:40,769 --> 00:12:36,940
some some dust every now and then could

285
00:12:43,560 --> 00:12:40,779
be the culprit for this okay so it's not

286
00:12:47,190 --> 00:12:43,570
due to cooling it could be due to large

287
00:12:49,110 --> 00:12:47,200
grain dust have we proven it no we will

288
00:12:52,769 --> 00:12:49,120

continue to take up more and more

289
00:12:56,490 --> 00:12:52,779
observations but things are actually

290
00:13:00,300 --> 00:12:56,500
looking up because Bale Jews reached a

291
00:13:03,600 --> 00:13:00,310
minimum on February 22nd and this is the

292
00:13:06,750 --> 00:13:03,610
plot from the account at baitul bot on

293
00:13:09,480 --> 00:13:06,760
Twitter which publishes light curves of

294
00:13:10,740 --> 00:13:09,490
baitul Jews every single day keeps you

295
00:13:12,540 --> 00:13:10,750
up to date on all the latest

296
00:13:16,140 --> 00:13:12,550
observations on bale Jews if you want to

297
00:13:19,079 --> 00:13:16,150
follow it and you can see that on

298
00:13:22,790 --> 00:13:19,089
February 22nd about 10-15 days ago

299
00:13:26,070 --> 00:13:22,800
it reached minimum at around magnitude

300
00:13:28,440 --> 00:13:26,080
1.6 mile which is just a little bit

301
00:13:30,390 --> 00:13:28,450
around 40% a little less than 40% if

302
00:13:34,699 --> 00:13:30,400
it's normal brightness and now it

303
00:13:36,720 --> 00:13:34,709
started to rise and this is I'm told

304
00:13:38,370 --> 00:13:36,730
reasonable this is what they sort of

305
00:13:41,780 --> 00:13:38,380
would predict if it's undergoing

306
00:13:44,790 --> 00:13:41,790
standard variations and such all right

307
00:13:46,199 --> 00:13:44,800
however I went through to the American

308
00:13:48,449 --> 00:13:46,209
Association of variable star observers

309
00:13:50,970 --> 00:13:48,459
website and I looked and I said hey what

310
00:13:54,769 --> 00:13:50,980
if what have you got and they had this

311
00:13:58,800 --> 00:13:54,779
plot here this goes all the way back to

312
00:14:02,730 --> 00:13:58,810
1911 and goes through to 2001 this is 90

313
00:14:05,579 --> 00:14:02,740

years of baitul juice data and the three

314
00:14:08,579 --> 00:14:05,589
orange boxes I've noted there also have

315
00:14:12,540 --> 00:14:08,589
dips that extend down to minus to expand

316
00:14:14,280 --> 00:14:12,550
down to about 1.5 in magnitude so while

317
00:14:16,440 --> 00:14:14,290
we think this is exceptional this is

318
00:14:17,970 --> 00:14:16,450
definitely exceptional under the

319
00:14:19,560 --> 00:14:17,980
the era where we really closely

320
00:14:20,940 --> 00:14:19,570
monitored and really get great

321
00:14:23,250 --> 00:14:20,950
observations of bale Jews

322
00:14:26,610 --> 00:14:23,260
it may not be exceptional because it

323
00:14:28,860 --> 00:14:26,620
looks like late 1940s and during the

324
00:14:31,530 --> 00:14:28,870
1970s and into the 80s there were at

325
00:14:34,440 --> 00:14:31,540
least a couple other times when bata

326
00:14:37,380 --> 00:14:34,450
juice dipped down that low alright so

327
00:14:41,300 --> 00:14:37,390
just this dip doesn't indicate that it's

328
00:14:44,820 --> 00:14:41,310
going to go supernova it's indicative of

329
00:14:46,470 --> 00:14:44,830
interesting trends in it and we'll have

330
00:14:51,270 --> 00:14:46,480
more for you on this story

331
00:14:56,190 --> 00:14:51,280
eventually okay all right our next story

332
00:14:58,110 --> 00:14:56,200
the sombrero galaxy mixes it up alright

333
00:15:00,330 --> 00:14:58,120
so first we got to start with spiral

334
00:15:03,360 --> 00:15:00,340
galaxies and our favorite spiral galaxy

335
00:15:05,910 --> 00:15:03,370
is the Milky Way galaxy and on the Left

336
00:15:08,220 --> 00:15:05,920
we see a face on view of a spiral galaxy

337
00:15:09,840 --> 00:15:08,230
with the beautiful spiral arms and a

338
00:15:13,170 --> 00:15:09,850

rough approximation of where our Sun

339
00:15:15,660 --> 00:15:13,180
would be in that spiral galaxy but well

340
00:15:18,600 --> 00:15:15,670
pay attention to is really on the right

341
00:15:20,970 --> 00:15:18,610
okay and you can see on the right that

342
00:15:23,580 --> 00:15:20,980
in the center we have this nice flat

343
00:15:26,940 --> 00:15:23,590
disc and in the core of that we have

344
00:15:30,090 --> 00:15:26,950
this bulge and around that we have these

345
00:15:32,520 --> 00:15:30,100
globular clusters and then well outside

346
00:15:34,920 --> 00:15:32,530
of that we have this faint stellar halo

347
00:15:37,260 --> 00:15:34,930
okay and those are the sort of typical

348
00:15:40,350 --> 00:15:37,270
structures we find in spiral galaxies

349
00:15:42,720 --> 00:15:40,360
and because star formation is going on

350
00:15:45,480 --> 00:15:42,730
in the disk the young stars in the disk

351
00:15:48,750 --> 00:15:45,490
and they're creating new elements what

352
00:15:50,700 --> 00:15:48,760
you find is that the most metal-rich

353
00:15:54,420 --> 00:15:50,710
which means just heavy element rich

354
00:15:56,220 --> 00:15:54,430
stars are in the disk and the stuff in

355
00:16:01,230 --> 00:15:56,230
the stellar halo is relatively

356
00:16:02,640 --> 00:16:01,240
metal-poor okay so some small amounts of

357
00:16:05,190 --> 00:16:02,650
heavy elements and the stars that are

358
00:16:07,680 --> 00:16:05,200
out in the halo large amounts that stuff

359
00:16:09,780 --> 00:16:07,690
that's in the disk and we find that's

360
00:16:12,720 --> 00:16:09,790
true in other galaxies we've looked at

361
00:16:14,460 --> 00:16:12,730
the Andromeda galaxy not at the main

362
00:16:17,190 --> 00:16:14,470
disk there but in that small little

363
00:16:19,080 --> 00:16:17,200

orange box up there Hubble took an

364
00:16:22,500 --> 00:16:19,090
amazing image called the stellar deep

365
00:16:25,410 --> 00:16:22,510
field and almost every star you see in

366
00:16:27,840 --> 00:16:25,420
this image is a star in Andromeda two

367
00:16:28,770 --> 00:16:27,850
and a half million light-years away we

368
00:16:31,640 --> 00:16:28,780
can study

369
00:16:35,040 --> 00:16:31,650
dual stars in Andromeda how cool is that

370
00:16:36,120 --> 00:16:35,050
and the Gallic stars in the halo fit our

371
00:16:39,030 --> 00:16:36,130
predictions that they would be

372
00:16:40,200 --> 00:16:39,040
metal-poor in the halo oh and by the way

373
00:16:42,780 --> 00:16:40,210
on the right hand side you see that

374
00:16:46,410 --> 00:16:42,790
globular cluster that's a globular

375
00:16:48,780 --> 00:16:46,420
cluster in Andromeda yeah

376
00:16:50,130 --> 00:16:48,790
Hubble can get that cool of an image of

377
00:16:51,540 --> 00:16:50,140
a globular cluster two and a half

378
00:16:54,750 --> 00:16:51,550
million light-years away

379
00:16:59,700 --> 00:16:54,760
that blew my mind when this came out was

380
00:17:02,280 --> 00:16:59,710
it 2004 2005 timeframe great so the

381
00:17:05,400 --> 00:17:02,290
story tonight concerns the sombrero

382
00:17:07,679 --> 00:17:05,410
galaxy and the sombrero is a spiral

383
00:17:09,329 --> 00:17:07,689
galaxy but it's also an elliptical

384
00:17:12,000 --> 00:17:09,339
galaxy because it's what we call a

385
00:17:14,520 --> 00:17:12,010
lenticular galaxy it's got that disk

386
00:17:17,340 --> 00:17:14,530
that is indicative of spiral galaxies

387
00:17:19,740 --> 00:17:17,350
but it's got that huge bulge filling out

388
00:17:22,800 --> 00:17:19,750

all of space that's indicative of

389
00:17:25,319 --> 00:17:22,810
elliptical galaxies so they wanted to

390
00:17:28,559 --> 00:17:25,329
study the halo of the stellar halo of

391
00:17:31,170 --> 00:17:28,569
this lenticular galaxy and see well do

392
00:17:33,900 --> 00:17:31,180
we have some ideas on how it formed all

393
00:17:36,000 --> 00:17:33,910
right so they took a region that's well

394
00:17:38,430 --> 00:17:36,010
up outside it this region here and

395
00:17:40,110 --> 00:17:38,440
observed it with Hubble and then within

396
00:17:41,970 --> 00:17:40,120
the Hubble view we're going to take a

397
00:17:45,660 --> 00:17:41,980
look at two close-ups this yellow one

398
00:17:48,300 --> 00:17:45,670
and there's blue one to see the stars in

399
00:17:50,010 --> 00:17:48,310
the sombrero galaxy now we don't see

400
00:17:52,410 --> 00:17:50,020
them as clearly as we do in Andromeda

401
00:17:54,120 --> 00:17:52,420
but let's sombrero galaxy is like twelve

402
00:17:55,620 --> 00:17:54,130
million light-years away

403
00:17:57,540 --> 00:17:55,630
so we don't have quite the same

404
00:18:00,540 --> 00:17:57,550
resolution on them but still it's

405
00:18:03,660 --> 00:18:00,550
amazing we're able to study stars in the

406
00:18:07,440 --> 00:18:03,670
sombrero galaxy but what's even more

407
00:18:12,570 --> 00:18:07,450
amazing is that it doesn't play by the

408
00:18:16,370 --> 00:18:12,580
rules there are almost no metal poor

409
00:18:20,640 --> 00:18:16,380
stars in the halo of the sombrero galaxy

410
00:18:22,860 --> 00:18:20,650
while there are metal-rich stars in the

411
00:18:26,550 --> 00:18:22,870
halo of the of the sombrero galaxy and

412
00:18:30,480 --> 00:18:26,560
that gets astronomers scratching their

413
00:18:32,910 --> 00:18:30,490

heads we thought we understood the halos

414
00:18:34,800 --> 00:18:32,920
we're supposed to be metal-poor but here

415
00:18:38,180 --> 00:18:34,810
we've got one we that has metal-rich

416
00:18:40,710 --> 00:18:38,190
stars in it now you can see there is um

417
00:18:42,120 --> 00:18:40,720
globular clusters out in this in these

418
00:18:43,890 --> 00:18:42,130
patches right

419
00:18:45,270 --> 00:18:43,900
and those Glauber clusters fit like

420
00:18:47,610 --> 00:18:45,280
globular clusters in our galaxy

421
00:18:50,610 --> 00:18:47,620
Andromeda galaxy and their metal-poor

422
00:18:53,160 --> 00:18:50,620
stars in those globular clusters but not

423
00:18:57,090 --> 00:18:53,170
in the field in the halo of some

424
00:18:59,940 --> 00:18:57,100
sombrero we have a thing at our news

425
00:19:02,900 --> 00:18:59,950
meetings and we often go oh us the

426
00:19:06,690 --> 00:19:02,910
headline will be astronomers baffled

427
00:19:08,910 --> 00:19:06,700
yeah this is kind of baffling but you

428
00:19:11,490 --> 00:19:08,920
know as an astronomer I sort of like it

429
00:19:14,610 --> 00:19:11,500
because it keeps us employed there are

430
00:19:18,420 --> 00:19:14,620
still puzzles to be solved so we don't

431
00:19:20,820 --> 00:19:18,430
actually know how this formed one of the

432
00:19:24,360 --> 00:19:20,830
ways you can get metal-rich stars out is

433
00:19:26,340 --> 00:19:24,370
if you have an interaction okay here are

434
00:19:28,350 --> 00:19:26,350
two galaxies that are smashing together

435
00:19:30,660 --> 00:19:28,360
and you can see material gets thrown out

436
00:19:32,910 --> 00:19:30,670
to huge distances right and you could

437
00:19:37,560 --> 00:19:32,920
populate the halo with metal-rich stars

438
00:19:39,960 --> 00:19:37,570

that way except you would also as you

439
00:19:42,420 --> 00:19:39,970
see disrupt the bay the regular features

440
00:19:46,470 --> 00:19:42,430
of the galaxies and when you look at

441
00:19:48,960 --> 00:19:46,480
sombrero galaxy it's not disrupted so

442
00:19:51,030 --> 00:19:48,970
there was no major merger that we can

443
00:19:54,900 --> 00:19:51,040
tell certainly not for the last five or

444
00:19:57,510 --> 00:19:54,910
six billion years that disrupted the

445
00:20:00,630 --> 00:19:57,520
sombrero galaxy and could have thrown

446
00:20:03,930 --> 00:20:00,640
metal-rich stuff out to the outside so

447
00:20:05,280 --> 00:20:03,940
it really is a head scratcher here so I

448
00:20:07,080 --> 00:20:05,290
guess I'm gonna give you two stories

449
00:20:09,720 --> 00:20:07,090
tonight where I'm not really gonna give

450
00:20:11,880 --> 00:20:09,730
you a bottom line I'm going to say hey

451
00:20:16,050 --> 00:20:11,890
this is interesting we're gonna continue

452
00:20:18,090 --> 00:20:16,060
studying it and more information later I

453
00:20:20,430 --> 00:20:18,100
guess that's my whole career it's like

454
00:20:23,160 --> 00:20:20,440
alright we'll figure this out eventually

455
00:20:26,850 --> 00:20:23,170
and we'll get some things but yeah the

456
00:20:29,130 --> 00:20:26,860
sombrero galaxy doesn't play by the

457
00:20:30,990 --> 00:20:29,140
rules it has mixed it up in terms of the

458
00:20:35,700 --> 00:20:31,000
metal-poor and metal-rich stars in its

459
00:20:37,410 --> 00:20:35,710
halo all right now that is our news from

460
00:20:39,360 --> 00:20:37,420
the universe and I know there's a

461
00:20:41,100 --> 00:20:39,370
question come ask me later cuz I gotta

462
00:20:42,960 --> 00:20:41,110
get to Nestor we're already late because

463
00:20:46,170 --> 00:20:42,970

of the technical difficulties all right

464
00:20:48,890 --> 00:20:46,180
so now we go to our featured speaker

465
00:20:53,610 --> 00:20:48,900
tonight and our featured speaker is

466
00:20:55,080 --> 00:20:53,620
Nestor Espinosa he is in the i ns group

467
00:20:55,900 --> 00:20:55,090
here and he can give you what the

468
00:20:58,240 --> 00:20:55,910
acronym mean

469
00:21:02,020 --> 00:20:58,250
ever he's working on the James Webb

470
00:21:05,500 --> 00:21:02,030
Space Telescope he did his uh his

471
00:21:07,390 --> 00:21:05,510
graduate work in Chile where he sells me

472
00:21:09,700 --> 00:21:07,400
he was the host of a radio program

473
00:21:12,010 --> 00:21:09,710
talking about astronomy so he has

474
00:21:13,680 --> 00:21:12,020
experience in doing that then he spent

475
00:21:16,270 --> 00:21:13,690
some time doing postdocs and

476
00:21:18,720 --> 00:21:16,280
postgraduate work in Germany at Max

477
00:21:20,830 --> 00:21:18,730
Planck Institute in Heidelberg and

478
00:21:22,780 --> 00:21:20,840
fortunately we were able to snare him

479
00:21:24,430 --> 00:21:22,790
from there bring him here because

480
00:21:25,570 --> 00:21:24,440
there's some amazing exoplanet

481
00:21:27,400 --> 00:21:25,580
discoveries to be had with the James

482
00:21:28,870 --> 00:21:27,410
Webb Space Telescope and he'll tell you

483
00:21:53,410 --> 00:21:28,880
about them tonight ladies and gentlemen

484
00:21:54,160 --> 00:21:53,420
Nestor Espinoza can you hear me all

485
00:21:57,130 --> 00:21:54,170
right

486
00:22:00,670 --> 00:21:57,140
I'm extremely excited once in a once in

487
00:22:03,010 --> 00:22:00,680
a couple years ago I was exactly where

488
00:22:04,590 --> 00:22:03,020

you were seated right now I remember

489
00:22:06,940 --> 00:22:04,600
coming to Baltimore at some point I'm

490
00:22:08,260 --> 00:22:06,950
coming to the Space Telescope Science

491
00:22:10,990 --> 00:22:08,270
Institute which is you know it's a

492
00:22:12,990 --> 00:22:11,000
renown Institute for doing a strong yen

493
00:22:16,420 --> 00:22:13,000
you know exoplanet science with a big

494
00:22:18,100 --> 00:22:16,430
telescopes in space I wouldn't have

495
00:22:20,440 --> 00:22:18,110
ambition that I will be sitting here

496
00:22:23,020 --> 00:22:20,450
kind of sharing what we're doing with

497
00:22:27,100 --> 00:22:23,030
exoplanets so it's really a privilege to

498
00:22:29,530 --> 00:22:27,110
be here so I'm gonna share with you a

499
00:22:32,230 --> 00:22:29,540
cup of bit of the science that we are

500
00:22:34,510 --> 00:22:32,240
doing in terms of the exoplanets and

501
00:22:38,440 --> 00:22:34,520
which is really a search for new worlds

502
00:22:42,880 --> 00:22:38,450
so because this is such a touching thing

503
00:22:44,950 --> 00:22:42,890
for us Earthlings I really have to give

504
00:22:47,170 --> 00:22:44,960
you a little bit of a context on here

505
00:22:51,670 --> 00:22:47,180
and I think the context touch deeply

506
00:22:54,180 --> 00:22:51,680
within our human nature so if you if you

507
00:22:56,920 --> 00:22:54,190
relax for a moment and start thinking of

508
00:22:59,680 --> 00:22:56,930
what have we lived here in Earth so

509
00:23:02,110 --> 00:22:59,690
think about you know every person has

510
00:23:06,730 --> 00:23:02,120
been burned every species that has been

511
00:23:09,730 --> 00:23:06,740
grown every kind of sunset or sunrise

512
00:23:11,800 --> 00:23:09,740
that have happened in this planet

513
00:23:14,890 --> 00:23:11,810

think of every book you know think of

514
00:23:16,960 --> 00:23:14,900
every scientific fact every relationship

515
00:23:19,090 --> 00:23:16,970
that you have established and that other

516
00:23:22,960 --> 00:23:19,100
people have stylish so all that has

517
00:23:24,880 --> 00:23:22,970
happened you know here in particular for

518
00:23:27,550 --> 00:23:24,890
some of you folks here in Baltimore for

519
00:23:30,730 --> 00:23:27,560
me back in Chile at some point and this

520
00:23:33,940 --> 00:23:30,740
little pale blue dot as Carl Sagan used

521
00:23:36,640 --> 00:23:33,950
to call it is just you know one little

522
00:23:38,500 --> 00:23:36,650
dot in the solar system of the noun

523
00:23:42,430 --> 00:23:38,510
eight planets in my heart they're still

524
00:23:45,430 --> 00:23:42,440
nine so the Plutonians will be happy

525
00:23:47,800 --> 00:23:45,440
with me so this little pale blue dot is

526
00:23:50,500 --> 00:23:47,810
just you know one in this big big solar

527
00:23:54,550 --> 00:23:50,510
system and the solar system of its one

528
00:23:57,520 --> 00:23:54,560
star of the hundreds of hundred

529
00:23:59,200 --> 00:23:57,530
thousands of millions of stars in the

530
00:24:01,570 --> 00:23:59,210
galaxy so if this galaxy where's the

531
00:24:04,450 --> 00:24:01,580
scale here just sound will be in atoms

532
00:24:07,330 --> 00:24:04,460
it's extremely strict small and this is

533
00:24:10,120 --> 00:24:07,340
at the same time one of hundreds of

534
00:24:13,360 --> 00:24:10,130
thousands of millions of galaxies in the

535
00:24:15,850 --> 00:24:13,370
universe so I want you to picture where

536
00:24:17,910 --> 00:24:15,860
you're standing right now so envision

537
00:24:21,820 --> 00:24:17,920
the numbers and I'm gonna repeat them

538
00:24:25,300 --> 00:24:21,830

hundred thousand millions meet billions

539
00:24:27,040 --> 00:24:25,310
as you call them sometimes of galaxies

540
00:24:29,890 --> 00:24:27,050
and the same amount of order of

541
00:24:32,500 --> 00:24:29,900
magnitude of stars per galaxy so we're

542
00:24:34,630 --> 00:24:32,510
just one dot smaller so think of the

543
00:24:36,310 --> 00:24:34,640
possibilities now things of the

544
00:24:37,780 --> 00:24:36,320
possibilities around all the stars that

545
00:24:40,360 --> 00:24:37,790
we look up when you look up in the sky

546
00:24:44,200 --> 00:24:40,370
so what we know today for example is

547
00:24:46,540 --> 00:24:44,210
that on average every star has at least

548
00:24:48,070 --> 00:24:46,550
one planet so if you pick a star when

549
00:24:50,080 --> 00:24:48,080
you go out if it you know clears out

550
00:24:52,390 --> 00:24:50,090
when you go out and see your star

551
00:24:53,530 --> 00:24:52,400
there's an average one planet orbiting

552
00:24:53,980 --> 00:24:53,540
each of the stars that you see in the

553
00:24:56,650 --> 00:24:53,990
sky

554
00:24:59,470 --> 00:24:56,660
so imagine the possibilities so are all

555
00:25:01,300 --> 00:24:59,480
these these planetary systems like ours

556
00:25:03,100 --> 00:25:01,310
are all like the solar system so for

557
00:25:04,750 --> 00:25:03,110
example we were thought and in the solar

558
00:25:06,310 --> 00:25:04,760
system the giant planets are in the

559
00:25:09,340 --> 00:25:06,320
outskirts of the solar system right

560
00:25:10,690 --> 00:25:09,350
these gaseous planets out here and then

561
00:25:13,960 --> 00:25:10,700
in the inside you have these rocky

562
00:25:17,230 --> 00:25:13,970
planets where that's us here so is this

563
00:25:19,810 --> 00:25:17,240

you know common is this are we weird or

564
00:25:21,520 --> 00:25:19,820
not so this is one of the questions that

565
00:25:23,070 --> 00:25:21,530
you can start answering today so we live

566
00:25:25,379 --> 00:25:23,080
in an amazing era

567
00:25:27,840 --> 00:25:25,389
which we can now start answering these

568
00:25:29,460 --> 00:25:27,850
questions like are we weird how common

569
00:25:32,100 --> 00:25:29,470
explants are bronze like Earth for

570
00:25:34,109 --> 00:25:32,110
example so before we turned you into

571
00:25:36,060 --> 00:25:34,119
dust dump those questions how weird are

572
00:25:38,700 --> 00:25:36,070
we I want to tell you a little bit about

573
00:25:41,970 --> 00:25:38,710
how how do we go in answering these

574
00:25:44,669 --> 00:25:41,980
questions from the exoplanet world I

575
00:25:47,279 --> 00:25:44,679
used when I when I went to schools

576
00:25:49,350 --> 00:25:47,289
giving public talks I usually would play

577
00:25:52,169 --> 00:25:49,360
this game in which I will ask you know

578
00:25:54,450 --> 00:25:52,179
kids what would you do if I gave you

579
00:25:56,999 --> 00:25:54,460
know 1 billion dollars and you can build

580
00:26:00,210 --> 00:25:57,009
whatever you want of course the last of

581
00:26:01,889 --> 00:26:00,220
the priorities were telescopes right but

582
00:26:04,109 --> 00:26:01,899
if I envisioned them to think about

583
00:26:06,629 --> 00:26:04,119
telescopes and I told them like okay

584
00:26:08,149 --> 00:26:06,639
let's let's play that you want to find

585
00:26:10,979 --> 00:26:08,159
planets how would you do it

586
00:26:13,769 --> 00:26:10,989
so the typical answer is war just will

587
00:26:15,899 --> 00:26:13,779
build a huge telescope and look at it

588
00:26:18,539 --> 00:26:15,909

and then try to look for planets around

589
00:26:21,060 --> 00:26:18,549
the stars extremely simple first sound

590
00:26:22,739 --> 00:26:21,070
that we can actually do that so today

591
00:26:25,919 --> 00:26:22,749
for example this is one of these systems

592
00:26:30,419 --> 00:26:25,929
in which you can actually see so here's

593
00:26:32,249 --> 00:26:30,429
like it's like a movie in time and you

594
00:26:34,349 --> 00:26:32,259
can actually see planets moving around

595
00:26:37,019 --> 00:26:34,359
so these in this case you can actually

596
00:26:40,590 --> 00:26:37,029
see four planets by you know I hear in

597
00:26:42,930 --> 00:26:40,600
this picture and these are this kind

598
00:26:45,060 --> 00:26:42,940
this method of detecting exoplanet it's

599
00:26:46,200 --> 00:26:45,070
what we call direct imaging it makes

600
00:26:50,759 --> 00:26:46,210
sense because you're actually

601
00:26:52,529 --> 00:26:50,769
imaging as you can see here however this

602
00:26:54,299 --> 00:26:52,539
is the star is being blocked so the

603
00:26:56,820 --> 00:26:54,309
technique that people use to detect

604
00:26:58,529 --> 00:26:56,830
planets should dig imaging what they

605
00:27:01,590 --> 00:26:58,539
actually do is what we do when we see

606
00:27:03,570 --> 00:27:01,600
the Sun is too bright on our eyes so we

607
00:27:05,879 --> 00:27:03,580
just block it with our hands so we do

608
00:27:07,590 --> 00:27:05,889
the same thing but we put like a small

609
00:27:09,919 --> 00:27:07,600
needle in front of the telescope when we

610
00:27:12,450 --> 00:27:09,929
block the star and that's how we get

611
00:27:14,570 --> 00:27:12,460
extremely simple it's actually extremely

612
00:27:18,869 --> 00:27:14,580
complicated but don't tell my colleagues

613
00:27:21,479 --> 00:27:18,879

so this kind of technique can only be

614
00:27:24,119 --> 00:27:21,489
applied however for a very very special

615
00:27:26,820 --> 00:27:24,129
types of systems so very closeby stars

616
00:27:29,430 --> 00:27:26,830
for example very bright planets usually

617
00:27:31,980 --> 00:27:29,440
very young so this is not really done

618
00:27:35,310 --> 00:27:31,990
right now for looking like planets like

619
00:27:36,840 --> 00:27:35,320
person for example so the method with

620
00:27:39,420 --> 00:27:36,850
which most of the plan

621
00:27:41,370 --> 00:27:39,430
today are discovered that's actually not

622
00:27:43,650 --> 00:27:41,380
with this method it's with another

623
00:27:47,090 --> 00:27:43,660
method that I want to introduce to you

624
00:27:52,740 --> 00:27:47,100
using the most famous creatures on earth

625
00:27:55,410 --> 00:27:52,750
which are cats I'm not particularly fond

626
00:27:59,280 --> 00:27:55,420
of cats so I'm gonna put them in space

627
00:28:02,820 --> 00:27:59,290
but don't do this at all so here's a

628
00:28:03,590 --> 00:28:02,830
star right like our Sun here's a little

629
00:28:08,400 --> 00:28:03,600
kitten

630
00:28:10,350 --> 00:28:08,410
experiment by the way so what you're

631
00:28:12,480 --> 00:28:10,360
gonna see is that I'm gonna put put the

632
00:28:13,530 --> 00:28:12,490
cat in orbit around the star right so at

633
00:28:17,460 --> 00:28:13,540
some point you're gonna see the cat

634
00:28:19,680 --> 00:28:17,470
happening did you see it when in front

635
00:28:22,710 --> 00:28:19,690
of it right so we say as astronomers we

636
00:28:25,620 --> 00:28:22,720
say the cat was transiting in front of

637
00:28:28,590 --> 00:28:25,630
the star right so for those folks that

638
00:28:30,870 --> 00:28:28,600

you did inside here's again so what we

639
00:28:32,250 --> 00:28:30,880
do to search and what we have been using

640
00:28:35,070 --> 00:28:32,260
the technique that we have been using to

641
00:28:38,160 --> 00:28:35,080
detect most of the exoplanets to date

642
00:28:40,710 --> 00:28:38,170
it's the same thing with a cat but with

643
00:28:43,650 --> 00:28:40,720
planets so what we do is that we stare

644
00:28:45,930 --> 00:28:43,660
at stars and we wait until planets pass

645
00:28:48,750 --> 00:28:45,940
in front of the star so when they do

646
00:28:50,670 --> 00:28:48,760
what happens is that if you look at the

647
00:28:52,620 --> 00:28:50,680
light they start from our point of view

648
00:28:54,690 --> 00:28:52,630
at birth when the planet goes in front

649
00:28:56,670 --> 00:28:54,700
of the star then there's some light that

650
00:29:00,120 --> 00:28:56,680
it's you know blocked by the planet and

651
00:29:02,100 --> 00:29:00,130
then the bigger the planet the bigger

652
00:29:04,800 --> 00:29:02,110
dimming and if you observe this

653
00:29:06,960 --> 00:29:04,810
periodically then you have discovered a

654
00:29:08,490 --> 00:29:06,970
planet so the idea with this technique

655
00:29:10,920 --> 00:29:08,500
is that you can get first information

656
00:29:13,140 --> 00:29:10,930
about the size right so the larger the

657
00:29:15,060 --> 00:29:13,150
dimming like in this case the larger is

658
00:29:16,590 --> 00:29:15,070
the planet so you can get information

659
00:29:19,350 --> 00:29:16,600
about the planet about the star as well

660
00:29:22,650 --> 00:29:19,360
and you can get orbital information

661
00:29:24,390 --> 00:29:22,660
about this system so with this technique

662
00:29:26,670 --> 00:29:24,400
we have discovered most of the

663
00:29:30,510 --> 00:29:26,680

exoplanets that we know of as of today

664
00:29:33,840 --> 00:29:30,520
we have found a sore lot of weird

665
00:29:35,220 --> 00:29:33,850
planets out there for example as I told

666
00:29:37,050 --> 00:29:35,230
you at the beginning in the solar system

667
00:29:39,030 --> 00:29:37,060
the giant planets are in the outskirts

668
00:29:41,640 --> 00:29:39,040
and then the rocky planets are in the

669
00:29:42,930 --> 00:29:41,650
interior part of the solar system but we

670
00:29:45,510 --> 00:29:42,940
have discovered planets that are the

671
00:29:48,150 --> 00:29:45,520
other way around their gaseous planets

672
00:29:50,460 --> 00:29:48,160
going around the stars that are very

673
00:29:50,840 --> 00:29:50,470
very close distances even closer than

674
00:29:53,360 --> 00:29:50,850
this

675
00:29:55,610 --> 00:29:53,370
that mercury has to the Sun so these

676
00:29:57,920 --> 00:29:55,620
planets actually we have seen the

677
00:30:01,160 --> 00:29:57,930
atmospheres just blowing out of their

678
00:30:03,980 --> 00:30:01,170
planets which is kind of amazing we have

679
00:30:05,930 --> 00:30:03,990
seen also planets that are large like

680
00:30:08,960 --> 00:30:05,940
almost the size of Neptune but that they

681
00:30:12,730 --> 00:30:08,970
are made appear to have rocky maybe

682
00:30:15,500 --> 00:30:12,740
rocky surfaces so this kind of weird

683
00:30:19,340 --> 00:30:15,510
planetary systems make us wonder if

684
00:30:22,730 --> 00:30:19,350
we're special or not so from all this

685
00:30:25,100 --> 00:30:22,740
diversity the most the largest number of

686
00:30:27,110 --> 00:30:25,110
exoplanet discovered to date have been

687
00:30:29,630 --> 00:30:27,120
discovered by this mission here have you

688
00:30:30,980 --> 00:30:29,640

heard of it the Kepler mission so the

689
00:30:33,140 --> 00:30:30,990
Kepler mission was a mission that

690
00:30:35,930 --> 00:30:33,150
basically stared at a region in the sky

691
00:30:38,270 --> 00:30:35,940
for like four years just looking for

692
00:30:40,100 --> 00:30:38,280
these small dimming of light trying to

693
00:30:41,480 --> 00:30:40,110
search for transiting planets we call

694
00:30:44,300 --> 00:30:41,490
them because they transmit their stars

695
00:30:47,840 --> 00:30:44,310
from our point of view here on earth so

696
00:30:49,610 --> 00:30:47,850
to date both adding up the kepler

697
00:30:51,320 --> 00:30:49,620
planets and all the planets from all

698
00:30:52,970 --> 00:30:51,330
their surveys that we have been doing

699
00:30:54,590 --> 00:30:52,980
from the ground as well we have

700
00:30:57,770 --> 00:30:54,600
discovery so far in the order of four

701
00:30:59,570 --> 00:30:57,780
thousand confirmed exoplanets as of

702
00:31:03,650 --> 00:30:59,580
yesterday so I made my homework and this

703
00:31:05,240 --> 00:31:03,660
is like the latest number now this four

704
00:31:08,120 --> 00:31:05,250
thousand exoplanets have been teaching

705
00:31:10,910 --> 00:31:08,130
or teaching us a lot about this order

706
00:31:13,190 --> 00:31:10,920
distant worlds one of the things that we

707
00:31:16,460 --> 00:31:13,200
have learned for example mainly based on

708
00:31:18,980 --> 00:31:16,470
Kepler is what is the fraction of

709
00:31:21,080 --> 00:31:18,990
planets based on their sizes so what

710
00:31:23,210 --> 00:31:21,090
you're seeing here is what the Kepler

711
00:31:27,860 --> 00:31:23,220
some some folks in the kepler team call

712
00:31:30,440 --> 00:31:27,870
the skittles diagram of the color I also

713
00:31:34,910 --> 00:31:30,450

love skills by the way just in case at

714
00:31:36,590 --> 00:31:34,920
the end so what date is but what they

715
00:31:39,260 --> 00:31:36,600
have been discovering is that basically

716
00:31:42,560 --> 00:31:39,270
the most abundant planets in our galaxy

717
00:31:44,420 --> 00:31:42,570
at least are these planets that are kind

718
00:31:47,390 --> 00:31:44,430
of between the Earth's and Neptune

719
00:31:50,450 --> 00:31:47,400
basically this neptune-sized from super

720
00:31:52,460 --> 00:31:50,460
Earths more or less which also means

721
00:31:54,680 --> 00:31:52,470
that living in our solar system kind of

722
00:31:56,840 --> 00:31:54,690
sucks because we don't have this kind of

723
00:31:59,360 --> 00:31:56,850
month so the most abundant planets in

724
00:32:02,840 --> 00:31:59,370
the galaxy are not present in our solar

725
00:32:04,860 --> 00:32:02,850
system that actually hints that were

726
00:32:07,169 --> 00:32:04,870
actually a bit

727
00:32:09,510 --> 00:32:07,179
the other important thing that we have

728
00:32:11,250 --> 00:32:09,520
discovering and this is like a huge huge

729
00:32:13,890 --> 00:32:11,260
recent discovery from like the last

730
00:32:15,660 --> 00:32:13,900
couple years is that if you look up at

731
00:32:18,720 --> 00:32:15,670
the occurrence rate of the smaller

732
00:32:21,570 --> 00:32:18,730
planets actually you see that small

733
00:32:23,220 --> 00:32:21,580
planets come in two sizes just as you

734
00:32:25,020 --> 00:32:23,230
know when you buy some clothing become

735
00:32:28,620 --> 00:32:25,030
different sizes the small planets

736
00:32:31,440 --> 00:32:28,630
actually come in at least two sizes so

737
00:32:34,860 --> 00:32:31,450
here you have the number of planets per

738
00:32:37,140 --> 00:32:34,870

star's base as the function of their

739
00:32:39,210 --> 00:32:37,150
relative size of the planets and you can

740
00:32:42,390 --> 00:32:39,220
see that you know there's one peak here

741
00:32:45,600 --> 00:32:42,400
or about 1.2 Earth radii and another one

742
00:32:47,460 --> 00:32:45,610
here about two Earth radii again by the

743
00:32:49,080 --> 00:32:47,470
way we don't have any of these kind of

744
00:32:51,870 --> 00:32:49,090
planets in our solar system but they

745
00:32:54,510 --> 00:32:51,880
exist out there now the big question is

746
00:32:57,090 --> 00:32:54,520
why these two kind of planets appeared

747
00:33:00,150 --> 00:32:57,100
someone just put them there it has to do

748
00:33:01,980 --> 00:33:00,160
with their formation perhaps maybe this

749
00:33:05,130 --> 00:33:01,990
ones are gaseous maybe these ones are

750
00:33:07,230 --> 00:33:05,140
rocky but the thing is that I have just

751
00:33:09,419 --> 00:33:07,240
been telling you right now about the

752
00:33:10,470 --> 00:33:09,429
sizes of the planets so if you pay

753
00:33:13,230 --> 00:33:10,480
attention to my words

754
00:33:17,549 --> 00:33:13,240
I was extremely careful to always talk

755
00:33:19,799 --> 00:33:17,559
about sizes and sizes you know aren't

756
00:33:24,960 --> 00:33:19,809
anything or isn't everything as the BG's

757
00:33:27,950 --> 00:33:24,970
setting one of their famous cities I see

758
00:33:31,020 --> 00:33:27,960
some VG's fans that's cool

759
00:33:31,580 --> 00:33:31,030
so sizes this does not tell us the whole

760
00:33:34,470 --> 00:33:31,590
story

761
00:33:37,080 --> 00:33:34,480
there's something more that actually can

762
00:33:39,090 --> 00:33:37,090
compliment sizes the reason why we're so

763
00:33:41,820 --> 00:33:39,100

focused in sizes by the way is because

764
00:33:43,770 --> 00:33:41,830
of the transiting method so it is this

765
00:33:45,150 --> 00:33:43,780
and this planet discovery technique that

766
00:33:47,640 --> 00:33:45,160
I just told you about the transit method

767
00:33:49,230 --> 00:33:47,650
we actually measure the light dimming

768
00:33:51,120 --> 00:33:49,240
when the planet passes in front of it

769
00:33:53,370 --> 00:33:51,130
and as I told you before that tells us

770
00:33:55,169 --> 00:33:53,380
about the sizes of the planet but it

771
00:33:58,020 --> 00:33:55,179
doesn't tell you anything about say the

772
00:34:00,630 --> 00:33:58,030
mass or the atmosphere if it has aliens

773
00:34:02,190 --> 00:34:00,640
or whatever so we really want to know

774
00:34:05,100 --> 00:34:02,200
that information right especially the

775
00:34:08,220 --> 00:34:05,110
aliens part so how do we move from there

776
00:34:10,169 --> 00:34:08,230
how do we know say that if we see these

777
00:34:12,330 --> 00:34:10,179
transiting planet for example how do we

778
00:34:15,990 --> 00:34:12,340
know that it's a big piece of rock or a

779
00:34:17,080 --> 00:34:16,000
big piece of gas the way in which I'm

780
00:34:19,690 --> 00:34:17,090
going to beach

781
00:34:23,020 --> 00:34:19,700
you how we do it is with one of my worst

782
00:34:24,970 --> 00:34:23,030
talent that I told my wife that sometime

783
00:34:27,490 --> 00:34:24,980
it will be beneficial for me and this is

784
00:34:29,460 --> 00:34:27,500
the time it will so my wife you're

785
00:34:33,370 --> 00:34:29,470
looking at this this is my time to shine

786
00:34:37,030 --> 00:34:33,380
which is choosing between fake plants

787
00:34:39,280 --> 00:34:37,040
and real plants I'm absolutely the worst

788
00:34:41,230 --> 00:34:39,290

at this and you can buy a plant for me

789
00:34:43,500 --> 00:34:41,240
and I will I would I want to see the

790
00:34:47,020 --> 00:34:43,510
difference it's just super bad at this

791
00:34:50,230 --> 00:34:47,030
so I'm gonna test it with you so one of

792
00:34:53,560 --> 00:34:50,240
these set of plants is fake we have the

793
00:34:56,850 --> 00:34:53,570
right and the left one who votes that

794
00:35:01,930 --> 00:34:56,860
the right ones are the real ones

795
00:35:04,480 --> 00:35:01,940
okay have two three four around I'm not

796
00:35:07,360 --> 00:35:04,490
sick 10% or 20% of us who says these

797
00:35:10,450 --> 00:35:07,370
ones are the real Oh God

798
00:35:12,100 --> 00:35:10,460
okay I have no idea

799
00:35:16,150 --> 00:35:12,110
you are obviously the experts because

800
00:35:18,460 --> 00:35:16,160
these ones are the real ones really good

801
00:35:20,670 --> 00:35:18,470
at this and these proves that my wife is

802
00:35:23,650 --> 00:35:20,680
right and I'm really bad at this

803
00:35:25,960 --> 00:35:23,660
however the way in which I know which

804
00:35:28,330 --> 00:35:25,970
ones are real or fake is by a very

805
00:35:30,820 --> 00:35:28,340
simple thing just go to the plans lift

806
00:35:33,310 --> 00:35:30,830
them up you know they're usually the

807
00:35:34,690 --> 00:35:33,320
fake plants they're just full of gas or

808
00:35:37,120 --> 00:35:34,700
air right because they don't have dirt

809
00:35:39,790 --> 00:35:37,130
they don't have soil so they're usually

810
00:35:42,190 --> 00:35:39,800
you know you know they're this ones wait

811
00:35:44,620 --> 00:35:42,200
wait much more than the than they wait

812
00:35:46,330 --> 00:35:44,630
less once over there so this is this is

813
00:35:48,580 --> 00:35:46,340

the way in which I do it and this is

814
00:35:51,520 --> 00:35:48,590
exactly what we do for planets so what

815
00:35:55,780 --> 00:35:51,530
do we go if if we want to know if this

816
00:35:58,000 --> 00:35:55,790
is a big piece of soil or some gas and

817
00:35:58,570 --> 00:35:58,010
we just go and measured just put just

818
00:36:00,640 --> 00:35:58,580
weigh it

819
00:36:02,740 --> 00:36:00,650
of course that's extremely tough to do

820
00:36:04,120 --> 00:36:02,750
so how do you weigh an exoplanet well

821
00:36:07,140 --> 00:36:04,130
this is actually a way we figured this

822
00:36:10,180 --> 00:36:07,150
out so the way in which we do it is

823
00:36:13,390 --> 00:36:10,190
basically using or taking advantage of a

824
00:36:15,850 --> 00:36:13,400
lie that we were taught in school in

825
00:36:18,490 --> 00:36:15,860
school the worst thought you were the

826
00:36:21,940 --> 00:36:18,500
teacher told you that the Earth orbits

827
00:36:24,580 --> 00:36:21,950
the Sun that's not absolutely correct as

828
00:36:26,080 --> 00:36:24,590
Frank pointed out earlier actually so

829
00:36:29,110 --> 00:36:26,090
what it actually happens is that both

830
00:36:30,820 --> 00:36:29,120
orbit the center of mass so whenever

831
00:36:33,250 --> 00:36:30,830
your planet orbits a star

832
00:36:34,810 --> 00:36:33,260
star also orbits around that point so

833
00:36:36,640 --> 00:36:34,820
they orbit around a common point which

834
00:36:39,010 --> 00:36:36,650
is like the average between the masses

835
00:36:41,140 --> 00:36:39,020
basically so weighted average between

836
00:36:43,450 --> 00:36:41,150
their masses and their distances so then

837
00:36:46,090 --> 00:36:43,460
they start dances a little bit with the

838
00:36:49,420 --> 00:36:46,100

planet and this dance depends on the

839
00:36:52,030 --> 00:36:49,430
mass so this is actually how we go and

840
00:36:54,520 --> 00:36:52,040
measure masses of exoplanets we just try

841
00:36:57,010 --> 00:36:54,530
to watch these dancing stars out there

842
00:36:58,750 --> 00:36:57,020
now doing this is extremely tough though

843
00:37:00,820 --> 00:36:58,760
because you need extremely bright stars

844
00:37:03,190 --> 00:37:00,830
from our point of view so you cannot do

845
00:37:05,860 --> 00:37:03,200
it for every star but we're actually

846
00:37:07,420 --> 00:37:05,870
working our way towards that so what we

847
00:37:09,250 --> 00:37:07,430
can do at the end when you have the

848
00:37:11,740 --> 00:37:09,260
radius on the mass of an exoplanet you

849
00:37:14,080 --> 00:37:11,750
can point put it in a plot like this one

850
00:37:16,150 --> 00:37:14,090
this is a beautiful pot recently show by

851
00:37:18,940 --> 00:37:16,160
fluke Doug Lee it has you know really

852
00:37:21,640 --> 00:37:18,950
recent paper in which here I have the

853
00:37:25,240 --> 00:37:21,650
mass of all the known exoplanet verses

854
00:37:28,420 --> 00:37:25,250
radios I have just cut the radius here

855
00:37:30,520 --> 00:37:28,430
like Premal smaller than they have cut

856
00:37:33,070 --> 00:37:30,530
the the plot from smaller login' Earth

857
00:37:35,290 --> 00:37:33,080
radii so imagine like the size of - more

858
00:37:36,730 --> 00:37:35,300
or less down so what you're seeing here

859
00:37:39,100 --> 00:37:36,740
for example is where the earth is

860
00:37:40,750 --> 00:37:39,110
position Venus and all the exoplanets

861
00:37:43,570 --> 00:37:40,760
here that we know there are smaller than

862
00:37:45,940 --> 00:37:43,580
around 3 Earth radii so why is this

863
00:37:47,590 --> 00:37:45,950

interesting you might be asking so look

864
00:37:49,780 --> 00:37:47,600
at these curves that you're seeing here

865
00:37:52,690 --> 00:37:49,790
so you're seeing here for example what

866
00:37:57,610 --> 00:37:52,700
happens if I put a hundred percent iron

867
00:38:00,880 --> 00:37:57,620
ball and then for example for a two mass

868
00:38:02,980 --> 00:38:00,890
earth mass iron ball it should have

869
00:38:04,870 --> 00:38:02,990
these radios just slightly smaller than

870
00:38:06,970 --> 00:38:04,880
the earth so we know this you know we

871
00:38:08,860 --> 00:38:06,980
know the physics of these materials so

872
00:38:11,650 --> 00:38:08,870
we know what they should look like if we

873
00:38:14,920 --> 00:38:11,660
created balls of say pure iron or half

874
00:38:17,260 --> 00:38:14,930
water have wrought etc so actually this

875
00:38:19,390 --> 00:38:17,270
tells us a lot of information about the

876
00:38:22,180 --> 00:38:19,400
bulk composition of the exoplanets so

877
00:38:24,580 --> 00:38:22,190
this is how we are now trying to figure

878
00:38:26,740 --> 00:38:24,590
out what these planets are made of and

879
00:38:28,870 --> 00:38:26,750
we can actually put these exoplanets in

880
00:38:30,790 --> 00:38:28,880
context say with the earth and venus so

881
00:38:32,860 --> 00:38:30,800
for example this line here it goes

882
00:38:35,680 --> 00:38:32,870
through all the what we believe are the

883
00:38:36,970 --> 00:38:35,690
rocky planets like or on earth so we

884
00:38:39,010 --> 00:38:36,980
know that all the planets that more or

885
00:38:40,210 --> 00:38:39,020
less cross this line they're more or

886
00:38:42,400 --> 00:38:40,220
less composed

887
00:38:44,740 --> 00:38:42,410
similarly perhaps like the earth at

888
00:38:47,800 --> 00:38:44,750

least based on their radios and masses

889
00:38:50,320 --> 00:38:47,810
so a very interesting thing is that as

890
00:38:52,390 --> 00:38:50,330
you see we don't have a huge sample

891
00:38:55,000 --> 00:38:52,400
especially for the small planet but we

892
00:38:57,160 --> 00:38:55,010
are building this huge sample and we are

893
00:39:00,010 --> 00:38:57,170
doing it thanks to a very very nice

894
00:39:02,260 --> 00:39:00,020
mission that it's now right now taking

895
00:39:03,970 --> 00:39:02,270
data as we speak which is the transiting

896
00:39:05,580 --> 00:39:03,980
exoplanet survey solids I've been

897
00:39:07,810 --> 00:39:05,590
working a lot with this mission lately

898
00:39:10,000 --> 00:39:07,820
and what this mission is doing is

899
00:39:11,260 --> 00:39:10,010
actually looking for planets that are

900
00:39:14,260 --> 00:39:11,270
bright enough for which we can measure

901
00:39:16,360 --> 00:39:14,270
the mass their masses so this mission is

902
00:39:18,760 --> 00:39:16,370
looking for transiting exoplanets just

903
00:39:20,260 --> 00:39:18,770
like Kepler did and what it's doing

904
00:39:22,960 --> 00:39:20,270
however is that it's looking at the

905
00:39:24,700 --> 00:39:22,970
whole sky for planets so what it does is

906
00:39:28,210 --> 00:39:24,710
that basically it stares with four

907
00:39:30,670 --> 00:39:28,220
cameras I got at a portion of the sky

908
00:39:33,370 --> 00:39:30,680
one of this sector each of these sectors

909
00:39:35,110 --> 00:39:33,380
goes for about one one so you go one

910
00:39:36,790 --> 00:39:35,120
month and then they'd already did the

911
00:39:38,680 --> 00:39:36,800
southern hemisphere the whole southern

912
00:39:40,240 --> 00:39:38,690
hemisphere it targeted the whole then

913
00:39:42,970 --> 00:39:40,250

now switch to the northern hemisphere

914
00:39:44,230 --> 00:39:42,980
and then it is surveying the whole sky

915
00:39:47,260 --> 00:39:44,240
basically so here you see the original

916
00:39:49,390 --> 00:39:47,270
Kepler mission then Kepler fail a little

917
00:39:51,220 --> 00:39:49,400
bit so it had to change its orbits orbit

918
00:39:53,500 --> 00:39:51,230
its orientation so these are the Kepler

919
00:39:55,630 --> 00:39:53,510
fields so you can see that test it's

920
00:39:57,520 --> 00:39:55,640
actually serving a larger portion of the

921
00:40:00,430 --> 00:39:57,530
sky than Kepler ever could

922
00:40:03,190 --> 00:40:00,440
so this is giving us actually a huge

923
00:40:04,450 --> 00:40:03,200
sample of exoplanets for which they had

924
00:40:05,980 --> 00:40:04,460
their bright enough from our point of

925
00:40:08,950 --> 00:40:05,990
your earth that we can actually measure

926
00:40:10,900 --> 00:40:08,960
their masses and put them here and see

927
00:40:13,180 --> 00:40:10,910
for example how common rocky planets

928
00:40:15,580 --> 00:40:13,190
like Earth actually are so we can

929
00:40:17,590 --> 00:40:15,590
actually start doing that for the ones

930
00:40:19,990 --> 00:40:17,600
that we have masses and radius it's

931
00:40:22,260 --> 00:40:20,000
actually around 400 right now in total

932
00:40:25,090 --> 00:40:22,270
so we're trying to build this sample up

933
00:40:27,460 --> 00:40:25,100
now if you want to look for aliens

934
00:40:30,160 --> 00:40:27,470
though mass and radius does not tell you

935
00:40:32,140 --> 00:40:30,170
the whole story you actually also want

936
00:40:34,300 --> 00:40:32,150
to know where they are located in their

937
00:40:36,340 --> 00:40:34,310
orbits around the stars so there's a

938
00:40:38,080 --> 00:40:36,350

very important thing for us here at

939
00:40:40,450 --> 00:40:38,090
Earth but we're a very particular

940
00:40:43,120 --> 00:40:40,460
distance from the star right so if if

941
00:40:45,520 --> 00:40:43,130
some magic happened and we were put

942
00:40:47,140 --> 00:40:45,530
closer to the star the heat on the

943
00:40:50,050 --> 00:40:47,150
atmosphere would just be too much for us

944
00:40:52,240 --> 00:40:50,060
to live here also if we were put by some

945
00:40:54,400 --> 00:40:52,250
magic and outskirts from what we are

946
00:40:57,380 --> 00:40:54,410
here right now from the Sun you know

947
00:40:59,240 --> 00:40:57,390
farther away we'll be too cold for life

948
00:41:01,460 --> 00:40:59,250
to happen so there's like a Goldilocks

949
00:41:03,950 --> 00:41:01,470
zone in which we can actually be here

950
00:41:06,080 --> 00:41:03,960
and performing like a habit of exoplanet

951
00:41:08,150 --> 00:41:06,090
as we have been doing for years so

952
00:41:10,790 --> 00:41:08,160
actually this happens for other stars as

953
00:41:12,650 --> 00:41:10,800
well but the distance to which the

954
00:41:14,570 --> 00:41:12,660
planets have to be with respect your

955
00:41:16,490 --> 00:41:14,580
stars changes because different stars

956
00:41:18,110 --> 00:41:16,500
have different temperatures so there's

957
00:41:20,000 --> 00:41:18,120
some stars that are cooler than the Sun

958
00:41:21,830 --> 00:41:20,010
for example and then you can be closer

959
00:41:23,360 --> 00:41:21,840
to them to feel the same heat so it's

960
00:41:26,390 --> 00:41:23,370
basically like you know different

961
00:41:28,820 --> 00:41:26,400
temperatures on your heater's as you

962
00:41:31,310 --> 00:41:28,830
might imagine in your house so here we

963
00:41:34,060 --> 00:41:31,320

have this is one of one of the most

964
00:41:36,980 --> 00:41:34,070
updated plot in which here you're seeing

965
00:41:38,720 --> 00:41:36,990
the set of half planets in this

966
00:41:41,450 --> 00:41:38,730
available zone that we call it which is

967
00:41:43,910 --> 00:41:41,460
the zone in which we believe that life

968
00:41:45,410 --> 00:41:43,920
could happen if these planets have

969
00:41:47,150 --> 00:41:45,420
atmospheres like year like the earth

970
00:41:49,430 --> 00:41:47,160
this is a really big if because we have

971
00:41:51,440 --> 00:41:49,440
no idea about the atmospheres so I just

972
00:41:53,330 --> 00:41:51,450
told you for most of the planets we

973
00:41:55,640 --> 00:41:53,340
surely know the masses and the radii but

974
00:41:59,840 --> 00:41:55,650
nothing about the atmospheres touch on

975
00:42:03,440 --> 00:41:59,850
that not a bit but I want to highlight

976
00:42:06,740 --> 00:42:03,450
one system that it's very dear to my

977
00:42:09,620 --> 00:42:06,750
heart in terms of a system that has

978
00:42:13,220 --> 00:42:09,630
habitable zone planets in it which is

979
00:42:15,860 --> 00:42:13,230
the Trappist one system have you ever

980
00:42:18,440 --> 00:42:15,870
heard of this no Trappist by the way

981
00:42:20,240 --> 00:42:18,450
it's a very good Belgium beer if I don't

982
00:42:25,580 --> 00:42:20,250
if I recall correctly so if you ever go

983
00:42:27,980 --> 00:42:25,590
you try to get a set but this system was

984
00:42:31,190 --> 00:42:27,990
I mean it's is one of perhaps one of the

985
00:42:33,290 --> 00:42:31,200
most important to date in the history of

986
00:42:37,520 --> 00:42:33,300
humankind I'm gonna tell you a little

987
00:42:41,600 --> 00:42:37,530
why first this was the cover of the

988
00:42:43,670 --> 00:42:41,610

scientific magazine nature that appear

989
00:42:45,020 --> 00:42:43,680
when this system was reported so it made

990
00:42:46,310 --> 00:42:45,030
the cover of the of the neck of the

991
00:42:48,620 --> 00:42:46,320
magazine which you know makes it really

992
00:42:50,540 --> 00:42:48,630
important but I think this is one of the

993
00:42:51,200 --> 00:42:50,550
most amazing scientific covers I have

994
00:42:54,890 --> 00:42:51,210
ever seen

995
00:42:58,450 --> 00:42:54,900
I'm gonna explain you why so this

996
00:43:00,680 --> 00:42:58,460
Trappist one system has seven planets

997
00:43:03,740 --> 00:43:00,690
transiting planets by the way so you can

998
00:43:06,320 --> 00:43:03,750
see the dimming going around and these

999
00:43:08,810 --> 00:43:06,330
planets are in this artistic view of the

1000
00:43:10,140 --> 00:43:08,820
system you can see that the innermost

1001
00:43:11,760 --> 00:43:10,150
planet

1002
00:43:13,890 --> 00:43:11,770
there's they have steam going around

1003
00:43:15,960 --> 00:43:13,900
right that means that basically the

1004
00:43:16,950 --> 00:43:15,970
planets are so close to the star that

1005
00:43:18,569 --> 00:43:16,960
it's too hot

1006
00:43:21,960 --> 00:43:18,579
and if they had water it would have

1007
00:43:24,480 --> 00:43:21,970
evaporated if you go little further away

1008
00:43:26,279 --> 00:43:24,490
the temperature decreases right and then

1009
00:43:28,559 --> 00:43:26,289
there's not more no more steaming and

1010
00:43:30,240 --> 00:43:28,569
there's actually liquid water so in fact

1011
00:43:33,089 --> 00:43:30,250
there's a set of those planets these

1012
00:43:35,010 --> 00:43:33,099
three ones here that could have liquid

1013
00:43:37,349 --> 00:43:35,020

water in their surfaces because there

1014
00:43:39,210 --> 00:43:37,359
are the right distance however you keep

1015
00:43:40,620 --> 00:43:39,220
moving away from the star like this ones

1016
00:43:44,250 --> 00:43:40,630
what do you see here

1017
00:43:46,650 --> 00:43:44,260
nice so these ones are too far away to

1018
00:43:48,599 --> 00:43:46,660
have liquid water if they have like

1019
00:43:50,940 --> 00:43:48,609
atmospheres like the earth so all of

1020
00:43:53,609 --> 00:43:50,950
them have more or less the size of the

1021
00:43:55,380 --> 00:43:53,619
earth once a little big larger a little

1022
00:43:57,960 --> 00:43:55,390
bit smaller but around you know average

1023
00:44:01,500 --> 00:43:57,970
like the earth but I still remember the

1024
00:44:04,349 --> 00:44:01,510
time when I when I when I found out

1025
00:44:08,099 --> 00:44:04,359
about these systems it was when I when a

1026
00:44:10,319 --> 00:44:08,109
colleague that will remain unnamed went

1027
00:44:13,410 --> 00:44:10,329
to visit in Chile and we were having

1028
00:44:16,859 --> 00:44:13,420
some beers but Westerners do that a lot

1029
00:44:18,809 --> 00:44:16,869
so we socialize a lot and I remember he

1030
00:44:20,400 --> 00:44:18,819
told me like they were baffled by this

1031
00:44:22,859 --> 00:44:20,410
system because they couldn't put it

1032
00:44:26,069 --> 00:44:22,869
together so the thing with this system

1033
00:44:27,569 --> 00:44:26,079
is that the planets are so packed that

1034
00:44:29,460 --> 00:44:27,579
at the time when I was speaking with my

1035
00:44:31,589 --> 00:44:29,470
colleague there was no way they could

1036
00:44:33,480 --> 00:44:31,599
figure out how this system was stable

1037
00:44:36,720 --> 00:44:33,490
and explain you what that means in a

1038
00:44:39,089 --> 00:44:36,730

minute just so you have an idea the trap

1039
00:44:42,120 --> 00:44:39,099
is one system in terms of distances from

1040
00:44:44,609 --> 00:44:42,130
each other there if you compare to this

1041
00:44:46,710 --> 00:44:44,619
the distances here in the solar system

1042
00:44:48,480 --> 00:44:46,720
they're extremely packed so if you could

1043
00:44:50,370 --> 00:44:48,490
bring them here the solar system they

1044
00:44:53,430 --> 00:44:50,380
will be extremely packed with one

1045
00:44:55,950 --> 00:44:53,440
another and the planet will be so close

1046
00:44:57,779 --> 00:44:55,960
together he told me that when they run

1047
00:44:59,339 --> 00:44:57,789
the simulation so if you put the planet

1048
00:45:02,190 --> 00:44:59,349
in a simulation the simulation just

1049
00:45:03,329 --> 00:45:02,200
explodes the planet just float away so

1050
00:45:05,640 --> 00:45:03,339
they were like cracking their heads

1051
00:45:09,329 --> 00:45:05,650
trying to find out what was going on

1052
00:45:11,490 --> 00:45:09,339
until they heard the music of the

1053
00:45:13,230 --> 00:45:11,500
planets and this is one of what I'm

1054
00:45:14,700 --> 00:45:13,240
going to show you right now and I want

1055
00:45:17,120 --> 00:45:14,710
you to pay attention to what's going to

1056
00:45:20,160 --> 00:45:17,130
happen so what's going to happen is that

1057
00:45:22,589 --> 00:45:20,170
we're going to put the orbits of the

1058
00:45:23,910 --> 00:45:22,599
planets they have a period so that means

1059
00:45:26,910 --> 00:45:23,920
that they have an Associated

1060
00:45:30,720 --> 00:45:26,920
Quincy sound so we're going to play the

1061
00:45:32,579 --> 00:45:30,730
periods as frequency RSS sounds and do

1062
00:45:37,010 --> 00:45:32,589
let me know when you start start to feel

1063
00:45:40,789 --> 00:45:37,020

the music so we're going to start with

1064
00:45:43,920 --> 00:45:40,799
deepest note we're gonna start adding

1065
00:45:48,880 --> 00:45:43,930
planets one by one

1066
00:45:56,499 --> 00:45:52,670
see how it's gonna change I've got the

1067
00:45:56,509 --> 00:46:08,070
hello

1068
00:47:10,960 --> 00:46:22,270
[Music]

1069
00:47:15,260 --> 00:47:13,010
by the way if you want to see more

1070
00:47:18,290 --> 00:47:15,270
sounds like this there's a web page

1071
00:47:21,110 --> 00:47:18,300
called system sounds calm it's made by

1072
00:47:22,430 --> 00:47:21,120
astrophysicists and musicians that got

1073
00:47:26,060 --> 00:47:22,440
together and try to make sounds from

1074
00:47:28,010 --> 00:47:26,070
planets so the trap is one system is

1075
00:47:30,560 --> 00:47:28,020
very special because this sound between

1076
00:47:33,350 --> 00:47:30,570
the planets means that there's some kind

1077
00:47:34,820 --> 00:47:33,360
of dance between the planets that

1078
00:47:37,130 --> 00:47:34,830
they're not they're not orbiting in

1079
00:47:39,520 --> 00:47:37,140
random orbits the orbits are in

1080
00:47:42,140 --> 00:47:39,530
resonance we call them with each other

1081
00:47:44,330 --> 00:47:42,150
with this resonant is actually what

1082
00:47:46,250 --> 00:47:44,340
makes us feel when when you hear chords

1083
00:47:48,350 --> 00:47:46,260
in the Attar or in a piano these

1084
00:47:51,200 --> 00:47:48,360
combinations are actually what we think

1085
00:47:53,180 --> 00:47:51,210
of as music so that's why you hear music

1086
00:47:56,840 --> 00:47:53,190
from this plant the orbits of these

1087
00:47:58,730 --> 00:47:56,850
planets turns out that this resonance

1088
00:48:01,190 --> 00:47:58,740

between the planet was fundamental to

1089
00:48:03,380 --> 00:48:01,200
understand why they keep their orbits as

1090
00:48:06,560 --> 00:48:03,390
they do right now because these exact

1091
00:48:08,690 --> 00:48:06,570
resonance what puts them but stacks them

1092
00:48:10,910 --> 00:48:08,700
together so it's not that that resonance

1093
00:48:12,530 --> 00:48:10,920
and in general systems or their other

1094
00:48:14,210 --> 00:48:12,540
systems that have resonances like this

1095
00:48:16,460 --> 00:48:14,220
between their periods that are

1096
00:48:18,650 --> 00:48:16,470
relationships between their periods they

1097
00:48:22,160 --> 00:48:18,660
tell you some story about how they form

1098
00:48:24,500 --> 00:48:22,170
so that gives you an amazing data set

1099
00:48:27,680 --> 00:48:24,510
for you to play with to understand how

1100
00:48:29,630 --> 00:48:27,690
would you make this system such as they

1101
00:48:32,030 --> 00:48:29,640
get to these final resonances that we

1102
00:48:34,130 --> 00:48:32,040
observe them today so the trap is one

1103
00:48:35,780 --> 00:48:34,140
system is my favorite system because of

1104
00:48:37,700 --> 00:48:35,790
many reasons you know they have planets

1105
00:48:40,010 --> 00:48:37,710
in the habitable zone their earth size

1106
00:48:41,510 --> 00:48:40,020
it turns out that planets like this one

1107
00:48:45,080 --> 00:48:41,520
their systems like this ones are really

1108
00:48:46,700 --> 00:48:45,090
rare but also the resonances between

1109
00:48:50,030 --> 00:48:46,710
their their planets makes them you know

1110
00:48:52,490 --> 00:48:50,040
a whole different story so I have been

1111
00:48:55,640 --> 00:48:52,500
telling you about distances from planets

1112
00:48:58,400 --> 00:48:55,650
masses from planets radios from planets

1113
00:49:01,250 --> 00:48:58,410

but what else do you need to form like a

1114
00:49:03,080 --> 00:49:01,260
navigable world like ours you need to

1115
00:49:05,510 --> 00:49:03,090
have an atmosphere right you need to

1116
00:49:09,680 --> 00:49:05,520
breathe you need to have a sustainable

1117
00:49:11,720 --> 00:49:09,690
environment to have life so this is the

1118
00:49:13,070 --> 00:49:11,730
next step right now so this is like the

1119
00:49:15,590 --> 00:49:13,080
cutting-edge science that we're doing

1120
00:49:18,350 --> 00:49:15,600
with exoplanets is trying to investigate

1121
00:49:20,940 --> 00:49:18,360
what they're made of so what what do

1122
00:49:22,890 --> 00:49:20,950
they are their atmospheres look like

1123
00:49:25,080 --> 00:49:22,900
the technique with which we do it or the

1124
00:49:26,610 --> 00:49:25,090
most famous thing right now and the

1125
00:49:28,920 --> 00:49:26,620
technique that it's gonna be probably

1126
00:49:30,660 --> 00:49:28,930
the leading technique with which we will

1127
00:49:33,870 --> 00:49:30,670
discover amazing things in the next

1128
00:49:36,450 --> 00:49:33,880
decades it's a method that you can

1129
00:49:40,500 --> 00:49:36,460
actually see by eye here so this is an

1130
00:49:44,100 --> 00:49:40,510
actual picture a whole planet going man

1131
00:49:47,370 --> 00:49:44,110
if I recall correctly Venus perhaps and

1132
00:49:49,800 --> 00:49:47,380
what you're seeing here is that these

1133
00:49:51,240 --> 00:49:49,810
are around the planet it's actually the

1134
00:49:54,150 --> 00:49:51,250
atmosphere of the planet and it's

1135
00:49:56,130 --> 00:49:54,160
generating some weird effects one of the

1136
00:49:58,170 --> 00:49:56,140
effect is that you see this glow from

1137
00:50:00,390 --> 00:49:58,180
here and this is actually the atmosphere

1138
00:50:02,580 --> 00:50:00,400

of the planet there's something going on

1139
00:50:03,840 --> 00:50:02,590
between the light that it's behind you

1140
00:50:05,700 --> 00:50:03,850
know the light from the star that is

1141
00:50:07,620 --> 00:50:05,710
going through the atmosphere and that's

1142
00:50:08,970 --> 00:50:07,630
imprinting some signatures that we're

1143
00:50:11,970 --> 00:50:08,980
actually we're actually seeing right now

1144
00:50:13,920 --> 00:50:11,980
we call this technique transmission

1145
00:50:15,840 --> 00:50:13,930
spectroscopy for August reasons because

1146
00:50:17,610 --> 00:50:15,850
basically we're seeing light that it's

1147
00:50:19,080 --> 00:50:17,620
being transmitted through the atmosphere

1148
00:50:22,140 --> 00:50:19,090
and we're trying to extract the

1149
00:50:25,040 --> 00:50:22,150
information from that from distant

1150
00:50:28,890 --> 00:50:25,050
exoplanets so the way we do it is very

1151
00:50:31,410 --> 00:50:28,900
Pink Floyd Ian so we basically pass that

1152
00:50:34,500 --> 00:50:31,420
light through a prism and then what we

1153
00:50:37,980 --> 00:50:34,510
do is to look at what light is actually

1154
00:50:41,910 --> 00:50:37,990
missing from this lighthouse that has

1155
00:50:43,620 --> 00:50:41,920
been dispersed dispersed because say the

1156
00:50:47,670 --> 00:50:43,630
atmosphere of the planet just absorbed

1157
00:50:49,200 --> 00:50:47,680
it so what we do basically to wait until

1158
00:50:52,020 --> 00:50:49,210
the planet passes in front of the star

1159
00:50:53,910 --> 00:50:52,030
then we wait for light to be transmitted

1160
00:50:56,070 --> 00:50:53,920
through the atmosphere we pass it

1161
00:50:57,930 --> 00:50:56,080
through a prism we get the information

1162
00:51:01,200 --> 00:50:57,940
from the atmosphere from there it's a

1163
00:51:02,850 --> 00:51:01,210

very tiny signal by the way and that's

1164
00:51:05,670 --> 00:51:02,860
it you discover and makes up an

1165
00:51:08,130 --> 00:51:05,680
atmosphere what we do in reality though

1166
00:51:09,720 --> 00:51:08,140
is that we measure the size of the

1167
00:51:12,150 --> 00:51:09,730
planet as a function of the different

1168
00:51:15,150 --> 00:51:12,160
colors so the idea behind this is that

1169
00:51:17,400 --> 00:51:15,160
for example water what it really enjoys

1170
00:51:20,700 --> 00:51:17,410
like it's the most exquisite thing for

1171
00:51:22,110 --> 00:51:20,710
water to eat red light so red light for

1172
00:51:24,210 --> 00:51:22,120
you put water you put real light through

1173
00:51:25,800 --> 00:51:24,220
it and it will just eat it so what will

1174
00:51:27,930 --> 00:51:25,810
happen here for example is that you will

1175
00:51:30,690 --> 00:51:27,940
have if this planet has water in it you

1176
00:51:32,880 --> 00:51:30,700
have missing water in the lines here

1177
00:51:34,769 --> 00:51:32,890
because they light from the red light

1178
00:51:38,729 --> 00:51:34,779
has been it's gonna be eaten up

1179
00:51:40,140 --> 00:51:38,739
by the atmosphere if it is eaten up that

1180
00:51:42,299 --> 00:51:40,150
means that the planet will look bigger

1181
00:51:44,759 --> 00:51:42,309
because you know the atmosphere is

1182
00:51:47,849 --> 00:51:44,769
blocking this light - coming to you so

1183
00:51:49,890 --> 00:51:47,859
what we do at the end is to look at the

1184
00:51:52,409 --> 00:51:49,900
planetary radius basically at different

1185
00:51:53,909 --> 00:51:52,419
wavelengths of light until we find you

1186
00:51:55,589 --> 00:51:53,919
know Peaks in which we see that the

1187
00:51:57,209 --> 00:51:55,599
planet is bigger and that's it that's

1188
00:52:00,269 --> 00:51:57,219

how you discover in an atmosphere we

1189
00:52:03,569 --> 00:52:00,279
call this a transmission spectrum for

1190
00:52:06,390 --> 00:52:03,579
all these reasons so I think that one of

1191
00:52:08,449 --> 00:52:06,400
the most exciting systems that for which

1192
00:52:11,880 --> 00:52:08,459
we have this current atmosphere so far

1193
00:52:13,620 --> 00:52:11,890
it's a system that it's called and it's

1194
00:52:16,019 --> 00:52:13,630
also the most controversial right now in

1195
00:52:20,399 --> 00:52:16,029
the exoplanet community it's like an

1196
00:52:22,140 --> 00:52:20,409
exoplanet which is called k2 18b which

1197
00:52:24,870 --> 00:52:22,150
is actually a planet in the habitable

1198
00:52:27,179 --> 00:52:24,880
zone of its star so you know if it has

1199
00:52:29,489 --> 00:52:27,189
they're saying radios the same mass and

1200
00:52:31,229 --> 00:52:29,499
they same atmosphere as the earth you

1201
00:52:33,599 --> 00:52:31,239
could expect perhaps habitable

1202
00:52:36,120 --> 00:52:33,609
conditions there so for this exoplanet

1203
00:52:38,519 --> 00:52:36,130
we actually discover these two teams

1204
00:52:41,069 --> 00:52:38,529
here independently yarns Banerjee's who

1205
00:52:43,319 --> 00:52:41,079
took the observations Angelo the Sierras

1206
00:52:46,649 --> 00:52:43,329
which also read onion and similar

1207
00:52:49,649 --> 00:52:46,659
analysis to Burns paper you can actually

1208
00:52:50,939 --> 00:52:49,659
see here some signatures in these data

1209
00:52:52,439 --> 00:52:50,949
that you're seeing here so this

1210
00:52:55,019 --> 00:52:52,449
signature that you're seeing here it is

1211
00:52:59,609 --> 00:52:55,029
up and down that's actually the

1212
00:53:02,729 --> 00:52:59,619
signature of water so this exoplanet in

1213
00:53:04,739 --> 00:53:02,739

this available zone has water vapour by

1214
00:53:06,089 --> 00:53:04,749
the way in its atmosphere so this was

1215
00:53:09,329 --> 00:53:06,099
actually observed by the Hubble Space

1216
00:53:11,489 --> 00:53:09,339
Telescope a couple years ago but it was

1217
00:53:14,039 --> 00:53:11,499
just analyzed last year very recently

1218
00:53:15,689 --> 00:53:14,049
and this has hit the news tremendously

1219
00:53:17,549 --> 00:53:15,699
because you know it's a navigable planet

1220
00:53:20,939 --> 00:53:17,559
it's a it's a planet in the habitable

1221
00:53:22,499 --> 00:53:20,949
zones sorry but actually there's one

1222
00:53:23,909 --> 00:53:22,509
thing that you have to have in mind if

1223
00:53:26,669 --> 00:53:23,919
you're actually buying your tickets

1224
00:53:28,439 --> 00:53:26,679
right now to go to this planet I will

1225
00:53:31,589 --> 00:53:28,449
warn you that it's not your classical

1226
00:53:34,709 --> 00:53:31,599
destination to go most likely this

1227
00:53:37,409 --> 00:53:34,719
planet it's a has a huge hiring and

1228
00:53:40,289 --> 00:53:37,419
helium envelope like Neptune for example

1229
00:53:42,599 --> 00:53:40,299
in that sense so I would really not buy

1230
00:53:45,839 --> 00:53:42,609
tickets to go here just just giving you

1231
00:53:48,549 --> 00:53:45,849
a heads up so Hubble has actually gave

1232
00:53:51,539 --> 00:53:48,559
us a tremendous advantage in terms of

1233
00:53:54,579 --> 00:53:51,549
the atmospheres of distant planets but

1234
00:53:55,900 --> 00:53:54,589
before Frank was mentioning the work

1235
00:53:58,449 --> 00:53:55,910
that we're doing at the James Webb Space

1236
00:54:00,849 --> 00:53:58,459
Telescope that it's set to launch next

1237
00:54:03,969 --> 00:54:00,859
year and I want you to give you I wanted

1238
00:54:06,759 --> 00:54:03,979

to give you a brief heads about what

1239
00:54:08,620 --> 00:54:06,769
what did James Webb is gonna do so right

1240
00:54:11,019 --> 00:54:08,630
now in terms of infrared light so all

1241
00:54:12,640 --> 00:54:11,029
the peaks that you see here all these

1242
00:54:15,099 --> 00:54:12,650
are different elements that you're

1243
00:54:18,039 --> 00:54:15,109
seeing here so right now have Oh

1244
00:54:21,099 --> 00:54:18,049
only has light how only has eyes for

1245
00:54:23,259 --> 00:54:21,109
this wavelength range and for a portions

1246
00:54:25,599 --> 00:54:23,269
of this wavelength range here but to

1247
00:54:28,539 --> 00:54:25,609
gather these ones which has also other

1248
00:54:30,309 --> 00:54:28,549
science signatures of water co2 and

1249
00:54:32,109 --> 00:54:30,319
these important signatures that we

1250
00:54:34,449 --> 00:54:32,119
observe in our own atmospheres you

1251
00:54:36,880 --> 00:54:34,459
really need eyes that can go beyond what

1252
00:54:39,519 --> 00:54:36,890
Hubble has done to down today

1253
00:54:42,999 --> 00:54:39,529
so it turns out that the James Webb so

1254
00:54:44,739 --> 00:54:43,009
if you if you could put the eyes of Webb

1255
00:54:46,870 --> 00:54:44,749
in terms of the wavelength range that

1256
00:54:48,279 --> 00:54:46,880
it's gonna target so the James Webb it's

1257
00:54:50,739 --> 00:54:48,289
gonna observe this whole wavelength

1258
00:54:53,199 --> 00:54:50,749
range so it's gonna give us you know an

1259
00:54:55,660 --> 00:54:53,209
exquisite view at this transiting

1260
00:54:58,660 --> 00:54:55,670
exoplanet atmospheres that we have not

1261
00:55:00,489 --> 00:54:58,670
yet explored so I can bet you right now

1262
00:55:02,739 --> 00:55:00,499
here that we're gonna discover stuff

1263
00:55:04,120 --> 00:55:02,749

that we were not expecting so imagine

1264
00:55:05,650 --> 00:55:04,130
the possibility so would right now we're

1265
00:55:08,019 --> 00:55:05,660
doing water what if we discover new

1266
00:55:09,849 --> 00:55:08,029
things new combination of elements in

1267
00:55:11,559 --> 00:55:09,859
this kind of planets including this K

1268
00:55:13,509 --> 00:55:11,569
2:18 that it's for sure than a meet

1269
00:55:16,150 --> 00:55:13,519
targeted by observers with the James

1270
00:55:19,179 --> 00:55:16,160
wave so we're really really excited

1271
00:55:20,829 --> 00:55:19,189
about working with web for for

1272
00:55:23,859 --> 00:55:20,839
especially Fortran in my case for

1273
00:55:25,479 --> 00:55:23,869
transiting exoplanet atmospheres so keep

1274
00:55:28,179 --> 00:55:25,489
your eyes open for this I think it's

1275
00:55:29,859 --> 00:55:28,189
gonna be extremely exciting it's going

1276
00:55:31,870 --> 00:55:29,869
to be exciting not only you know because

1277
00:55:34,390 --> 00:55:31,880
of these available zone planets but also

1278
00:55:36,279 --> 00:55:34,400
the composition of these atmospheres can

1279
00:55:38,949 --> 00:55:36,289
tell you a lot about how they formed

1280
00:55:41,589 --> 00:55:38,959
depending where they form we predict

1281
00:55:43,870 --> 00:55:41,599
they must have different compositions in

1282
00:55:45,459 --> 00:55:43,880
their atmospheres so we would web we're

1283
00:55:48,839 --> 00:55:45,469
gonna start doing this for the first

1284
00:55:52,779 --> 00:55:48,849
time ever in humanity and it is really

1285
00:55:54,130 --> 00:55:52,789
I'm you know an unthinkable thing for

1286
00:55:56,109 --> 00:55:54,140
previous astronomers that we are

1287
00:55:59,620 --> 00:55:56,119
actually able we're gonna be able to do

1288
00:56:01,730 --> 00:55:59,630

this with web compositions formation

1289
00:56:04,609 --> 00:56:01,740
signatures it will be basic

1290
00:56:07,070 --> 00:56:04,619
like standing on this exoplanet yourself

1291
00:56:10,480 --> 00:56:07,080
so keep your eye open and keep looking

1292
00:56:28,259 --> 00:56:10,490
at the sky thank you very much

1293
00:56:46,359 --> 00:56:44,440
questions something alien yeah yeah yeah

1294
00:56:49,839 --> 00:56:46,369
just so the folks online can hear you

1295
00:56:51,819 --> 00:56:49,849
when you talk about residents are you

1296
00:56:53,980 --> 00:56:51,829
implying harmonics and if you're

1297
00:56:56,259 --> 00:56:53,990
implying harmonics you got to have

1298
00:56:58,749 --> 00:56:56,269
boundary conditions and constraints yeah

1299
00:57:00,579 --> 00:56:58,759
and what are they yeah well for these

1300
00:57:03,519 --> 00:57:00,589
for the trapeze one system right now

1301
00:57:05,079 --> 00:57:03,529
yeah so every single word you said

1302
00:57:07,269 --> 00:57:05,089
actually makes total sense with the

1303
00:57:09,160 --> 00:57:07,279
trapeze one system and these are

1304
00:57:11,349 --> 00:57:09,170
actually so first of all these

1305
00:57:13,509 --> 00:57:11,359
resonances put themselves on boundary

1306
00:57:17,170 --> 00:57:13,519
conditions to the simulations so they

1307
00:57:18,279 --> 00:57:17,180
don't break and from there the the

1308
00:57:20,349 --> 00:57:18,289
current boundary condition that we

1309
00:57:22,239 --> 00:57:20,359
impose is basically the observed system

1310
00:57:23,410 --> 00:57:22,249
now so what people have been doing is

1311
00:57:25,569 --> 00:57:23,420
that they they put them in the

1312
00:57:29,200 --> 00:57:25,579
resonances as we observe them right now

1313
00:57:30,670 --> 00:57:29,210

and then they track into time so they

1314
00:57:32,380 --> 00:57:30,680
put the simulate they put like play in

1315
00:57:34,660 --> 00:57:32,390
the simulations and they see how it

1316
00:57:36,579 --> 00:57:34,670
evolves so the beautiful thing about the

1317
00:57:38,829 --> 00:57:36,589
resonances is that if if you don't put

1318
00:57:41,559 --> 00:57:38,839
them physically like you these ratios

1319
00:57:44,229 --> 00:57:41,569
between the periods this music the

1320
00:57:45,819 --> 00:57:44,239
system just blows out in you know a very

1321
00:57:47,859 --> 00:57:45,829
short amount of time but if you put them

1322
00:57:49,299 --> 00:57:47,869
this actually maintains the accordance

1323
00:57:51,099 --> 00:57:49,309
of the system for years and years and

1324
00:57:53,319 --> 00:57:51,109
years and years and people what they're

1325
00:57:54,880 --> 00:57:53,329
trying to do now is to track them from

1326
00:57:56,650 --> 00:57:54,890
all the simulation models right now

1327
00:57:58,150 --> 00:57:56,660
they're trying to see you know the

1328
00:58:00,910 --> 00:57:58,160
fraction of systems that actually

1329
00:58:02,620 --> 00:58:00,920
generates these resonances without much

1330
00:58:04,390 --> 00:58:02,630
boundary conditions on these ones and

1331
00:58:06,999 --> 00:58:04,400
this is the tough part because you need

1332
00:58:09,130 --> 00:58:07,009
to build like a bunch a lot of

1333
00:58:10,509 --> 00:58:09,140
simulations to actually get to the ones

1334
00:58:12,670 --> 00:58:10,519
that generate the resonances that we

1335
00:58:14,079 --> 00:58:12,680
observe today so I've spoken with some

1336
00:58:15,819 --> 00:58:14,089
of these folks and they're I mean some

1337
00:58:18,700 --> 00:58:15,829
of them are still trying to get this to

1338
00:58:20,440 --> 00:58:18,710

perfection but you're absolutely right

1339
00:58:21,880 --> 00:58:20,450
that there can be some you know

1340
00:58:24,160 --> 00:58:21,890
harmonics in tones and some of these

1341
00:58:25,989 --> 00:58:24,170
resonant systems for sure yeah yeah like

1342
00:58:28,180 --> 00:58:25,999
a piano string you know the two edges

1343
00:58:30,579 --> 00:58:28,190
are boundary conditions and so therefore

1344
00:58:32,109 --> 00:58:30,589
it's got the harmonics yes yes yes

1345
00:58:32,470 --> 00:58:32,119
there's some so leave honoree conditions

1346
00:58:34,450 --> 00:58:32,480
here

1347
00:58:36,550 --> 00:58:34,460
actually the loss of physics right like

1348
00:58:38,740 --> 00:58:36,560
gravity in this case so that's what put

1349
00:58:39,910 --> 00:58:38,750
them together yeah so in the case of the

1350
00:58:42,760 --> 00:58:39,920
string it's actually you know the

1351
00:58:44,349 --> 00:58:42,770
gravitation versus the tension right so

1352
00:58:46,450 --> 00:58:44,359
that's what you build how you build up

1353
00:58:50,940 --> 00:58:46,460
these boundary conditions so it's very

1354
00:58:55,210 --> 00:58:53,830
so I've read the rather more stars that

1355
00:58:58,480 --> 00:58:55,220
we can see with the naked eye are

1356
00:59:01,900 --> 00:58:58,490
actually double star systems how many

1357
00:59:03,970 --> 00:59:01,910
what does that do for planets yeah is

1358
00:59:06,040 --> 00:59:03,980
there many in orbit around such systems

1359
00:59:08,380 --> 00:59:06,050
yeah this is a really cool question

1360
00:59:12,070 --> 00:59:08,390
because there's tons of people trying to

1361
00:59:14,950 --> 00:59:12,080
figure this out so we do we have

1362
00:59:18,040 --> 00:59:14,960
discovered planets around this binary

1363
00:59:20,020 --> 00:59:18,050

even even binary stars are very far away

1364
00:59:21,970 --> 00:59:20,030
from each other but as soon as you start

1365
00:59:24,220 --> 00:59:21,980
putting them really close basically it's

1366
00:59:25,750 --> 00:59:24,230
like tough first of all there's like a

1367
00:59:28,870 --> 00:59:25,760
discussion in the literature is how

1368
00:59:30,460 --> 00:59:28,880
tough is to form the planets there so to

1369
00:59:32,530 --> 00:59:30,470
be completely honest right now I think

1370
00:59:34,840 --> 00:59:32,540
we don't have the the number of planets

1371
00:59:37,390 --> 00:59:34,850
discovered right now to give you like a

1372
00:59:38,830 --> 00:59:37,400
complete answer yes it's easier to form

1373
00:59:41,710 --> 00:59:38,840
planets around binary stars for example

1374
00:59:44,410 --> 00:59:41,720
but there's definitely people working on

1375
00:59:49,390 --> 00:59:44,420
exactly that topic as we speak Centauri

1376
00:59:56,720 --> 00:59:54,650
ready that's fun to catch all right so

1377
00:59:59,390 --> 00:59:56,730
I'm thinking of maybe pursuing a career

1378
01:00:02,060 --> 00:59:59,400
and like all this so could you possibly

1379
01:00:07,760 --> 01:00:02,070
just like tell me like what is like your

1380
01:00:13,940 --> 01:00:07,770
daily life like like when you go keep it

1381
01:00:16,340 --> 01:00:13,950
short we only have so much time so the

1382
01:00:18,050 --> 01:00:16,350
daily life is really fun in general so

1383
01:00:21,380 --> 01:00:18,060
right now my time is split between

1384
01:00:24,530 --> 01:00:21,390
working on web on my own science but I

1385
01:00:26,510 --> 01:00:24,540
would I would tell you that most of my

1386
01:00:29,360 --> 01:00:26,520
life daily has to do with computer

1387
01:00:31,100 --> 01:00:29,370
programming that's like basic thing for

1388
01:00:32,600 --> 01:00:31,110

astronomist today because you have to

1389
01:00:34,430 --> 01:00:32,610
analyze a lot of data and then you leave

1390
01:00:36,710 --> 01:00:34,440
the computer do it

1391
01:00:38,840 --> 01:00:36,720
but right I'm in Space Telescope by the

1392
01:00:40,130 --> 01:00:38,850
way the daily life it's completely

1393
01:00:41,900 --> 01:00:40,140
different to what I have experience in

1394
01:00:44,120 --> 01:00:41,910
other places because it's very dynamic

1395
01:00:45,410 --> 01:00:44,130
so there's lots of instrument meetings

1396
01:00:47,030 --> 01:00:45,420
there's a lot of stuff to do there's

1397
01:00:49,490 --> 01:00:47,040
always things to do with instruments

1398
01:00:50,900 --> 01:00:49,500
calibration commissioning happening so

1399
01:00:52,580 --> 01:00:50,910
it's very dynamic in that sense but if

1400
01:00:55,310 --> 01:00:52,590
you want to you want to take the

1401
01:00:58,640 --> 01:00:55,320
classical career in in terms of academia

1402
01:01:00,950 --> 01:00:58,650
like full-time research it's as dynamic

1403
01:01:03,110 --> 01:01:00,960
as you wanted basically so you sit down

1404
01:01:05,270 --> 01:01:03,120
you think about your ideas you develop

1405
01:01:06,980 --> 01:01:05,280
your ideas if you are a serious for

1406
01:01:08,840 --> 01:01:06,990
example you develop your models if

1407
01:01:12,440 --> 01:01:08,850
you're an observer then you analyze a

1408
01:01:14,240 --> 01:01:12,450
lot of data but it done sense life can

1409
01:01:16,520 --> 01:01:14,250
be as dynamic as you wanted in terms of

1410
01:01:18,410 --> 01:01:16,530
a researcher what I would suggest though

1411
01:01:20,960 --> 01:01:18,420
is that the career path us astronomers

1412
01:01:23,630 --> 01:01:20,970
it's it's told its varies a little bit

1413
01:01:25,850 --> 01:01:23,640

between people person to person so you

1414
01:01:28,160 --> 01:01:25,860
first do your PhD then you do typically

1415
01:01:30,320 --> 01:01:28,170
a postdoc so that means that you do 100%

1416
01:01:32,000 --> 01:01:30,330
research and then you get to these you

1417
01:01:34,190 --> 01:01:32,010
know staff positions in which you have

1418
01:01:36,080 --> 01:01:34,200
divided your work you to have in my case

1419
01:01:40,670 --> 01:01:36,090
training I'll work for the instruments

1420
01:01:43,700 --> 01:01:40,680
and have my own research at the end

1421
01:01:46,760 --> 01:01:43,710
stage let's say like that but if I can

1422
01:01:48,470 --> 01:01:46,770
give one advice programming it's like

1423
01:01:50,360 --> 01:01:48,480
the main thing right now and it will

1424
01:01:53,000 --> 01:01:50,370
simplify your life even if you don't

1425
01:01:54,650 --> 01:01:53,010
become you know an extract the thing

1426
01:01:56,870 --> 01:01:54,660
path of astronomer that you're thinking

1427
01:01:59,030 --> 01:01:56,880
right now and I would add to programming

1428
01:02:00,530 --> 01:01:59,040
collaboration okay you're going to work

1429
01:02:01,720 --> 01:02:00,540
if you're an astronomy you're going to

1430
01:02:03,190 --> 01:02:01,730
work in big groups

1431
01:02:05,170 --> 01:02:03,200
and you're gonna collaborate with people

1432
01:02:06,880 --> 01:02:05,180
across the country around the world so

1433
01:02:08,530 --> 01:02:06,890
learning collaboration and programming

1434
01:02:10,410 --> 01:02:08,540
and I think that'll help you all right

1435
01:02:20,830 --> 01:02:10,420
next question

1436
01:02:23,770 --> 01:02:20,840
good throw over here have you got any

1437
01:02:26,320 --> 01:02:23,780
insights from studying exoplanets that

1438
01:02:31,690 --> 01:02:26,330

help us understand the formation of our

1439
01:02:36,340 --> 01:02:31,700
solar system right when I said that the

1440
01:02:39,010 --> 01:02:36,350
solar system was weird I really meant it

1441
01:02:41,410 --> 01:02:39,020
there's an actual there's an actual

1442
01:02:43,540 --> 01:02:41,420
couple papers one of them the series of

1443
01:02:46,440 --> 01:02:43,550
them leads by geeks Mulder's from

1444
01:02:49,240 --> 01:02:46,450
Arizona right now he's in Chicago though

1445
01:02:51,640 --> 01:02:49,250
that have been studying the population

1446
01:02:54,010 --> 01:02:51,650
of known exoplanets we can actually now

1447
01:02:55,750 --> 01:02:54,020
say hey the solar system is actually

1448
01:02:57,430 --> 01:02:55,760
pretty weird with respect to what we see

1449
01:02:59,530 --> 01:02:57,440
are around the in other solar system in

1450
01:03:02,050 --> 01:02:59,540
order stellar systems so yes we can

1451
01:03:03,970 --> 01:03:02,060
learn a lot right now just now about how

1452
01:03:06,730 --> 01:03:03,980
weird our system is but I'm really

1453
01:03:09,010 --> 01:03:06,740
excited it's the next step right now how

1454
01:03:11,980 --> 01:03:09,020
weird our atmospheres like the earth

1455
01:03:15,520 --> 01:03:11,990
that's really the next path I would say

1456
01:03:17,680 --> 01:03:15,530
and right now we have no idea of this so

1457
01:03:19,060 --> 01:03:17,690
say for example people always think that

1458
01:03:20,560 --> 01:03:19,070
when we discovered that our planet with

1459
01:03:22,210 --> 01:03:20,570
the radius and mass of the earth

1460
01:03:23,830 --> 01:03:22,220
at the orbit that we see the earth

1461
01:03:26,290 --> 01:03:23,840
around other stars oh that's you know

1462
01:03:28,720 --> 01:03:26,300
airs 2.0 but think about that for a

1463
01:03:30,609 --> 01:03:28,730

minute could it be that maybe businesses

1464
01:03:32,109 --> 01:03:30,619
around there are actually the most

1465
01:03:34,060 --> 01:03:32,119
common in the galaxy could it be that

1466
01:03:36,460 --> 01:03:34,070
planets like Mars perhaps are the most

1467
01:03:37,990 --> 01:03:36,470
common we have absolutely no idea in

1468
01:03:41,140 --> 01:03:38,000
terms of the atmospheres right now and

1469
01:03:43,270 --> 01:03:41,150
that's where we're heading so no planet

1470
01:03:45,460 --> 01:03:43,280
number 9 or 10 for our solar system yet

1471
01:03:47,740 --> 01:03:45,470
no way you're not gonna find planet

1472
01:03:49,650 --> 01:03:47,750
number 9 or planet number 10 for us Oh

1473
01:03:54,970 --> 01:03:49,660
in the solar system

1474
01:03:56,950 --> 01:03:54,980
yeah there's divided opinions alright so

1475
01:03:58,950 --> 01:03:56,960
we have a question from online we had a

1476
01:04:02,290 --> 01:03:58,960
discussion online about statistics okay

1477
01:04:04,900 --> 01:04:02,300
in that transiting exoplanets are going

1478
01:04:07,780 --> 01:04:04,910
to be rare so we're only discovering

1479
01:04:09,750 --> 01:04:07,790
maybe 10 percent of the planets bio

1480
01:04:13,359 --> 01:04:09,760
transits simply because the geometric

1481
01:04:14,500 --> 01:04:13,369
proportion that then somebody said what

1482
01:04:15,970 --> 01:04:14,510
about period

1483
01:04:18,430 --> 01:04:15,980
I mean if you

1484
01:04:20,770 --> 01:04:18,440
you know Earth's period is a year and

1485
01:04:23,800 --> 01:04:20,780
you got to observe for many years how

1486
01:04:25,330 --> 01:04:23,810
are we limited in our statistics by the

1487
01:04:27,250 --> 01:04:25,340
length of our observations not being

1488
01:04:28,960 --> 01:04:27,260

able to see the very long period planets

1489
01:04:31,930 --> 01:04:28,970
yeah this is a really tough problem

1490
01:04:33,550 --> 01:04:31,940
right now so I think this person know

1491
01:04:36,220 --> 01:04:33,560
about what we're doing in the sense that

1492
01:04:39,640 --> 01:04:36,230
right now the mission that has observed

1493
01:04:41,530 --> 01:04:39,650
the longest period so far is Kepler so

1494
01:04:43,900 --> 01:04:41,540
Kepler spent like four entire years you

1495
01:04:46,120 --> 01:04:43,910
know target out the same region so we do

1496
01:04:49,060 --> 01:04:46,130
have statistics on long periods but so

1497
01:04:52,030 --> 01:04:49,070
far we have not detected one planet in

1498
01:04:54,970 --> 01:04:52,040
the same mass radius and period range as

1499
01:04:56,290 --> 01:04:54,980
Earth however we do extrapolations to

1500
01:04:58,300 --> 01:04:56,300
learn about the occurrence rates of

1501
01:05:00,730 --> 01:04:58,310
those periods but do be completely

1502
01:05:02,140 --> 01:05:00,740
honest those those extrapolations might

1503
01:05:03,460 --> 01:05:02,150
be a bit dangerous you know there's some

1504
01:05:07,680 --> 01:05:03,470
statistics that you have to pull out

1505
01:05:09,849 --> 01:05:07,690
here right now this is an issue for sure

1506
01:05:11,650 --> 01:05:09,859
this is an issue that has to be

1507
01:05:14,650 --> 01:05:11,660
addressed by future missions like the

1508
01:05:16,540 --> 01:05:14,660
plateau mission from ISA that's gonna be

1509
01:05:18,160 --> 01:05:16,550
pretty good in joining these two

1510
01:05:19,870 --> 01:05:18,170
datasets and seeing what you can say in

1511
01:05:21,340 --> 01:05:19,880
terms of the occurrence rates of planets

1512
01:05:23,590 --> 01:05:21,350
like Earth for sure but this is an issue

1513
01:05:25,780 --> 01:05:23,600

that we account in the MOUs for sure so

1514
01:05:26,650 --> 01:05:25,790
these transit geometry people when they

1515
01:05:28,270 --> 01:05:26,660
do occurrence rates

1516
01:05:30,880 --> 01:05:28,280
estimate so how common are planets

1517
01:05:33,010 --> 01:05:30,890
around you know sort of like stars at

1518
01:05:34,599 --> 01:05:33,020
this distance from the earth this is

1519
01:05:36,400 --> 01:05:34,609
being accounted for whenever you read

1520
01:05:38,470 --> 01:05:36,410
how common those kind of planets are

1521
01:05:40,090 --> 01:05:38,480
there's an error bar associated with

1522
01:05:42,340 --> 01:05:40,100
that and we we think we understand that

1523
01:05:44,410 --> 01:05:42,350
error pretty well I mean because like

1524
01:05:47,050 --> 01:05:44,420
our first planets were discovered in the

1525
01:05:48,910 --> 01:05:47,060
90s less than 30 years ago and Saturn

1526
01:05:50,950 --> 01:05:48,920
takes 30 years to orbit the Sun so

1527
01:05:53,320 --> 01:05:50,960
discovering a Saturn sized planet in a

1528
01:05:54,849 --> 01:05:53,330
Saturn sized orbit I would only just

1529
01:05:58,900 --> 01:05:54,859
become possible to see it one full

1530
01:06:01,180 --> 01:05:58,910
period right now that's working a lot

1531
01:06:04,540 --> 01:06:01,190
and this is a word that I am personally

1532
01:06:06,190 --> 01:06:04,550
doing what we call single translators so

1533
01:06:08,500 --> 01:06:06,200
I told you that yes you have to observe

1534
01:06:10,570 --> 01:06:08,510
several translates to get the period but

1535
01:06:12,430 --> 01:06:10,580
that's not entirely true the shape of

1536
01:06:13,960 --> 01:06:12,440
the transit light curve actually gives

1537
01:06:15,849 --> 01:06:13,970
you some information about the period

1538
01:06:17,680 --> 01:06:15,859

that you can extract even it gives there

1539
01:06:19,630 --> 01:06:17,690
only one transit and we're actually

1540
01:06:21,250 --> 01:06:19,640
doing it and we have nailed down a

1541
01:06:22,750 --> 01:06:21,260
couple system like this but they're

1542
01:06:25,359 --> 01:06:22,760
still not polish but they will look in

1543
01:06:29,260 --> 01:06:25,369
the near future all right other

1544
01:06:30,960 --> 01:06:29,270
questions here yes following up on the

1545
01:06:34,270 --> 01:06:30,970
man's question to you earlier about

1546
01:06:36,700 --> 01:06:34,280
career in astrophysics and also I'm

1547
01:06:45,040 --> 01:06:36,710
thinking of a career change as well does

1548
01:06:49,330 --> 01:06:45,050
it pay well I think so in the sense that

1549
01:06:52,090 --> 01:06:49,340
um I I now can leave very comfortably

1550
01:06:54,280 --> 01:06:52,100
you won't be a super millionaire for

1551
01:06:56,260 --> 01:06:54,290
sure but you can leave comfort to me I

1552
01:06:57,820 --> 01:06:56,270
think the most complicated thing about a

1553
01:07:01,330 --> 01:06:57,830
career in astrophysics has to be the

1554
01:07:04,150 --> 01:07:01,340
Moving's so moving I have a three

1555
01:07:05,650 --> 01:07:04,160
countries right now and um I mean

1556
01:07:09,370 --> 01:07:05,660
there's people that have moved 10 times

1557
01:07:11,530 --> 01:07:09,380
or more they once you finish your PhD

1558
01:07:14,700 --> 01:07:11,540
when you move to postdoc positions these

1559
01:07:18,370 --> 01:07:14,710
100% research sometimes they're usually

1560
01:07:20,470 --> 01:07:18,380
short limited to three years four years

1561
01:07:23,140 --> 01:07:20,480
of you're lucky and then that means

1562
01:07:25,000 --> 01:07:23,150
moving a lot between continents that's

1563
01:07:28,660 --> 01:07:25,010

the toughest part really like family

1564
01:07:30,820 --> 01:07:28,670
that's but money-wise you know the the

1565
01:07:37,300 --> 01:07:30,830
career as an astrophysicist space pays

1566
01:07:38,890 --> 01:07:37,310
well I mean if they want you like here

1567
01:07:40,960 --> 01:07:38,900
for example they they pay for your

1568
01:07:43,120 --> 01:07:40,970
relocation costs some of them you know

1569
01:07:45,100 --> 01:07:43,130
we're not like real business okay all

1570
01:07:48,130 --> 01:07:45,110
right come on my wife works in real

1571
01:07:50,440 --> 01:07:48,140
business and she yeah real businesses do

1572
01:07:53,560 --> 01:07:50,450
a lot more academia they give you a

1573
01:07:57,250 --> 01:07:53,570
little bit of space telescope is better

1574
01:07:59,590 --> 01:07:57,260
than most it's a professional salary but

1575
01:08:01,720 --> 01:07:59,600
it's no nowhere near top tier type

1576
01:08:05,110 --> 01:08:01,730
professional salaries for sure it

1577
01:08:07,960 --> 01:08:05,120
wouldn't make more industry well

1578
01:08:10,300 --> 01:08:07,970
actually the the guy who is second in

1579
01:08:12,430 --> 01:08:10,310
line for my postdoc at Princeton he went

1580
01:08:16,500 --> 01:08:12,440
to Wall Street and earned many many

1581
01:08:22,690 --> 01:08:19,840
have you discovered any moons exomoons

1582
01:08:24,579 --> 01:08:22,700
oh not me but there's a couple

1583
01:08:27,039 --> 01:08:24,589
colleagues working on this

1584
01:08:30,340 --> 01:08:27,049
David keeping an Alex tici so I like

1585
01:08:33,519 --> 01:08:30,350
teaching lead led a candidate Exim on a

1586
01:08:34,660 --> 01:08:33,529
couple years ago that to be completely

1587
01:08:35,829 --> 01:08:34,670
honest is still debated in the

1588
01:08:38,650 --> 01:08:35,839

literature but they're trying to follow

1589
01:08:41,349 --> 01:08:38,660
it up very heavily with you know Space

1590
01:08:42,450 --> 01:08:41,359
Telescope's like Hubble there's one

1591
01:08:44,550 --> 01:08:42,460
signature

1592
01:08:47,160 --> 01:08:44,560
what Hubble in one hubble data set and

1593
01:08:49,740 --> 01:08:47,170
in a Kepler data set for this EXO moon

1594
01:08:52,079 --> 01:08:49,750
the thing is that it's a moon the size

1595
01:08:54,450 --> 01:08:52,089
of like Neptune orbiting a planet like

1596
01:08:56,490 --> 01:08:54,460
Jupiter which is right it's like that's

1597
01:08:59,519 --> 01:08:56,500
pretty weird right that's not what we

1598
01:09:01,260 --> 01:08:59,529
think about moons but to be honest one

1599
01:09:03,599 --> 01:09:01,270
has to keep an open mind in this

1600
01:09:05,010 --> 01:09:03,609
business sometimes stuff happens that

1601
01:09:07,470 --> 01:09:05,020
it's outside the solar system we have

1602
01:09:10,050 --> 01:09:07,480
seen it with planets why not weed once

1603
01:09:11,760 --> 01:09:10,060
but look if we were in another solar

1604
01:09:13,829 --> 01:09:11,770
system observing our solar system hoping

1605
01:09:15,599 --> 01:09:13,839
we wouldn't believe that an earth could

1606
01:09:17,249 --> 01:09:15,609
have object this I'm moving the size of

1607
01:09:18,030 --> 01:09:17,259
our moon right it would be like no

1608
01:09:26,880 --> 01:09:18,040
that's crazy

1609
01:09:31,470 --> 01:09:26,890
all right so grant there's one way in

1610
01:09:33,809 --> 01:09:31,480
the back okay well grant travels to the

1611
01:09:37,650 --> 01:09:33,819
back of the room there is one question

1612
01:09:39,630 --> 01:09:37,660
here online how stable is Trappist one

1613
01:09:42,059 --> 01:09:39,640

does it flare have coronal mass

1614
01:09:44,130 --> 01:09:42,069
ejections more or less than our Sun if

1615
01:09:48,390 --> 01:09:44,140
those planets are in so close you know

1616
01:09:50,099 --> 01:09:48,400
solar flares can do some damage yeah so

1617
01:09:52,140 --> 01:09:50,109
it turns out that this star is very

1618
01:09:54,780 --> 01:09:52,150
small stars like the size of Jupiter

1619
01:09:57,510 --> 01:09:54,790
Morris you know really we're studying

1620
01:10:01,620 --> 01:09:57,520
that sense and it's a lot yes that's

1621
01:10:04,740 --> 01:10:01,630
true so there's there's huge concern for

1622
01:10:07,620 --> 01:10:04,750
the aliens living there that they might

1623
01:10:09,810 --> 01:10:07,630
be experiencing that that's definitely

1624
01:10:12,270 --> 01:10:09,820
happening so the atmosphere would be

1625
01:10:14,220 --> 01:10:12,280
bombarded by some radiation there but

1626
01:10:16,110 --> 01:10:14,230
it's important to take into account and

1627
01:10:17,700 --> 01:10:16,120
that's what makes these systems so

1628
01:10:20,040 --> 01:10:17,710
interesting in that sense because it's

1629
01:10:22,290 --> 01:10:20,050
it's something we have not seen so far

1630
01:10:24,510 --> 01:10:22,300
what happens for example maybe we can

1631
01:10:26,490 --> 01:10:24,520
learn what happens to atmospheres like

1632
01:10:29,190 --> 01:10:26,500
ours if we are bombarded by these kind

1633
01:10:31,350 --> 01:10:29,200
of huge energies so yes it's a concern

1634
01:10:32,850 --> 01:10:31,360
but it's also a source of study so a

1635
01:10:35,490 --> 01:10:32,860
Trappist one might have some barbecued

1636
01:10:38,640 --> 01:10:35,500
planets yeah okay all right last

1637
01:10:40,320 --> 01:10:38,650
question goes to the back row there so

1638
01:10:42,479 --> 01:10:40,330

when you were talking about the most

1639
01:10:45,930 --> 01:10:42,489
common planets being one to two to one

1640
01:10:47,610 --> 01:10:45,940
point four times earth so we think that

1641
01:10:49,050 --> 01:10:47,620
the moon is actually was part of the

1642
01:10:50,459 --> 01:10:49,060
earth at one point are you including the

1643
01:10:53,520 --> 01:10:50,469
moon in the mass of the earth when you

1644
01:10:57,060 --> 01:10:53,530
say that or are you know it

1645
01:10:59,100 --> 01:10:57,070
only it's only planets so far here right

1646
01:11:00,630 --> 01:10:59,110
I guess when I'm asking when you're

1647
01:11:02,760 --> 01:11:00,640
sitting in one to point two times earth

1648
01:11:05,250 --> 01:11:02,770
like when we think that the moon was

1649
01:11:06,720 --> 01:11:05,260
once part of Earth right when you're

1650
01:11:07,890 --> 01:11:06,730
talking about five or one point two is

1651
01:11:10,290 --> 01:11:07,900
not including the moon it's just

1652
01:11:12,240 --> 01:11:10,300
including the earth right but also right

1653
01:11:14,910 --> 01:11:12,250
if we put the earth in that sample is

1654
01:11:16,800 --> 01:11:14,920
just one among you know a huge I mean I

1655
01:11:19,080 --> 01:11:16,810
see your point that the earth might have

1656
01:11:21,630 --> 01:11:19,090
might be a little bit larger perhaps in

1657
01:11:23,670 --> 01:11:21,640
the past but it's just a little bit I

1658
01:11:25,130 --> 01:11:23,680
don't think it's extremely hard for the

1659
01:11:27,210 --> 01:11:25,140
precision that we have right now I'm

1660
01:11:29,820 --> 01:11:27,220
given that the earth is one data point

1661
01:11:31,560 --> 01:11:29,830
in the four thousand data point here I

1662
01:11:34,440 --> 01:11:31,570
might not be dying point but that's your

1663
01:11:36,690 --> 01:11:34,450

car right and just for reference the

1664
01:11:39,030 --> 01:11:36,700
moon's mass is only one percent the mass

1665
01:11:42,960 --> 01:11:39,040
of Earth so it's not that much of a

1666
01:11:44,760 --> 01:11:42,970
difference okay yeah so the idea that

1667
01:11:47,160 --> 01:11:44,770
the moon came from it came from the

1668
01:11:49,860 --> 01:11:47,170
crust of Earth it's got a lower density

1669
01:11:51,750 --> 01:11:49,870
much lower density than Earth's and

1670
01:11:53,670 --> 01:11:51,760
Earth's density so even though it's kind

1671
01:11:59,940 --> 01:11:53,680
of big it's low density all the way

1672
01:12:01,590 --> 01:11:59,950
through okay all right

1673
01:12:02,700 --> 01:12:01,600
you're gonna give one more question do

1674
01:12:05,550 --> 01:12:02,710
you have somebody you're headed

1675
01:12:09,530 --> 01:12:05,560
somewhere oh right we're done okay great

1676
01:12:12,090 --> 01:12:09,540
you had purpose to your walk there grant

1677
01:12:15,060 --> 01:12:12,100
know we're getting late it's it's about

1678
01:12:17,760 --> 01:12:15,070
time to go I need to quick ask is

1679
01:12:20,010 --> 01:12:17,770
anybody from Hopkins across the street

1680
01:12:21,210 --> 01:12:20,020
gonna do observing I didn't expect so

1681
01:12:25,050 --> 01:12:21,220
because it's cloudy

1682
01:12:28,050 --> 01:12:25,060
no fantastic all right next month April

1683
01:12:30,120 --> 01:12:28,060
7th 30 years of the Hubble Space

1684
01:12:32,520 --> 01:12:30,130
Telescope we're gonna do it let's give