

1
00:00:00,680 --> 00:00:06,000
there we go hello everybody welcome to

2
00:00:04,110 --> 00:00:07,470
our latest Hubble hangout my name is

3
00:00:06,000 --> 00:00:09,900
Tony Darnell work at the Space Telescope

4
00:00:07,469 --> 00:00:11,580
Science Institute and we've got a really

5
00:00:09,900 --> 00:00:13,080
interesting hangout plan for you today

6
00:00:11,580 --> 00:00:15,419
we have dr. mark clamping from the

7
00:00:13,080 --> 00:00:18,118
Goddard Space Flight Center here to talk

8
00:00:15,419 --> 00:00:21,089
to us about exoplanet observations both

9
00:00:18,118 --> 00:00:24,089
past present and the future and so we're

10
00:00:21,089 --> 00:00:26,969
looking very interesting hang out so we

11
00:00:24,089 --> 00:00:29,518
hope you will bring lots of questions

12
00:00:26,969 --> 00:00:31,948
and comments which brings me to how you

13
00:00:29,518 --> 00:00:33,750
can interact with us we hope we hope you

14
00:00:31,949 --> 00:00:36,450
will send us questions with the Q&A app

15
00:00:33,750 --> 00:00:38,340
on YouTube as well and the Google+ event

16
00:00:36,450 --> 00:00:41,640
page we're also monitoring the Hubble

17
00:00:38,340 --> 00:00:43,650
hangout ash tagged on Twitter and you

18
00:00:41,640 --> 00:00:45,870
can also comment on the Google+ event

19
00:00:43,649 --> 00:00:48,689
page itself so we're monitoring all

20
00:00:45,869 --> 00:00:50,549
these different avenues for you to

21
00:00:48,689 --> 00:00:52,559
interact so we hope to get lots of great

22
00:00:50,549 --> 00:00:55,530
questions from you later in the Hangout

23
00:00:52,560 --> 00:00:57,660
with me also is dr. Carol Christian

24
00:00:55,530 --> 00:00:59,310
Christian she is from the Space

25
00:00:57,659 --> 00:01:00,089
Telescope Science Institute as well hi

26
00:00:59,310 --> 00:01:03,690
Carol

27
00:01:00,090 --> 00:01:06,090
hello I'm Scott Lewis how's it going

28
00:01:03,689 --> 00:01:08,789
Tony hey ready to drive the Internet I

29

00:01:06,090 --> 00:01:11,280
I'm always ready to drive I know you're

30
00:01:08,790 --> 00:01:17,730
expert driver NASCAR of the Internet

31
00:01:11,280 --> 00:01:21,329
drivers f1f1 known as car any new Thank

32
00:01:17,730 --> 00:01:24,109
You Peggy so as I mentioned our guest

33
00:01:21,329 --> 00:01:26,489
today is dr. mark clamp and he is the

34
00:01:24,109 --> 00:01:28,319
observatory project scientist for the

35
00:01:26,489 --> 00:01:29,399
James Webb Space Telescope at Goddard

36
00:01:28,319 --> 00:01:33,000
welcome mark

37
00:01:29,400 --> 00:01:35,100
hi thanks I'm really excited to get you

38
00:01:33,000 --> 00:01:37,200
in a hangout because you've got a lot of

39
00:01:35,099 --> 00:01:38,879
great research going on you're involved

40
00:01:37,200 --> 00:01:41,189
in all kinds of great things but first I

41
00:01:38,879 --> 00:01:43,109
have to ask you observatory project

42
00:01:41,189 --> 00:01:45,390
scientists how was that different what

43
00:01:43,109 --> 00:01:47,159

is it what is it what does that mean and

44

00:01:45,390 --> 00:01:50,579

how does that differ from say just a

45

00:01:47,159 --> 00:01:51,960

regular project science well it comes

46

00:01:50,579 --> 00:01:54,989

down to the fact that James Webb Space

47

00:01:51,959 --> 00:01:58,199

Telescope is such a massive project and

48

00:01:54,989 --> 00:01:59,849

it's a very large telescope so my job is

49

00:01:58,200 --> 00:02:03,420

to be responsible for the observatory

50

00:01:59,849 --> 00:02:06,449

which is three pieces the telescope the

51

00:02:03,420 --> 00:02:08,818

Sun shield and then the spacecraft bus

52

00:02:06,450 --> 00:02:10,140

so my job is to work with the engineers

53

00:02:08,818 --> 00:02:12,839

to make sure that the science

54

00:02:10,139 --> 00:02:14,399

requirements for the telescope for the

55

00:02:12,840 --> 00:02:17,250

observatory are met

56

00:02:14,400 --> 00:02:19,739

or preferably exceeded and when they

57

00:02:17,250 --> 00:02:21,719

have problems I I'm the guy that gets to

58
00:02:19,739 --> 00:02:23,759
sit down with them and help them figure

59
00:02:21,719 --> 00:02:26,068
out how they can meet our requirements

60
00:02:23,759 --> 00:02:28,439
and still you know meet the budget or

61
00:02:26,068 --> 00:02:30,060
the schedule also really not not very

62
00:02:28,439 --> 00:02:36,870
much then you don't really have much to

63
00:02:30,060 --> 00:02:44,098
do they keep me very busy like an

64
00:02:36,870 --> 00:02:45,150
achiever there okay well that sounds

65
00:02:44,098 --> 00:02:47,219
great we're hope to get some more

66
00:02:45,150 --> 00:02:49,260
insights into the status of JWST a

67
00:02:47,219 --> 00:02:50,400
little bit later on in the Hangout but

68
00:02:49,259 --> 00:02:51,959
before we do that I want to talk a

69
00:02:50,400 --> 00:02:54,180
little bit about your research interest

70
00:02:51,959 --> 00:02:56,340
before you were building the James

71
00:02:54,180 --> 00:02:58,920
whatever coordinating all these efforts

72
00:02:56,340 --> 00:03:01,590
so what's your primary research interest

73
00:02:58,919 --> 00:03:04,889
so my primary research interest has

74
00:03:01,590 --> 00:03:07,140
always been direct imaging or taking

75
00:03:04,889 --> 00:03:09,298
pictures of debris disks which of the

76
00:03:07,139 --> 00:03:11,878
early stages of the formation of planets

77
00:03:09,299 --> 00:03:14,819
and then actually trying to directly

78
00:03:11,878 --> 00:03:18,268
image planets themselves so I started

79
00:03:14,818 --> 00:03:20,848
off 20 years ago building an instrument

80
00:03:18,269 --> 00:03:22,789
called a chronograph and I guess we'll

81
00:03:20,848 --> 00:03:26,578
get into how chronograph work later on

82
00:03:22,789 --> 00:03:30,750
for tellus telescopes that would be put

83
00:03:26,579 --> 00:03:31,469
on the chilean telescopes down in at

84
00:03:30,750 --> 00:03:34,169
lasya

85
00:03:31,469 --> 00:03:36,479
and then la serena and then i slowly

86

00:03:34,169 --> 00:03:38,099
evolved to working on flight hardware

87
00:03:36,479 --> 00:03:39,750
and I actually helped build the advanced

88
00:03:38,098 --> 00:03:42,719
camera for surveys which had a

89
00:03:39,750 --> 00:03:44,609
chronograph that's on double that's on

90
00:03:42,719 --> 00:03:46,378
Hubble so I've always kind of worked on

91
00:03:44,609 --> 00:03:48,989
building hardware to do this kind of

92
00:03:46,378 --> 00:03:51,239
problem and we started off as I said you

93
00:03:48,989 --> 00:03:53,400
know studying debris disks and the more

94
00:03:51,239 --> 00:03:54,810
you get into imaging debris disks the

95
00:03:53,400 --> 00:03:57,150
more you want to sort of go the next

96
00:03:54,810 --> 00:03:59,430
step and actually be able to direct the

97
00:03:57,150 --> 00:04:01,079
image the planets so that's what I've

98
00:03:59,430 --> 00:04:02,969
been kind of working on with Hubble on

99
00:04:01,079 --> 00:04:05,639
and off for the last you know 10 15

100
00:04:02,969 --> 00:04:07,859

years right so today's today's hangout

101

00:04:05,639 --> 00:04:10,079

topic obviously is about exoplanets but

102

00:04:07,859 --> 00:04:14,669

one of the things that really amazes me

103

00:04:10,079 --> 00:04:17,668

about this this branch of astronomy or

104

00:04:14,669 --> 00:04:20,129

research is that this really is a pretty

105

00:04:17,668 --> 00:04:21,810

brand-new research area isn't it you

106

00:04:20,129 --> 00:04:24,449

said yourself 20 years ago that pretty

107

00:04:21,810 --> 00:04:25,589

much marks the beginning of exoplanet

108

00:04:24,449 --> 00:04:27,810

research doesn't it I mean we have been

109

00:04:25,589 --> 00:04:28,229

doing this for very long no that's

110

00:04:27,810 --> 00:04:31,019

correct

111

00:04:28,230 --> 00:04:34,410

it's about 20 years and this is just a

112

00:04:31,019 --> 00:04:36,000

rapidly expanding field a lot of the new

113

00:04:34,410 --> 00:04:38,250

young people coming into astronomy

114

00:04:36,000 --> 00:04:39,959

they're all sort of coming into this

115
00:04:38,250 --> 00:04:42,720
field because there's just so much going

116
00:04:39,959 --> 00:04:44,370
on there's you know new planets being

117
00:04:42,720 --> 00:04:46,680
discovered every day it's just a really

118
00:04:44,370 --> 00:04:48,329
exciting and dynamic field right now and

119
00:04:46,680 --> 00:04:50,220
correct me if I'm wrong but if this

120
00:04:48,329 --> 00:04:52,589
field the exoplanet research really had

121
00:04:50,220 --> 00:04:54,510
I think pretty humble beginnings from my

122
00:04:52,589 --> 00:04:57,089
understanding I mean I remember at the

123
00:04:54,509 --> 00:05:00,000
high altitude observatory

124
00:04:57,089 --> 00:05:02,339
there was people there observing a

125
00:05:00,000 --> 00:05:05,069
project called stare sta re which

126
00:05:02,339 --> 00:05:07,919
basically used Mead telescopes in a

127
00:05:05,069 --> 00:05:12,269
parking lot to and this was with dr.

128
00:05:07,920 --> 00:05:15,090
carbon oh and and is it it was at Mike

129
00:05:12,269 --> 00:05:18,500
Brown it was old gosh I'm dating myself

130
00:05:15,089 --> 00:05:21,439
now but anyway they were looking at

131
00:05:18,500 --> 00:05:23,399
exoplanets or trying to find exoplanets

132
00:05:21,439 --> 00:05:24,209
presumably with the transit method which

133
00:05:23,399 --> 00:05:29,399
we'll get to in a minute

134
00:05:24,209 --> 00:05:31,349
with amateur grade instruments exactly I

135
00:05:29,399 --> 00:05:33,539
mean this well as you say well talk

136
00:05:31,350 --> 00:05:35,250
about transiting exoplanets in a minute

137
00:05:33,540 --> 00:05:37,920
but I think one of the amazing things

138
00:05:35,250 --> 00:05:39,959
about studying transits is you can

139
00:05:37,920 --> 00:05:41,939
actually stand in a car park like they

140
00:05:39,959 --> 00:05:45,180
Charbonneau did with a Celestron

141
00:05:41,939 --> 00:05:46,949
telescope and take data that you know

142
00:05:45,180 --> 00:05:52,620
shows you there's an exoplanet orbiting

143

00:05:46,949 --> 00:05:55,560
a star that's pretty amazing yeah we - a

144
00:05:52,620 --> 00:05:58,259
year and a half ago I held a hangout on

145
00:05:55,560 --> 00:06:00,899
here where I had one of our amateur

146
00:05:58,259 --> 00:06:04,259
astronomers that works with the AP a VSO

147
00:06:00,899 --> 00:06:05,939
and we did a live observation of a

148
00:06:04,259 --> 00:06:07,949
transiting exoplanets we were able to

149
00:06:05,939 --> 00:06:10,529
get the data there and show the curve

150
00:06:07,949 --> 00:06:12,000
going on afterwards and talk about what

151
00:06:10,529 --> 00:06:14,699
was going on these are things that can

152
00:06:12,000 --> 00:06:17,040
be done by every month and it's it's

153
00:06:14,699 --> 00:06:19,949
amazing and that this is real we're

154
00:06:17,040 --> 00:06:22,920
using advanced telescopes you know it

155
00:06:19,949 --> 00:06:24,810
you know orbiting in space and also very

156
00:06:22,920 --> 00:06:28,680
large telescopes here on earth to

157
00:06:24,810 --> 00:06:30,600

discover completely new worlds exactly

158

00:06:28,680 --> 00:06:33,240

they're transiting exoplanet method is

159

00:06:30,600 --> 00:06:35,370

great because it just scales from you

160

00:06:33,240 --> 00:06:37,050

know your telescope in the car park all

161

00:06:35,370 --> 00:06:40,319

the way up to James Webb Space Telescope

162

00:06:37,050 --> 00:06:42,030

and that every step or every scale you

163

00:06:40,319 --> 00:06:44,069

can make lots of really amazing

164

00:06:42,029 --> 00:06:47,129

discoveries all right well let's go

165

00:06:44,069 --> 00:06:49,349

ahead and bring that up so I believe

166

00:06:47,129 --> 00:06:50,610

you've got a good illustration of what

167

00:06:49,350 --> 00:06:52,830

the transit method is so let's talk

168

00:06:50,610 --> 00:06:54,629

about before we get to the future of

169

00:06:52,829 --> 00:06:55,919

exoplanet observations let's talk about

170

00:06:54,629 --> 00:06:57,930

how it's been done in the past as we

171

00:06:55,920 --> 00:07:00,870

talked about ahead relatively exoplanet

172
00:06:57,930 --> 00:07:03,240
research has been is a new field very

173
00:07:00,870 --> 00:07:06,180
young very exciting red hot right now in

174
00:07:03,240 --> 00:07:08,400
astronomy and and

175
00:07:06,180 --> 00:07:12,090
the observations have been done

176
00:07:08,399 --> 00:07:14,159
primarily by looking at very very tiny

177
00:07:12,089 --> 00:07:17,310
dips in brightness of a star and Scott

178
00:07:14,160 --> 00:07:20,610
has this up now basically when a planet

179
00:07:17,310 --> 00:07:23,250
passes in front of a star it gets just a

180
00:07:20,610 --> 00:07:25,770
little tiny bit dimmer and as the buzz

181
00:07:23,250 --> 00:07:28,199
up as the light is blocked from the star

182
00:07:25,769 --> 00:07:29,129
and Dave out I mean I'm sorry mark I'll

183
00:07:28,199 --> 00:07:31,229
let you go ahead and explain this

184
00:07:29,129 --> 00:07:33,629
animation a little bit okay so the

185
00:07:31,230 --> 00:07:36,660
animation is just showing what happens

186
00:07:33,629 --> 00:07:39,480
when you look at a star where the planet

187
00:07:36,660 --> 00:07:42,180
is actually moving across the face of

188
00:07:39,480 --> 00:07:44,580
the star as it orbit it's that star and

189
00:07:42,180 --> 00:07:46,889
so what happens is you see a very tiny

190
00:07:44,579 --> 00:07:49,769
dip in the amount of light coming from

191
00:07:46,889 --> 00:07:52,439
the star as the planet orbits across the

192
00:07:49,769 --> 00:07:54,839
face of the star and the dip is

193
00:07:52,439 --> 00:07:56,550
basically a function of the area of the

194
00:07:54,839 --> 00:08:01,769
star that you're looking at in the area

195
00:07:56,550 --> 00:08:04,590
of the planet so large gas giant planets

196
00:08:01,769 --> 00:08:07,049
like Jupiter z-- might produce a dip of

197
00:08:04,589 --> 00:08:09,119
a few percent whereas if you were

198
00:08:07,050 --> 00:08:11,129
looking at a terrestrial earth-like

199
00:08:09,120 --> 00:08:14,370
planet then the dip is much smaller it's

200

00:08:11,129 --> 00:08:16,920
about 0.05 percent and then it becomes

201
00:08:14,370 --> 00:08:18,990
very challenging measurement but just

202
00:08:16,920 --> 00:08:21,300
looking at some of these big Jupiter

203
00:08:18,990 --> 00:08:22,829
planets that's the kind of stuff you can

204
00:08:21,300 --> 00:08:25,170
do with a you know it's very simple

205
00:08:22,829 --> 00:08:27,750
telescope as we were talking about a few

206
00:08:25,170 --> 00:08:29,220
minutes ago Ryan this was the first

207
00:08:27,750 --> 00:08:31,110
measurements we made out of the first

208
00:08:29,220 --> 00:08:33,330
ways in which we detected exoplanets and

209
00:08:31,110 --> 00:08:34,620
this is an indirect method a meaning

210
00:08:33,330 --> 00:08:37,230
that we're not seeing the planet

211
00:08:34,620 --> 00:08:39,450
directly we're seeing we're seeing the

212
00:08:37,230 --> 00:08:41,970
the effect of that planet in orbit

213
00:08:39,450 --> 00:08:44,280
around the star and inferring the

214
00:08:41,970 --> 00:08:45,899

existence of that planet being there how

215

00:08:44,279 --> 00:08:47,129

hard is instamate how hard is this to

216

00:08:45,899 --> 00:08:49,169

make I mean we said we can do it with

217

00:08:47,129 --> 00:08:51,360

with amateur great instruments but we

218

00:08:49,169 --> 00:08:53,549

can do better jobs with with bigger

219

00:08:51,360 --> 00:08:55,980

telescopes correct I mean how how hard

220

00:08:53,549 --> 00:08:58,319

is this measurement it is

221

00:08:55,980 --> 00:09:00,329

it's not too hard if as I said if you're

222

00:08:58,320 --> 00:09:01,920

trying to just do gas giant planets

223

00:09:00,328 --> 00:09:04,439

where you're looking for a you know a

224

00:09:01,919 --> 00:09:07,019

few percent dip as you start trying to

225

00:09:04,440 --> 00:09:09,449

look for terrestrial planets it becomes

226

00:09:07,019 --> 00:09:12,269

a real problem because you need to have

227

00:09:09,448 --> 00:09:14,370

extremely precise photometry and that's

228

00:09:12,269 --> 00:09:16,620

why we've had to go into space to really

229
00:09:14,370 --> 00:09:18,389
look for the earth sized planets and

230
00:09:16,620 --> 00:09:19,980
that's as you know that's what the

231
00:09:18,389 --> 00:09:22,649
Kepler mission has been doing for the

232
00:09:19,980 --> 00:09:25,440
last you know six or seven years it's

233
00:09:22,649 --> 00:09:27,720
just been staring at 150,000 stars

234
00:09:25,440 --> 00:09:30,870
trying to find the ones that have

235
00:09:27,720 --> 00:09:32,910
transits that are directly traceable to

236
00:09:30,870 --> 00:09:36,899
something the size of a sort of small

237
00:09:32,909 --> 00:09:39,360
rocky planet so it it gets very easy to

238
00:09:36,899 --> 00:09:42,480
very very hard here's an example

239
00:09:39,360 --> 00:09:44,639
Kepler - and you'll be able to see I'll

240
00:09:42,480 --> 00:09:46,769
have it pop up here in a second where

241
00:09:44,639 --> 00:09:48,990
we're seeing those dips and brightness

242
00:09:46,769 --> 00:09:52,220
that's being detected I'm on the lower

243
00:09:48,990 --> 00:09:58,129
right-hand side of the screen right here

244
00:09:52,220 --> 00:09:58,129
right that's a very generous light curve

245
00:09:59,839 --> 00:10:04,620
right and when you look at real data

246
00:10:02,639 --> 00:10:06,448
you know without doing the analysis of

247
00:10:04,620 --> 00:10:08,639
the data and the processing it's very

248
00:10:06,448 --> 00:10:11,338
hard especially for the small planets to

249
00:10:08,639 --> 00:10:15,028
see any dip at all you need any planet

250
00:10:11,339 --> 00:10:17,490
to give you a so it's this technique

251
00:10:15,028 --> 00:10:19,350
really thrives on especially when you're

252
00:10:17,490 --> 00:10:21,539
trying to do the small planets on having

253
00:10:19,350 --> 00:10:24,120
as much light as possible even from very

254
00:10:21,539 --> 00:10:26,490
bright stars so this is one of the

255
00:10:24,120 --> 00:10:28,139
reasons why JWST is going to be such a

256
00:10:26,490 --> 00:10:31,049
powerful tool for doing this kind of

257

00:10:28,139 --> 00:10:33,000
science yes we're getting into that a

258
00:10:31,049 --> 00:10:36,000
little more detail in a bit but then we

259
00:10:33,000 --> 00:10:39,720
have used to do this I mean people did

260
00:10:36,000 --> 00:10:42,328
want to try and just go for an HST sized

261
00:10:39,720 --> 00:10:44,610
telescope what could be done it's not a

262
00:10:42,328 --> 00:10:47,578
primary thing that we do because these

263
00:10:44,610 --> 00:10:49,818
other observatories will concentrate on

264
00:10:47,578 --> 00:10:53,338
that but a few observations were taken

265
00:10:49,818 --> 00:10:54,838
with HST just to to make sure we knew

266
00:10:53,339 --> 00:10:56,370
what we're up against yeah I think

267
00:10:54,839 --> 00:10:58,500
Carolyn correct me if I'm wrong but the

268
00:10:56,370 --> 00:11:00,448
the reason HST is an ideally suited for

269
00:10:58,500 --> 00:11:02,278
this kind of work is that it takes

270
00:11:00,448 --> 00:11:04,528
generally these light curves take many

271
00:11:02,278 --> 00:11:06,629

days to sometimes depending on the

272

00:11:04,528 --> 00:11:08,188

period of the planet to create right so

273

00:11:06,629 --> 00:11:09,208

you really kind of need to take up a lot

274

00:11:08,188 --> 00:11:11,818

of Hubble time

275

00:11:09,208 --> 00:11:14,099

to do to get a decent curb right right

276

00:11:11,818 --> 00:11:18,659

and that's why as mark says the strategy

277

00:11:14,100 --> 00:11:20,550

that Kepler is using is so important so

278

00:11:18,659 --> 00:11:22,219

you can take a long time to make sure

279

00:11:20,549 --> 00:11:23,368

and you don't you can't just have one

280

00:11:22,220 --> 00:11:24,990

sample

281

00:11:23,369 --> 00:11:26,369

you can't just see it once to say oh

282

00:11:24,990 --> 00:11:28,678

there must be a planet no you're gonna

283

00:11:26,369 --> 00:11:30,569

it has to be periodic he has to keep

284

00:11:28,678 --> 00:11:33,838

coming back it has to be similar every

285

00:11:30,568 --> 00:11:36,360

time right and and so you you need that

286
00:11:33,839 --> 00:11:39,329
and so Kepler and staring for many years

287
00:11:36,360 --> 00:11:42,629
at the same region of the sky can then

288
00:11:39,328 --> 00:11:44,969
do that and as they acquire more and

289
00:11:42,629 --> 00:11:47,970
more data they can as Mark said get to

290
00:11:44,970 --> 00:11:50,428
some tinier and tinier planets that they

291
00:11:47,970 --> 00:11:52,230
can discover because initially the data

292
00:11:50,428 --> 00:11:54,360
is a little noisy so you have to keep

293
00:11:52,230 --> 00:11:56,159
accumulating the data until you get good

294
00:11:54,360 --> 00:11:59,159
statistics and you're confident about

295
00:11:56,159 --> 00:12:00,958
that you've detected a transit oh yeah

296
00:11:59,159 --> 00:12:02,639
this is a great segue into the past of

297
00:12:00,958 --> 00:12:04,078
observations hope Kepler was designed

298
00:12:02,639 --> 00:12:05,879
I'm just gonna fill in the gaps what we

299
00:12:04,078 --> 00:12:07,618
what we didn't say about Kepler is it's

300
00:12:05,879 --> 00:12:10,619
staring at one spot this guy looking at

301
00:12:07,619 --> 00:12:12,360
over 150,000 stars for a very very long

302
00:12:10,619 --> 00:12:14,879
time five years I believe was wouldn't

303
00:12:12,360 --> 00:12:16,709
was it Sun was its mission it went a

304
00:12:14,879 --> 00:12:19,769
little bit past that before it stopped

305
00:12:16,708 --> 00:12:22,318
being able to point precisely but for so

306
00:12:19,769 --> 00:12:24,360
we got five years of Kepler data looking

307
00:12:22,318 --> 00:12:26,789
at the same hundred and fifty some odd

308
00:12:24,360 --> 00:12:29,039
thousand stars and as Carol said we

309
00:12:26,789 --> 00:12:30,778
built this up over time to get these

310
00:12:29,039 --> 00:12:32,730
tiny dips and brightness and eight uses

311
00:12:30,778 --> 00:12:35,399
the transit method but that's not the

312
00:12:32,730 --> 00:12:37,110
only method to find these exoplanets

313
00:12:35,399 --> 00:12:39,839
it's just what Kepler uses and it was

314

00:12:37,110 --> 00:12:41,970
the beginning it was the way we started

315
00:12:39,839 --> 00:12:43,230
finding exoplanets in the first place

316
00:12:41,970 --> 00:12:45,809
but there's another method it's called

317
00:12:43,230 --> 00:12:48,480
the radial velocity method and Scott has

318
00:12:45,808 --> 00:12:50,610
a an animation that sort of illustrates

319
00:12:48,480 --> 00:12:52,558
that and Mark can you give us some

320
00:12:50,610 --> 00:12:55,048
insight into what that method is and and

321
00:12:52,558 --> 00:12:58,618
what are the best ways of making that

322
00:12:55,048 --> 00:13:00,958
kind of measurement okay so the radial

323
00:12:58,619 --> 00:13:04,139
velocity method was actually the first

324
00:13:00,958 --> 00:13:06,178
one that made up exoplanet discovery oh

325
00:13:04,139 --> 00:13:10,528
that was first I had it wrong on my ipod

326
00:13:06,178 --> 00:13:12,419
and it was me show my odd Geoff Marcy

327
00:13:10,528 --> 00:13:15,119
some of the early pioneers in this field

328
00:13:12,419 --> 00:13:19,558

and the basic idea is that if you have a

329

00:13:15,119 --> 00:13:22,980

star on its own it's it's and you add a

330

00:13:19,558 --> 00:13:25,948

planet you as the planet orbits

331

00:13:22,980 --> 00:13:27,778

start the combine center gravity of the

332

00:13:25,948 --> 00:13:30,990

two is just slightly offset from the

333

00:13:27,778 --> 00:13:33,328

center of the star and so you see the

334

00:13:30,990 --> 00:13:36,120

Stars and you know essentially orbit a

335

00:13:33,328 --> 00:13:37,948

very small amount and thus it's coming

336

00:13:36,120 --> 00:13:40,620

towards you and going away from you and

337

00:13:37,948 --> 00:13:44,399

you can actually measure that velocity

338

00:13:40,620 --> 00:13:47,549

in the dispersed light from the star you

339

00:13:44,399 --> 00:13:48,809

need extremely high sensitivity to do

340

00:13:47,549 --> 00:13:52,169

that because you're talking about

341

00:13:48,809 --> 00:13:55,198

measuring the order of kilometers or

342

00:13:52,169 --> 00:13:57,448

second differences in the lines as they

343
00:13:55,198 --> 00:13:58,948
move backwards and forwards so to do

344
00:13:57,448 --> 00:14:02,129
that you need very large ground-based

345
00:13:58,948 --> 00:14:04,919
telescopes that disperse the light you

346
00:14:02,129 --> 00:14:06,570
know a very large amount but a large

347
00:14:04,919 --> 00:14:08,250
number of the original planet

348
00:14:06,570 --> 00:14:10,949
discoveries were found using this

349
00:14:08,250 --> 00:14:12,659
technique and then we realize that some

350
00:14:10,948 --> 00:14:15,000
of these stars were probably transiting

351
00:14:12,659 --> 00:14:16,850
and we started to follow up the

352
00:14:15,000 --> 00:14:19,500
observations using the transit technique

353
00:14:16,850 --> 00:14:21,180
right so let's bring them together real

354
00:14:19,500 --> 00:14:23,100
quick so there's each of these methods

355
00:14:21,179 --> 00:14:24,419
has their own strengths and weaknesses

356
00:14:23,100 --> 00:14:26,639
and we can get different information

357
00:14:24,419 --> 00:14:28,620
about the exoplanet from each one you

358
00:14:26,639 --> 00:14:30,299
want to tell us what what can we learn

359
00:14:28,620 --> 00:14:33,328
from transit methods about exoplanets

360
00:14:30,299 --> 00:14:35,250
versus a radial velocity yeah I think

361
00:14:33,328 --> 00:14:38,578
that the story really is that when you

362
00:14:35,250 --> 00:14:40,528
put the two together you if you combine

363
00:14:38,578 --> 00:14:42,919
a system where you've got radial

364
00:14:40,528 --> 00:14:47,730
velocity measurements which give you the

365
00:14:42,919 --> 00:14:51,479
the mass times $M \sin i$ or the with the

366
00:14:47,730 --> 00:14:53,819
inclination and the transit method which

367
00:14:51,480 --> 00:14:55,740
gives you some idea of the radius of the

368
00:14:53,818 --> 00:14:58,379
star when you combine those together you

369
00:14:55,740 --> 00:15:00,959
can actually back out the mass the

370
00:14:58,379 --> 00:15:03,028
radius and then you've got some idea of

371

00:15:00,958 --> 00:15:04,828
the density and since you know the

372
00:15:03,028 --> 00:15:06,899
radius of the star you can start making

373
00:15:04,828 --> 00:15:09,000
inferences about the composition of the

374
00:15:06,899 --> 00:15:10,740
planet so when you put these two

375
00:15:09,000 --> 00:15:13,259
techniques together you start to get

376
00:15:10,740 --> 00:15:14,940
really useful data you know the kind of

377
00:15:13,259 --> 00:15:17,759
stuff astronomers like where you plot

378
00:15:14,940 --> 00:15:19,769
mass and radius on a on a chart and you

379
00:15:17,759 --> 00:15:23,338
can start to categorize these different

380
00:15:19,769 --> 00:15:24,899
planets does not do that right that it

381
00:15:23,339 --> 00:15:26,940
just does the radio or the transit

382
00:15:24,899 --> 00:15:28,740
method correct right so Kepler was

383
00:15:26,940 --> 00:15:32,329
designed to answer one very simple

384
00:15:28,740 --> 00:15:35,100
question what fraction of stars have a

385
00:15:32,328 --> 00:15:36,899

terrestrial or rocky planet orbiting

386

00:15:35,100 --> 00:15:39,629
them so it's really a

387

00:15:36,899 --> 00:15:42,019
Society in statistics but that's a very

388

00:15:39,629 --> 00:15:44,459
important number to know because

389

00:15:42,019 --> 00:15:47,188
ultimately we would like to directly

390

00:15:44,458 --> 00:15:49,768
image earth-like planets around other

391

00:15:47,188 --> 00:15:51,719
stars and even gets better of them but

392

00:15:49,769 --> 00:15:54,299
we can't really build a telescope to do

393

00:15:51,720 --> 00:15:56,369
that until we know what the probability

394

00:15:54,299 --> 00:15:58,708
that if we look at a given star it's

395

00:15:56,369 --> 00:16:01,079
gonna have a terrestrial planet it

396

00:15:58,708 --> 00:16:03,178
really determines how big your your

397

00:16:01,078 --> 00:16:04,708
mirror has to be so that's a very

398

00:16:03,178 --> 00:16:06,869
important number that we need to

399

00:16:04,708 --> 00:16:11,849
understand and that's what Kepler was

400
00:16:06,869 --> 00:16:13,199
designed to do so we got transit method

401
00:16:11,850 --> 00:16:15,899
will show you something about the radius

402
00:16:13,198 --> 00:16:17,159
of the planet and the radial velocity

403
00:16:15,899 --> 00:16:19,350
method will give you some idea of how

404
00:16:17,159 --> 00:16:20,669
massive the planet is so yeah he knows

405
00:16:19,350 --> 00:16:24,178
together we can get a pretty complete

406
00:16:20,669 --> 00:16:27,328
indirect picture of the the exoplanet

407
00:16:24,178 --> 00:16:28,588
itself but we're not satisfied with that

408
00:16:27,328 --> 00:16:31,109
either I mean this is how it's been done

409
00:16:28,589 --> 00:16:32,399
with the past and now we want to look at

410
00:16:31,110 --> 00:16:33,869
these things directly you said at the

411
00:16:32,399 --> 00:16:36,448
beginning that one of your research

412
00:16:33,869 --> 00:16:38,730
interest is to observe exoplanets

413
00:16:36,448 --> 00:16:43,169
directly can we do that now

414
00:16:38,730 --> 00:16:44,819
yes we can so observing exoplanet is

415
00:16:43,169 --> 00:16:47,938
directly it's a real challenge because

416
00:16:44,818 --> 00:16:49,948
they are extremely faint and they're

417
00:16:47,938 --> 00:16:53,068
orbiting very close to stars that are

418
00:16:49,948 --> 00:16:55,169
extremely bright and contrast so this

419
00:16:53,068 --> 00:16:58,169
whole field we call high dynamic range

420
00:16:55,169 --> 00:17:00,178
imaging or high contrast imaging and the

421
00:16:58,169 --> 00:17:03,539
basic idea is that you need to figure

422
00:17:00,178 --> 00:17:05,759
out a way whereby you can essentially

423
00:17:03,539 --> 00:17:08,009
suppress the light from the star you're

424
00:17:05,759 --> 00:17:10,349
looking at so that you can increase the

425
00:17:08,009 --> 00:17:13,048
region of contrast around the star and

426
00:17:10,349 --> 00:17:17,219
be able to direct the image of planet

427
00:17:13,048 --> 00:17:19,588
and just to give you an example if you

428

00:17:17,220 --> 00:17:22,350
were looking at our Sun from another

429
00:17:19,588 --> 00:17:25,078
solar system Jupiter will be about a

430
00:17:22,349 --> 00:17:27,298
billion times fainter than the star and

431
00:17:25,078 --> 00:17:29,490
if you were looking at the earth it will

432
00:17:27,298 --> 00:17:32,278
be about ten billion times fainter but

433
00:17:29,490 --> 00:17:34,200
also much closer and it's it's a very

434
00:17:32,278 --> 00:17:36,148
difficult very challenging problem it

435
00:17:34,200 --> 00:17:38,548
you have to think about a lot of

436
00:17:36,148 --> 00:17:40,379
different optical aspects of your

437
00:17:38,548 --> 00:17:43,139
telescope design when you try to do this

438
00:17:40,380 --> 00:17:47,250
so I was I was just going to comment and

439
00:17:43,140 --> 00:17:50,220
jump in here is that in the initial in

440
00:17:47,250 --> 00:17:50,609
any of these studies especially the

441
00:17:50,220 --> 00:17:53,759
trends

442
00:17:50,609 --> 00:17:55,649

method initially they were large planets

443

00:17:53,759 --> 00:17:57,629

that were found for the reasons that

444

00:17:55,650 --> 00:17:59,519

Mark was talking about is you need a big

445

00:17:57,630 --> 00:18:02,340

dip but you needed to go around several

446

00:17:59,519 --> 00:18:06,000

times where you needed to do that you

447

00:18:02,339 --> 00:18:09,000

can't have it's hard to detect a planet

448

00:18:06,000 --> 00:18:11,849

that is going to take ten years you know

449

00:18:09,000 --> 00:18:15,839

to cross in front of its star from your

450

00:18:11,849 --> 00:18:21,359

perspective so what happened was that

451

00:18:15,839 --> 00:18:24,539

many of the Jupiter Saturn type planets

452

00:18:21,359 --> 00:18:26,609

that were found were relatively close to

453

00:18:24,539 --> 00:18:28,289

their parent star which is not the

454

00:18:26,609 --> 00:18:30,479

situation that we have in our solar

455

00:18:28,289 --> 00:18:33,329

system so that was a puzzle for a while

456

00:18:30,480 --> 00:18:36,599

but it it's an artifact to the fact that

457
00:18:33,329 --> 00:18:39,149
that's how the transit observations work

458
00:18:36,599 --> 00:18:41,250
is that they are predisposed to find

459
00:18:39,150 --> 00:18:43,440
things that block a lot of light and are

460
00:18:41,250 --> 00:18:46,200
close to the parent star and go around a

461
00:18:43,440 --> 00:18:49,710
lot but that doesn't mean those are the

462
00:18:46,200 --> 00:18:51,090
only planets around other stars yeah

463
00:18:49,710 --> 00:18:52,950
there's a but there's an inherent bias

464
00:18:51,089 --> 00:18:54,689
in that observation because yeah it has

465
00:18:52,950 --> 00:18:56,850
to it has to pass the night it has to

466
00:18:54,690 --> 00:18:58,259
pass between us and the star of the even

467
00:18:56,849 --> 00:19:00,389
know it's there we don't get those other

468
00:18:58,259 --> 00:19:02,519
right and also Mark had mentioned

469
00:19:00,390 --> 00:19:06,240
inclination so if you have an

470
00:19:02,519 --> 00:19:08,519
inclination which is close to what we

471
00:19:06,240 --> 00:19:11,009
call edge onto the planet when it does

472
00:19:08,519 --> 00:19:13,500
orbit it crosses in front of the disk of

473
00:19:11,009 --> 00:19:16,169
the star we can see that dip but if it's

474
00:19:13,500 --> 00:19:19,200
or if the our vantage point is different

475
00:19:16,169 --> 00:19:22,410
we may not ever see that there are stars

476
00:19:19,200 --> 00:19:23,910
that don't know that have planets that

477
00:19:22,410 --> 00:19:25,980
we just haven't seen them so we need

478
00:19:23,910 --> 00:19:28,080
these other techniques so if anything

479
00:19:25,980 --> 00:19:29,700
Kepler has undercounted its region of

480
00:19:28,079 --> 00:19:30,960
the sky that is looking at because it's

481
00:19:29,700 --> 00:19:32,490
only counting those with the

482
00:19:30,960 --> 00:19:36,058
line-of-sight issues that we just talked

483
00:19:32,490 --> 00:19:38,519
about i Scott can you put that and that

484
00:19:36,058 --> 00:19:40,980
one animation back up where the worth of

485

00:19:38,519 --> 00:19:45,960
the planet going around the star and

486
00:19:40,980 --> 00:19:47,849
while he's doing - they're all through

487
00:19:45,960 --> 00:19:49,529
the one the first one the first one you

488
00:19:47,849 --> 00:19:51,779
show us one yes come by the transit

489
00:19:49,529 --> 00:19:56,720
method and the route of import

490
00:19:51,779 --> 00:20:01,069
planet going around all right all right

491
00:19:56,720 --> 00:20:01,069
the show is on exoplanets

492
00:20:10,869 --> 00:20:16,129
that one okay you gotta read my mind

493
00:20:14,900 --> 00:20:20,570
Scott I thought that's what that's what

494
00:20:16,130 --> 00:20:22,730
you did so I'm not too directly so to

495
00:20:20,569 --> 00:20:25,158
directly see this planet we're gonna

496
00:20:22,730 --> 00:20:27,890
need to block the light out from the

497
00:20:25,159 --> 00:20:30,020
star somehow and to do that we use

498
00:20:27,890 --> 00:20:33,320
something you know we use something

499
00:20:30,019 --> 00:20:36,529

called a coronagraph to see things close

500

00:20:33,319 --> 00:20:38,029

to the Sun to see for example the the

501

00:20:36,529 --> 00:20:41,569

atmosphere of the Sun we block out the

502

00:20:38,029 --> 00:20:45,470

disk using just a you know Anna Coulter

503

00:20:41,569 --> 00:20:47,480

here is it better to when we in order to

504

00:20:45,470 --> 00:20:49,159

see this exoplanet directly the one that

505

00:20:47,480 --> 00:20:51,470

Scott is currently showing we would have

506

00:20:49,159 --> 00:20:54,980

to somehow block the light from That

507

00:20:51,470 --> 00:20:57,650

star and we would see it like stuck if

508

00:20:54,980 --> 00:20:59,480

we Scott stopped it when it gets off to

509

00:20:57,650 --> 00:21:01,400

the limb of the star like right there if

510

00:20:59,480 --> 00:21:02,929

you can stop it somewhere when it gets

511

00:21:01,400 --> 00:21:03,860

to the side there you go yeah well

512

00:21:02,929 --> 00:21:05,780

that's close enough

513

00:21:03,859 --> 00:21:07,219

it's okay in order to see that we'd have

514
00:21:05,779 --> 00:21:09,950
to block the light out from that star

515
00:21:07,220 --> 00:21:12,140
right that is correct yes but we need

516
00:21:09,950 --> 00:21:13,880
the orientation to be such that it's

517
00:21:12,140 --> 00:21:17,450
either off to one side or the other this

518
00:21:13,880 --> 00:21:21,710
is only for exoplanets that are within

519
00:21:17,450 --> 00:21:24,169
our society exactly and so Scott's just

520
00:21:21,710 --> 00:21:25,640
put up a picture of a system called

521
00:21:24,169 --> 00:21:28,179
formal heart which is one I actually

522
00:21:25,640 --> 00:21:31,610
studied with Hubble Space Telescope and

523
00:21:28,179 --> 00:21:33,288
in this one you can actually see how of

524
00:21:31,609 --> 00:21:37,609
the chronograph on the advanced camera

525
00:21:33,288 --> 00:21:39,798
and subsequently Stace worked so we

526
00:21:37,609 --> 00:21:41,569
block out the light from the central

527
00:21:39,798 --> 00:21:43,490
star in this case former heart which is

528
00:21:41,569 --> 00:21:45,589
extremely bright star in the southern

529
00:21:43,490 --> 00:21:50,089
hemisphere and what you see in that

530
00:21:45,589 --> 00:21:54,199
image is a ring of dust very analogous

531
00:21:50,089 --> 00:21:57,889
to the Kuiper belt disc in our own solar

532
00:21:54,200 --> 00:22:01,538
system and then just inside it's

533
00:21:57,890 --> 00:22:04,038
highlighted in a box several different

534
00:22:01,538 --> 00:22:06,379
observations of a planet that's actually

535
00:22:04,038 --> 00:22:09,079
orbit informal heart and this we were

536
00:22:06,380 --> 00:22:10,640
able to do using direct imaging high

537
00:22:09,079 --> 00:22:14,178
contrast imaging with the Hubble Space

538
00:22:10,640 --> 00:22:16,940
Telescope yeah I know you said it

539
00:22:14,179 --> 00:22:18,890
yourself the debris disc around that is

540
00:22:16,940 --> 00:22:20,660
very visible here huh yeah so how is

541
00:22:18,890 --> 00:22:23,420
this done how do you block out the light

542

00:22:20,660 --> 00:22:27,519
from these from these stars so put very

543
00:22:23,420 --> 00:22:30,800
simply you put very simply you have a

544
00:22:27,519 --> 00:22:34,099
some kind of mask in your optical system

545
00:22:30,799 --> 00:22:36,799
so you focus the light from the image

546
00:22:34,099 --> 00:22:39,619
down onto a very small mask and then you

547
00:22:36,799 --> 00:22:41,599
re have to reimage that light and also

548
00:22:39,619 --> 00:22:43,849
block out a lot of the scattered light

549
00:22:41,599 --> 00:22:47,599
that's produced by optical effects in

550
00:22:43,849 --> 00:22:50,359
the system once you've done that you can

551
00:22:47,599 --> 00:22:53,089
then re image the picture again and it

552
00:22:50,359 --> 00:22:55,009
it gives you a pretty good what we call

553
00:22:53,089 --> 00:22:57,379
circumstellar image an image of the

554
00:22:55,009 --> 00:23:00,109
region around the star you don't always

555
00:22:57,380 --> 00:23:02,930
get to remove most the light from the

556
00:23:00,109 --> 00:23:04,879

central star so certainly in the case of

557

00:23:02,930 --> 00:23:07,640

Hubble which cannot achieve the kind of

558

00:23:04,880 --> 00:23:11,330

contrasts I mentioned so Hubble we can

559

00:23:07,640 --> 00:23:14,300

get contrasts of about a thousand to ten

560

00:23:11,329 --> 00:23:15,829

thousand maybe so to do Hubble

561

00:23:14,299 --> 00:23:18,079

observations we actually take a picture

562

00:23:15,829 --> 00:23:20,240

of our system and then we take a picture

563

00:23:18,079 --> 00:23:22,879

of a star that we don't think has a

564

00:23:20,240 --> 00:23:24,410

planet or several stars that we don't

565

00:23:22,880 --> 00:23:27,500

think have a planet and we actually have

566

00:23:24,410 --> 00:23:29,600

to do a subtraction of one from the

567

00:23:27,500 --> 00:23:31,819

other to remove the residual halo of

568

00:23:29,599 --> 00:23:35,179

light so that we can actually find these

569

00:23:31,819 --> 00:23:36,589

planets oh wow okay so I understand in

570

00:23:35,180 --> 00:23:38,930

this diagram that that's up right now I

571
00:23:36,589 --> 00:23:40,549
understand the occulting spot part I get

572
00:23:38,930 --> 00:23:42,500
I get what's going on there but I don't

573
00:23:40,549 --> 00:23:45,549
understand the leo stop what is that

574
00:23:42,500 --> 00:23:48,470
doing so the Leo stop is to deal with

575
00:23:45,549 --> 00:23:50,659
what we call diffraction so every edge

576
00:23:48,470 --> 00:23:52,880
in the optical system the telescope

577
00:23:50,660 --> 00:23:55,160
spider that holds a secondary mirror the

578
00:23:52,880 --> 00:23:57,230
edge of the secondary mirror the edge of

579
00:23:55,160 --> 00:23:59,960
the primary mirror is diffracting light

580
00:23:57,230 --> 00:24:03,019
and you can first order think of that as

581
00:23:59,960 --> 00:24:05,870
just scattering light and so that light

582
00:24:03,019 --> 00:24:07,609
needs to be suppressed so the leo filter

583
00:24:05,869 --> 00:24:10,039
just removes although that scattered

584
00:24:07,609 --> 00:24:12,559
light in what we call the pupil plane

585
00:24:10,039 --> 00:24:14,899
and then when you re image you don't get

586
00:24:12,559 --> 00:24:17,319
all of that additional stray light or

587
00:24:14,900 --> 00:24:21,320
scattered light contaminating your image

588
00:24:17,319 --> 00:24:24,109
now this is a very simple coronagraph

589
00:24:21,319 --> 00:24:25,759
design it's the original EO design that

590
00:24:24,109 --> 00:24:27,919
I showed you there are lots more now

591
00:24:25,759 --> 00:24:30,680
which are infinitely more complicated

592
00:24:27,920 --> 00:24:32,900
that use bending mirrors the

593
00:24:30,680 --> 00:24:35,750
for mobile mirrors and there are also

594
00:24:32,900 --> 00:24:38,570
designs use you know very small

595
00:24:35,750 --> 00:24:40,250
interferometers to interfere pieces of

596
00:24:38,569 --> 00:24:42,470
the light in the focal plane with each

597
00:24:40,250 --> 00:24:44,509
other to block out the light from the

598
00:24:42,470 --> 00:24:47,660
central star so there's a there's a

599

00:24:44,509 --> 00:24:49,460
whole universe of different approaches

600
00:24:47,660 --> 00:24:51,800
to doing choreography now based on

601
00:24:49,460 --> 00:24:53,870
different optical techniques right so

602
00:24:51,799 --> 00:24:56,720
the future of exoplanet observations is

603
00:24:53,869 --> 00:24:59,479
to see them directly and let's talk

604
00:24:56,720 --> 00:25:02,660
about what JWST is planning on doing

605
00:24:59,480 --> 00:25:04,519
they have is it correct me if I'm wrong

606
00:25:02,660 --> 00:25:05,690
but is that what the micro shutters are

607
00:25:04,519 --> 00:25:07,700
supposed to be for there's these things

608
00:25:05,690 --> 00:25:10,039
called micro shutters on JWST that are

609
00:25:07,700 --> 00:25:13,340
designed I think to block out light from

610
00:25:10,039 --> 00:25:16,069
stars is that correct the micro shutters

611
00:25:13,339 --> 00:25:18,559
are actually allowed to allow us to look

612
00:25:16,069 --> 00:25:21,230
at multiple objects at the same time so

613
00:25:18,559 --> 00:25:25,490

they're more geared towards the deep

614

00:25:21,230 --> 00:25:28,880

imaging of galaxies problem but several

615

00:25:25,490 --> 00:25:31,220

of the JWST instruments have

616

00:25:28,880 --> 00:25:33,410

coronagraphs built into them that will

617

00:25:31,220 --> 00:25:35,809

give us different levels of performance

618

00:25:33,410 --> 00:25:38,330

in near-infrared and then the medium

619

00:25:35,809 --> 00:25:41,509

Freret so in the near-infrared we use

620

00:25:38,329 --> 00:25:44,359

very traditional coronagraphs much like

621

00:25:41,509 --> 00:25:46,490

the one we just saw in the figure in the

622

00:25:44,359 --> 00:25:48,469

mid infrared at longer wavelengths we

623

00:25:46,490 --> 00:25:50,690

actually use a small interferometer

624

00:25:48,470 --> 00:25:53,779

where we divide the focal plane into

625

00:25:50,690 --> 00:25:56,480

four and in to interfere pieces against

626

00:25:53,779 --> 00:26:00,019

each other to block out on now the light

627

00:25:56,480 --> 00:26:02,960

from the central star so JWST has some

628
00:26:00,019 --> 00:26:05,389
extremely capable coronagraphs and they

629
00:26:02,960 --> 00:26:08,000
will allow us to really study that

630
00:26:05,390 --> 00:26:09,980
parameter space that isn't sort of met

631
00:26:08,000 --> 00:26:12,559
by doing transit observations to further

632
00:26:09,980 --> 00:26:15,160
out objects but all bits of you know

633
00:26:12,559 --> 00:26:17,869
roughly akin to jupiter and further out

634
00:26:15,160 --> 00:26:19,310
ok well that you brought up the topic I

635
00:26:17,869 --> 00:26:21,919
want to get to it whereas as an

636
00:26:19,309 --> 00:26:24,319
exoplanet researcher what most excites

637
00:26:21,920 --> 00:26:25,610
you about JWST I mean what kinds of

638
00:26:24,319 --> 00:26:29,960
planets are we going to be able to image

639
00:26:25,609 --> 00:26:32,209
with that so I I think for me the two

640
00:26:29,960 --> 00:26:34,789
most exciting things are one being able

641
00:26:32,210 --> 00:26:36,529
to take images of systems like formal

642
00:26:34,789 --> 00:26:40,279
hearts at different wavelengths I think

643
00:26:36,529 --> 00:26:42,920
we all really be able to stop the piece

644
00:26:40,279 --> 00:26:44,149
apart that system now by imaging at

645
00:26:42,920 --> 00:26:44,690
different wavelengths we can see

646
00:26:44,150 --> 00:26:46,820
different

647
00:26:44,690 --> 00:26:49,789
distributions or different populations

648
00:26:46,819 --> 00:26:51,859
are dust within the system and we can

649
00:26:49,789 --> 00:26:53,659
also hunt for the other planets that we

650
00:26:51,859 --> 00:26:57,409
think might be there that we can't right

651
00:26:53,660 --> 00:27:00,140
now see as far as the transiting systems

652
00:26:57,410 --> 00:27:02,840
goes that's where I think JWST is going

653
00:27:00,140 --> 00:27:04,460
to be the killer application it just has

654
00:27:02,839 --> 00:27:07,549
everything you need to do really

655
00:27:04,460 --> 00:27:09,230
fantastic transiting exoplanet science

656

00:27:07,549 --> 00:27:12,019
and we haven't actually talked much

657
00:27:09,230 --> 00:27:14,240
about doing spectroscopy but the next

658
00:27:12,019 --> 00:27:16,970
step in doing transit transiting

659
00:27:14,240 --> 00:27:19,490
observations is to disperse the light as

660
00:27:16,970 --> 00:27:21,289
you measure the transit and by doing

661
00:27:19,490 --> 00:27:23,480
that you can actually back out the

662
00:27:21,289 --> 00:27:25,909
spectrum or the dispersed light

663
00:27:23,480 --> 00:27:27,920
signature of the planet's atmosphere and

664
00:27:25,910 --> 00:27:29,420
once you can do that then you can start

665
00:27:27,920 --> 00:27:31,759
studying lots of different planets

666
00:27:29,420 --> 00:27:34,820
looking at their atmospheres and really

667
00:27:31,759 --> 00:27:37,730
doing a lot more comparison of different

668
00:27:34,819 --> 00:27:40,399
types of planets so can you can you

669
00:27:37,730 --> 00:27:42,440
quantify that a little bit how we work

670
00:27:40,400 --> 00:27:44,210

presumably we're doing are we able to

671

00:27:42,440 --> 00:27:45,830

wobble to me back up are we able to do

672

00:27:44,210 --> 00:27:48,019

this now with anything that currently

673

00:27:45,829 --> 00:27:51,199

exists get these get the composition of

674

00:27:48,019 --> 00:27:55,150

exoplanet atmospheres so we can do this

675

00:27:51,200 --> 00:27:57,230

now with HST is they're extremely hard

676

00:27:55,150 --> 00:27:59,690

observations as you said because a

677

00:27:57,230 --> 00:28:02,299

single transit can last many hours and

678

00:27:59,690 --> 00:28:04,940

you know Hubble goes around the earth

679

00:28:02,299 --> 00:28:06,919

every 90 minutes so you only get half of

680

00:28:04,940 --> 00:28:08,809

90 minutes to actually do science you

681

00:28:06,920 --> 00:28:11,779

have to piece together several transits

682

00:28:08,809 --> 00:28:13,700

and Hubble doesn't work out into the

683

00:28:11,779 --> 00:28:16,990

full range of the near-infrared you know

684

00:28:13,700 --> 00:28:20,330

it does you know what one to 1.7 microns

685
00:28:16,990 --> 00:28:23,509
rather than one to five which JW can do

686
00:28:20,329 --> 00:28:26,689
and then JW can also do the 5 to 30

687
00:28:23,509 --> 00:28:30,279
range W it's kind of like you're on

688
00:28:26,690 --> 00:28:30,279
first name basis with you know just

689
00:28:31,630 --> 00:28:36,080
that's right yeah I called me on the

690
00:28:34,339 --> 00:28:39,379
breast ice and NDT cuz we're like that

691
00:28:36,079 --> 00:28:41,480
so yeah and and the other thing is that

692
00:28:39,380 --> 00:28:44,120
spits has also started to do this but

693
00:28:41,480 --> 00:28:46,700
it's has to build up a spectrum by

694
00:28:44,119 --> 00:28:48,739
taking images and then you get a

695
00:28:46,700 --> 00:28:51,170
spectrum with what we call a spectral

696
00:28:48,740 --> 00:28:52,940
energy distribution four or five data

697
00:28:51,170 --> 00:28:55,279
points and you're trying to fit to those

698
00:28:52,940 --> 00:28:57,590
so being able to get a real spectrum

699
00:28:55,279 --> 00:28:58,579
with a very high resolution in a single

700
00:28:57,589 --> 00:29:00,769
transit which is

701
00:28:58,579 --> 00:29:02,839
James Webb will give you is that going

702
00:29:00,769 --> 00:29:04,009
to be very powerful okay that brings to

703
00:29:02,839 --> 00:29:05,240
the question I initially wanted to ask

704
00:29:04,009 --> 00:29:07,429
you which we can you quantify it a

705
00:29:05,240 --> 00:29:09,470
little bit how much better JWST might do

706
00:29:07,429 --> 00:29:12,380
then how these current observations are

707
00:29:09,470 --> 00:29:15,950
being done or I don't know maybe orders

708
00:29:12,380 --> 00:29:17,690
of magnitude estimate that's tough but

709
00:29:15,950 --> 00:29:20,750
you know you know the bottom line is

710
00:29:17,690 --> 00:29:23,720
that most of the observations we're

711
00:29:20,750 --> 00:29:25,548
doing now the resolutions may be the

712
00:29:23,720 --> 00:29:28,220
order of spectral resolution of a

713

00:29:25,548 --> 00:29:30,200
hundred with jwe we can go to two

714
00:29:28,220 --> 00:29:32,600
thousand three thousand spectral

715
00:29:30,200 --> 00:29:34,819
resolution and we can get get a full

716
00:29:32,599 --> 00:29:37,579
transit in one visit for a lot of gas

717
00:29:34,819 --> 00:29:39,319
giant planets so you've said that the

718
00:29:37,579 --> 00:29:42,819
the transit method is going to be one of

719
00:29:39,319 --> 00:29:49,730
the bread-and-butter uh applications of

720
00:29:42,819 --> 00:29:52,519
JWST or you said JW yeah so what did did

721
00:29:49,730 --> 00:29:55,490
the results from Kepler surprised you at

722
00:29:52,519 --> 00:29:59,509
all as a scientist just how many planets

723
00:29:55,490 --> 00:30:02,960
Kepler found I know I think one of the

724
00:29:59,509 --> 00:30:04,730
thing I know I was I have actually one

725
00:30:02,960 --> 00:30:06,620
of the believers who was expecting that

726
00:30:04,730 --> 00:30:09,169
Kepler would find a lot of planets and

727
00:30:06,619 --> 00:30:11,538

it has I think it's been one of the

728

00:30:09,169 --> 00:30:14,419

surprising things is just how many small

729

00:30:11,538 --> 00:30:17,450

planets and also planets in the sort of

730

00:30:14,419 --> 00:30:20,210

super earth range midway between the

731

00:30:17,450 --> 00:30:23,569

size of our earth and uranus and neptune

732

00:30:20,210 --> 00:30:25,880

so it's discovered i for me one of its

733

00:30:23,569 --> 00:30:29,629

big discoveries is just how many super s

734

00:30:25,880 --> 00:30:31,370

and small rocky there are out there yeah

735

00:30:29,630 --> 00:30:33,740

i bring that up because one of the big

736

00:30:31,369 --> 00:30:35,750

things that I always hear JWST project

737

00:30:33,740 --> 00:30:37,099

members talk about is that one of the

738

00:30:35,750 --> 00:30:39,230

most exciting things about the James

739

00:30:37,099 --> 00:30:41,480

Webb Space Telescope isn't the kinds of

740

00:30:39,230 --> 00:30:43,220

science that we are we know we can do

741

00:30:41,480 --> 00:30:44,569

with Jay are the kinds of answers are

742
00:30:43,220 --> 00:30:47,569
two questions we know we're going to get

743
00:30:44,569 --> 00:30:49,369
but the answers to questions that we do

744
00:30:47,569 --> 00:30:52,189
haven't even thought to answer ask yet

745
00:30:49,369 --> 00:30:54,709
and so there's a whole unknown area of

746
00:30:52,190 --> 00:30:56,690
things that we expect JWST will show us

747
00:30:54,710 --> 00:30:59,450
and from Kay and I use Kepler as an

748
00:30:56,690 --> 00:31:01,190
example because from my mind I think

749
00:30:59,450 --> 00:31:03,319
it's just blown everybody away I mean

750
00:31:01,190 --> 00:31:06,649
staring at one spot in the sky for years

751
00:31:03,319 --> 00:31:09,109
and years is a pretty simple thing to do

752
00:31:06,648 --> 00:31:11,629
and it blew us away with what it is

753
00:31:09,109 --> 00:31:13,879
about our place in the universe so

754
00:31:11,630 --> 00:31:16,820
I'm just excited about JWST coming out

755
00:31:13,880 --> 00:31:18,470
but that's not all let's talk about some

756
00:31:16,819 --> 00:31:20,629
other things well real quick before we

757
00:31:18,470 --> 00:31:25,279
do that for those that aren't aware of

758
00:31:20,630 --> 00:31:27,620
the just how spectacular JWST is I mean

759
00:31:25,279 --> 00:31:30,049
I know you and I've done some outreach

760
00:31:27,619 --> 00:31:33,369
with the full-scale model but here's a

761
00:31:30,049 --> 00:31:40,309
wonderful animation just showing how

762
00:31:33,369 --> 00:31:44,419
fantastic de WS t is so it's going to be

763
00:31:40,309 --> 00:31:46,369
owned at the the l2 point and it is what

764
00:31:44,420 --> 00:31:48,230
the area of a tennis court and four

765
00:31:46,369 --> 00:31:54,019
stories tall is that about accurate

766
00:31:48,230 --> 00:31:56,240
that's right it's the best rent and I

767
00:31:54,019 --> 00:31:58,639
was as I was telling you earlier Tony I

768
00:31:56,240 --> 00:32:01,279
just participated in the first-ever

769
00:31:58,640 --> 00:32:03,230
deployment of those five layers on the

770

00:32:01,279 --> 00:32:05,750
ground and it's really amazing when

771
00:32:03,230 --> 00:32:07,039
you're standing inside the tennis I know

772
00:32:05,750 --> 00:32:08,480
and I want to do and I want to get you

773
00:32:07,039 --> 00:32:10,159
back and another hangout to talk about

774
00:32:08,480 --> 00:32:11,930
that specifically because I want to know

775
00:32:10,160 --> 00:32:13,610
how it went maybe everything's on track

776
00:32:11,930 --> 00:32:15,650
if you guys learned anything on you

777
00:32:13,609 --> 00:32:17,240
doing that deployment but unfortunately

778
00:32:15,650 --> 00:32:19,220
we don't have time because I want to get

779
00:32:17,240 --> 00:32:21,109
to so many other things so mark your

780
00:32:19,220 --> 00:32:25,210
calendar and for another for another

781
00:32:21,109 --> 00:32:29,599
hangout where we'll go into this okay so

782
00:32:25,210 --> 00:32:30,740
a Coulter well what's the next I'll let

783
00:32:29,599 --> 00:32:32,029
you drive this part of the conversation

784
00:32:30,740 --> 00:32:33,079

yeah what do you want to talk about

785

00:32:32,029 --> 00:32:34,609

knife you've got all these different

786

00:32:33,079 --> 00:32:37,549

missions coming up we've got something

787

00:32:34,609 --> 00:32:42,109

called at last we've got tests we've got

788

00:32:37,549 --> 00:32:46,009

we've got star shades coming up what

789

00:32:42,109 --> 00:32:49,789

would pick your pick one so let me start

790

00:32:46,009 --> 00:32:51,740

with test so as you said Kepler has done

791

00:32:49,789 --> 00:32:54,139

a great job of answering the question

792

00:32:51,740 --> 00:32:56,269

you know what's the probability if I

793

00:32:54,140 --> 00:32:58,880

look at a star it's got a planet the

794

00:32:56,269 --> 00:33:01,519

terrestrial planet around it but a lot

795

00:32:58,880 --> 00:33:03,500

of the targets that Kepler is

796

00:33:01,519 --> 00:33:06,049

identifying forests are just way too

797

00:33:03,500 --> 00:33:08,869

faint to be able to do good spectroscopy

798

00:33:06,049 --> 00:33:10,519

with James Webb so it turns out that

799
00:33:08,869 --> 00:33:12,829
even though James Webb is six and a half

800
00:33:10,519 --> 00:33:14,629
meters across the kind of signal

801
00:33:12,829 --> 00:33:16,369
strengths you need to in order to be

802
00:33:14,630 --> 00:33:19,220
able to back out the spectrum in these

803
00:33:16,369 --> 00:33:20,839
planets you need much brighter power and

804
00:33:19,220 --> 00:33:24,289
Stiles to be able to do the observations

805
00:33:20,839 --> 00:33:25,519
so my colleague George Ricker at MIT

806
00:33:24,289 --> 00:33:28,789
came up with a mission

807
00:33:25,519 --> 00:33:31,579
which I'm participating called Tess and

808
00:33:28,789 --> 00:33:35,839
the basic idea of Tess is we're going to

809
00:33:31,579 --> 00:33:39,019
go find nearby transiting exoplanet Airy

810
00:33:35,839 --> 00:33:42,379
systems around bright stars that people

811
00:33:39,019 --> 00:33:44,210
can study using JWST or even the next

812
00:33:42,380 --> 00:33:48,710
generation of very large ground-based

813
00:33:44,210 --> 00:33:51,049
telescopes so that raises a problem how

814
00:33:48,710 --> 00:33:53,600
you know you've heard you have to stare

815
00:33:51,049 --> 00:33:55,430
for a long time so if you wanted to map

816
00:33:53,599 --> 00:33:57,859
all the bright stars in the sky how do

817
00:33:55,430 --> 00:34:01,610
you do that and George came up with this

818
00:33:57,859 --> 00:34:03,769
very neat approach using tests where we

819
00:34:01,609 --> 00:34:06,409
will map out the whole sky over two

820
00:34:03,769 --> 00:34:08,780
years and basically study most of the

821
00:34:06,410 --> 00:34:10,820
bright stars to see which ones would

822
00:34:08,780 --> 00:34:13,220
make great candidates follow up with

823
00:34:10,820 --> 00:34:14,780
JWST and again that's a transit

824
00:34:13,219 --> 00:34:17,389
telescope brightest looking at transits

825
00:34:14,780 --> 00:34:20,450
exactly it's a transit telescope it has

826
00:34:17,389 --> 00:34:21,949
four cameras and they basically scan the

827

00:34:20,449 --> 00:34:23,839
whole of the Northern Hemisphere and

828
00:34:21,949 --> 00:34:27,289
then the whole of the Sun Hemisphere and

829
00:34:23,840 --> 00:34:30,740
we get close to the ecliptic equator

830
00:34:27,289 --> 00:34:33,889
something like a continuous period of 27

831
00:34:30,739 --> 00:34:35,839
days up to the ecliptic poles where Tess

832
00:34:33,889 --> 00:34:39,619
actually gets your four years coverage

833
00:34:35,840 --> 00:34:41,630
in the JWST continuous viewing zone so

834
00:34:39,619 --> 00:34:44,509
it's really geared towards finding

835
00:34:41,630 --> 00:34:48,169
targets wins it wins it launching so

836
00:34:44,510 --> 00:34:52,100
that one will launch in 2017 2017 right

837
00:34:48,168 --> 00:34:54,219
before the JWST goes up so that'll then

838
00:34:52,099 --> 00:34:56,329
that's an entire sky survey of

839
00:34:54,219 --> 00:34:58,669
transiting exoplanets so that's going to

840
00:34:56,329 --> 00:35:00,230
be exciting and but it will not image

841
00:34:58,670 --> 00:35:01,840

directly that's one of the things even

842

00:35:00,230 --> 00:35:03,619
though we said it's the future of

843

00:35:01,840 --> 00:35:04,970
exoplanet observations that's not

844

00:35:03,619 --> 00:35:08,839
necessarily something the tests will be

845

00:35:04,969 --> 00:35:11,329
able to do right there of tests and the

846

00:35:08,840 --> 00:35:12,530
four cameras going on - ah okay there's

847

00:35:11,329 --> 00:35:13,750
an image of the spacecraft so that's

848

00:35:12,530 --> 00:35:23,900
cool

849

00:35:13,750 --> 00:35:25,489
at last so the the ultimate goal I think

850

00:35:23,900 --> 00:35:28,369
of a lot of people working in the field

851

00:35:25,489 --> 00:35:32,929
of exoplanets right now is to find earth

852

00:35:28,369 --> 00:35:35,630
2.0 an earth-like planet orbiting a star

853

00:35:32,929 --> 00:35:38,449
like star and what they would like to be

854

00:35:35,630 --> 00:35:39,410
able to do is take images or conduct a

855

00:35:38,449 --> 00:35:41,239
survey and take

856
00:35:39,409 --> 00:35:44,000
images of these planets and then follow

857
00:35:41,239 --> 00:35:45,409
up by doing spectroscopy are the ones

858
00:35:44,000 --> 00:35:47,809
that are interesting to look for

859
00:35:45,409 --> 00:35:49,819
biomarkers you know the usual things

860
00:35:47,809 --> 00:35:51,739
that we would look for there's evidence

861
00:35:49,820 --> 00:35:54,650
that there might be the possibility of

862
00:35:51,739 --> 00:35:57,500
life on that planet and to do that you

863
00:35:54,650 --> 00:36:00,079
need to have a very large telescope so

864
00:35:57,500 --> 00:36:03,260
there are two approaches one is to build

865
00:36:00,079 --> 00:36:05,989
a 1012 metre telescope with a

866
00:36:03,260 --> 00:36:08,870
coronagraph and another is to build a

867
00:36:05,989 --> 00:36:11,959
large telescope and use this external a

868
00:36:08,869 --> 00:36:14,239
Coulter that you mentioned so in both

869
00:36:11,960 --> 00:36:17,360
cases they're very challenging problems

870
00:36:14,239 --> 00:36:19,309
because you're trying to measure planets

871
00:36:17,360 --> 00:36:21,860
that are extremely close to their bright

872
00:36:19,309 --> 00:36:24,980
central star and a 10 million times

873
00:36:21,860 --> 00:36:28,099
fainter so you've got to knock down 10

874
00:36:24,980 --> 00:36:30,079
billion times the light of the star so

875
00:36:28,099 --> 00:36:31,730
that you can bring up the contrast in

876
00:36:30,079 --> 00:36:34,279
the surrounding region enough to be able

877
00:36:31,730 --> 00:36:36,170
to identify the planets what's the

878
00:36:34,280 --> 00:36:37,760
acronym stand for I always forget what

879
00:36:36,170 --> 00:36:40,639
does that last stand for do you know a

880
00:36:37,760 --> 00:36:44,630
Bond technology large aperture Space

881
00:36:40,639 --> 00:36:48,469
Telescope okay and that that was not one

882
00:36:44,630 --> 00:36:53,570
of the ones that use the NRO chassis is

883
00:36:48,469 --> 00:36:56,349
it or my no so the the ones that use the

884

00:36:53,570 --> 00:37:00,500
those chassis czar is after which is

885
00:36:56,349 --> 00:37:02,829
also being called w first that that's

886
00:37:00,500 --> 00:37:06,789
the next mission that will come after

887
00:37:02,829 --> 00:37:09,349
JWST and is another step where they will

888
00:37:06,789 --> 00:37:12,380
include a chronograph that would allow

889
00:37:09,349 --> 00:37:15,259
them to take images of gas giant planets

890
00:37:12,380 --> 00:37:18,440
and possibly some super Earths right so

891
00:37:15,260 --> 00:37:22,010
at last is kind of the end of the road

892
00:37:18,440 --> 00:37:23,420
if you like okay studying a 2.0 and

893
00:37:22,010 --> 00:37:26,900
there are a number of steps along the

894
00:37:23,420 --> 00:37:31,300
way you know JWST then this mission

895
00:37:26,900 --> 00:37:34,820
called w first and then this big

896
00:37:31,300 --> 00:37:36,800
flagship later on good so that with a

897
00:37:34,820 --> 00:37:38,510
lotta i just can't believe how many

898
00:37:36,800 --> 00:37:40,310

things are on the pipeline right now

899

00:37:38,510 --> 00:37:42,350

being built and and ready to be launched

900

00:37:40,309 --> 00:37:45,289

one of them I'm most excited about is

901

00:37:42,349 --> 00:37:47,989

this thing that uses talked about a coal

902

00:37:45,289 --> 00:37:50,059

ting star so that we can see the planets

903

00:37:47,989 --> 00:37:52,819

directly is uses this thing called a

904

00:37:50,059 --> 00:37:54,199

star shade and Scott

905

00:37:52,820 --> 00:37:56,990

have some pretty cool animations can you

906

00:37:54,199 --> 00:37:59,000

put one of those up for us I can so I'm

907

00:37:56,989 --> 00:38:01,689

gonna look the first one first just to

908

00:37:59,000 --> 00:38:04,309

show it unfurling yeah yeah it's

909

00:38:01,690 --> 00:38:05,929

fantastic yeah so mark while he's doing

910

00:38:04,309 --> 00:38:06,469

that why don't you describe what what

911

00:38:05,929 --> 00:38:11,089

this is

912

00:38:06,469 --> 00:38:13,939

so the ACOTA is one of the concepts that

913
00:38:11,090 --> 00:38:17,300
people are looking at for doing this

914
00:38:13,940 --> 00:38:19,940
earth 2.0 measurement and the basic idea

915
00:38:17,300 --> 00:38:22,480
is that you can either make the Large

916
00:38:19,940 --> 00:38:26,480
Telescope with the internal chronograph

917
00:38:22,480 --> 00:38:28,070
to extremely demanding specifications in

918
00:38:26,480 --> 00:38:31,130
terms of its stability we're talking

919
00:38:28,070 --> 00:38:34,010
about tens of Pico meters here you know

920
00:38:31,130 --> 00:38:36,650
and holding a big structure 1012 meters

921
00:38:34,010 --> 00:38:39,680
wide to that kind of tolerance an

922
00:38:36,650 --> 00:38:42,380
alternate approach is to go with this

923
00:38:39,679 --> 00:38:45,649
external occulta which is basically a

924
00:38:42,380 --> 00:38:48,140
mask that you fly something like a

925
00:38:45,650 --> 00:38:50,570
hundred to 150,000 kilometers from the

926
00:38:48,139 --> 00:38:53,299
telescope then you align the two so that

927
00:38:50,570 --> 00:38:56,620
this free flying mask or a Coulter

928
00:38:53,300 --> 00:38:59,390
blocks out the light from the star and

929
00:38:56,619 --> 00:39:01,969
allows you to image the planets around

930
00:38:59,389 --> 00:39:03,679
the star with the coronagraph and the

931
00:39:01,969 --> 00:39:06,079
nice thing about this approach is that

932
00:39:03,679 --> 00:39:08,899
it doesn't put any demanding

933
00:39:06,079 --> 00:39:11,059
requirements on the telescope instead

934
00:39:08,900 --> 00:39:13,340
the demanding requirements of the mask

935
00:39:11,059 --> 00:39:15,710
which is you know extremely big you know

936
00:39:13,340 --> 00:39:18,980
we're talking 20 to 30 metres wide and

937
00:39:15,710 --> 00:39:21,409
you have to fly in formation with the

938
00:39:18,980 --> 00:39:22,699
telescope to keep them aligned and then

939
00:39:21,409 --> 00:39:24,829
when you're ready to go to your next

940
00:39:22,699 --> 00:39:27,500
target you have to fly it around the sky

941

00:39:24,829 --> 00:39:29,690
to align with your next target I don't

942
00:39:27,500 --> 00:39:33,500
look if it swings around abouts

943
00:39:29,690 --> 00:39:35,690
yeah I thought I did oh yes he was it

944
00:39:33,500 --> 00:39:37,940
was intricate look at that thing I mean

945
00:39:35,690 --> 00:39:39,670
that's amazing and you said it was how

946
00:39:37,940 --> 00:39:41,960
big again I'm sorry you said 30

947
00:39:39,670 --> 00:39:44,559
depending on the size of the telescope

948
00:39:41,960 --> 00:39:46,940
today it can be 20 to 30 meters diameter

949
00:39:44,559 --> 00:39:49,190
okay so this is a big thing we were

950
00:39:46,940 --> 00:39:51,500
talking about up in space so yeah and

951
00:39:49,190 --> 00:39:53,450
this is this is the this is showing this

952
00:39:51,500 --> 00:39:54,980
animation showing how it blocks the

953
00:39:53,449 --> 00:39:58,159
light light from the stars and you can

954
00:39:54,980 --> 00:40:00,050
see these planets becoming visible once

955
00:39:58,159 --> 00:40:01,940

that's been done because they are all

956

00:40:00,050 --> 00:40:04,070

that extraneous light as being as being

957

00:40:01,940 --> 00:40:06,349

blocked out what's up with that shape

958

00:40:04,070 --> 00:40:09,729

how come is shaped that way

959

00:40:06,349 --> 00:40:12,829

the shape is basically designed again to

960

00:40:09,728 --> 00:40:16,938

optimize the or minimize the diffracted

961

00:40:12,829 --> 00:40:19,729

light from the edge of the mask itself

962

00:40:16,938 --> 00:40:22,068

if you just use a circular aperture that

963

00:40:19,728 --> 00:40:24,768

circular edge you know creates a lot of

964

00:40:22,068 --> 00:40:26,449

scattered light or diffracted light that

965

00:40:24,768 --> 00:40:28,458

you don't want right where the planets

966

00:40:26,449 --> 00:40:30,889

will be but by using this fully

967

00:40:28,458 --> 00:40:32,719

optimized shape you can basically decide

968

00:40:30,889 --> 00:40:36,288

where you want the diffracted light to

969

00:40:32,719 --> 00:40:38,418

finish up so it puts the scattered light

970
00:40:36,289 --> 00:40:40,339
where it's not going to interfere with

971
00:40:38,418 --> 00:40:43,668
your imaging of the planet saying it's a

972
00:40:40,338 --> 00:40:45,558
simple way of sort of putting it so how

973
00:40:43,668 --> 00:40:47,328
is this thing going to be pointed I mean

974
00:40:45,559 --> 00:40:48,949
you've got this thing flowing floating

975
00:40:47,329 --> 00:40:53,150
out in space I mean how do you point

976
00:40:48,949 --> 00:40:54,769
this thing very carefully right so this

977
00:40:53,150 --> 00:40:56,778
is one of the challenges that people are

978
00:40:54,768 --> 00:40:59,328
working on right now as I said that

979
00:40:56,778 --> 00:41:02,239
these things are still in the probably

980
00:40:59,329 --> 00:41:04,219
Bacoor the tray stage so we're trading

981
00:41:02,239 --> 00:41:06,499
off the benefits of the occult of us the

982
00:41:04,219 --> 00:41:08,838
benefits of the internal coronagraph and

983
00:41:06,498 --> 00:41:11,658
they each have their pros and cons and

984
00:41:08,838 --> 00:41:14,688
the idea is to figure out which one wins

985
00:41:11,659 --> 00:41:17,150
out at the end of the day ok in you know

986
00:41:14,688 --> 00:41:20,208
to align these things you have to have a

987
00:41:17,150 --> 00:41:22,249
way of the telescope knowing exactly

988
00:41:20,208 --> 00:41:24,038
where your coulter is and being able to

989
00:41:22,248 --> 00:41:26,478
stay aligned with respect to the ACOTA

990
00:41:24,039 --> 00:41:29,359
okay so as you so you just pointed out

991
00:41:26,478 --> 00:41:33,168
this is still being in the design stage

992
00:41:29,358 --> 00:41:34,909
or early early so no timelines or

993
00:41:33,168 --> 00:41:37,668
anything like that for when this might

994
00:41:34,909 --> 00:41:39,338
get deployed no yeah this is you know

995
00:41:37,668 --> 00:41:42,558
we're still in the sort of early days

996
00:41:39,338 --> 00:41:44,568
phase I would say okay but that's

997
00:41:42,559 --> 00:41:46,099
something definitely that's gonna wait

998

00:41:44,568 --> 00:41:48,288
and we're what well we know where it'll

999
00:41:46,099 --> 00:41:51,349
go right roughly it'll will go out to I2

1000
00:41:48,289 --> 00:41:53,419
well well yeah but right most of these

1001
00:41:51,349 --> 00:41:55,579
missions now are looking at going to our

1002
00:41:53,418 --> 00:41:58,608
- in fact they actually all be I2

1003
00:41:55,579 --> 00:42:01,939
they're not at I2 and let's talk real

1004
00:41:58,608 --> 00:42:05,088
quick what I was gonna okay I'll go for

1005
00:42:01,938 --> 00:42:09,199
Scott so we're talking about Lagrangian

1006
00:42:05,088 --> 00:42:11,659
points which are a balance as far as the

1007
00:42:09,199 --> 00:42:14,119
were the gravity and the mass are within

1008
00:42:11,659 --> 00:42:16,818
system so this is a particular point

1009
00:42:14,119 --> 00:42:19,309
that's where Jamie's WSC is going and

1010
00:42:16,818 --> 00:42:20,150
where we had other things go as well and

1011
00:42:19,309 --> 00:42:22,099
so we have different

1012
00:42:20,150 --> 00:42:24,139

points between us and the moon and the

1013

00:42:22,099 --> 00:42:26,720

Sun and the way things are balanced out

1014

00:42:24,139 --> 00:42:28,639

within the gravity field we can hold

1015

00:42:26,719 --> 00:42:32,389

them there with very minimal adjustments

1016

00:42:28,639 --> 00:42:34,338

and that's why with JWST for instance we

1017

00:42:32,389 --> 00:42:36,019

do need have some fuel on board to

1018

00:42:34,338 --> 00:42:38,929

adjust but it's going to be staying

1019

00:42:36,019 --> 00:42:40,880

there primarily fairly easily and just

1020

00:42:38,929 --> 00:42:43,940

at those balancing points between

1021

00:42:40,880 --> 00:42:46,608

objects right it's it's a spot where it

1022

00:42:43,940 --> 00:42:49,608

will match Earth's orbit as it goes

1023

00:42:46,608 --> 00:42:50,838

around the Sun and will always be you

1024

00:42:49,608 --> 00:42:52,848

know we'll be able to look in the same

1025

00:42:50,838 --> 00:42:54,920

region to be able to communicate with it

1026

00:42:52,849 --> 00:42:56,960

and things like that so it's a really

1027
00:42:54,920 --> 00:43:00,680
important area in the solar system it's

1028
00:42:56,960 --> 00:43:02,480
also gonna get really crowded there any

1029
00:43:00,679 --> 00:43:03,769
worries about that mark any I mean we're

1030
00:43:02,480 --> 00:43:06,170
launching all this stuff and putting it

1031
00:43:03,769 --> 00:43:09,949
at L2 is there any any worries about

1032
00:43:06,170 --> 00:43:12,260
crowding you nodded L2 I mean that's an

1033
00:43:09,949 --> 00:43:14,538
extremely large volume of space I mean

1034
00:43:12,260 --> 00:43:18,349
as you know there's certainly growing

1035
00:43:14,539 --> 00:43:20,720
worries about the number of satellites

1036
00:43:18,349 --> 00:43:23,930
in low Earth orbit and the impact that

1037
00:43:20,719 --> 00:43:25,730
you know debris when when you launch and

1038
00:43:23,929 --> 00:43:28,568
when you operate these satellites might

1039
00:43:25,730 --> 00:43:31,250
have on the you you know standard

1040
00:43:28,568 --> 00:43:33,769
operational modes of low Earth orbit

1041
00:43:31,250 --> 00:43:36,528
ones but out Adel - it's just not an

1042
00:43:33,769 --> 00:43:40,159
issue because it's such a big volume so

1043
00:43:36,528 --> 00:43:42,019
yeah so I guess exoplanets are probably

1044
00:43:40,159 --> 00:43:43,519
one of the most exciting areas of

1045
00:43:42,019 --> 00:43:46,068
astronomy right now it's certainly one

1046
00:43:43,519 --> 00:43:48,230
of the biggest growing and we've got a

1047
00:43:46,068 --> 00:43:50,538
lot not only in the building stages

1048
00:43:48,230 --> 00:43:52,159
coming up and how we plan to observe

1049
00:43:50,539 --> 00:43:53,599
exoplanets directly and we've given you

1050
00:43:52,159 --> 00:43:55,399
a brief overview about some of those

1051
00:43:53,599 --> 00:43:57,349
different ways and plans of the future

1052
00:43:55,400 --> 00:43:59,119
but I want to get to a couple of

1053
00:43:57,349 --> 00:44:01,338
comments here first of all Craig Landon

1054
00:43:59,119 --> 00:44:06,950
on YouTube is saying why doesn't anyone

1055

00:44:01,338 --> 00:44:08,808
mention Tess I think we did yeah there

1056
00:44:06,949 --> 00:44:11,389
you go Craig so we talked about Tess

1057
00:44:08,809 --> 00:44:14,528
it's coming up 2017 like Mark said it's

1058
00:44:11,389 --> 00:44:17,239
going to be a really great really great

1059
00:44:14,528 --> 00:44:21,880
piece of the exoplanet research puzzle

1060
00:44:17,239 --> 00:44:26,298
and here's one from let me see here I

1061
00:44:21,880 --> 00:44:30,140
went oops I just lost it there it is me

1062
00:44:26,298 --> 00:44:33,018
hello me hello Jeannot Jeannot Vic from

1063
00:44:30,139 --> 00:44:35,418
YouTube what do we need to do

1064
00:44:33,018 --> 00:44:38,629
to get images of exoplanets similar to

1065
00:44:35,418 --> 00:44:40,908
those of series or Pluto by Hubble do we

1066
00:44:38,630 --> 00:44:43,519
need to get 50 meter space-based mirror

1067
00:44:40,909 --> 00:44:45,769
or do we need much better camera

1068
00:44:43,518 --> 00:44:50,688
technology or even both so eight

1069
00:44:45,768 --> 00:44:52,898

unicorns space unicorns so what we do is

1070

00:44:50,688 --> 00:44:57,398

so what do we need to be able to see

1071

00:44:52,898 --> 00:44:59,989

smaller exoplanets like Pluto and Ceres

1072

00:44:57,398 --> 00:45:02,778

in order to do that you just need an

1073

00:44:59,989 --> 00:45:04,278

extremely large aperture because that's

1074

00:45:02,778 --> 00:45:06,858

the only way you can actually resolve

1075

00:45:04,278 --> 00:45:09,139

them I mean the better cameras might go

1076

00:45:06,858 --> 00:45:11,268

to better contrast but you'll never have

1077

00:45:09,139 --> 00:45:15,078

enough spatial resolution to really be

1078

00:45:11,268 --> 00:45:18,098

able to get the kind of resolution that

1079

00:45:15,079 --> 00:45:20,269

this question is asking for right so a

1080

00:45:18,099 --> 00:45:21,709

resolution with whether you can resolve

1081

00:45:20,268 --> 00:45:23,328

something as a function of two things

1082

00:45:21,708 --> 00:45:27,288

the wavelength you're looking at and the

1083

00:45:23,329 --> 00:45:29,599

diameter of the collecting surface and

1084
00:45:27,289 --> 00:45:31,159
so once you have depending on what

1085
00:45:29,599 --> 00:45:32,719
wavelength you're trying to look at it

1086
00:45:31,159 --> 00:45:36,019
at you can actually hope to resolve it

1087
00:45:32,719 --> 00:45:37,909
but these things are so small that to

1088
00:45:36,018 --> 00:45:39,558
look at them and other systems would

1089
00:45:37,909 --> 00:45:41,419
need an enormous telescope one that I

1090
00:45:39,559 --> 00:45:44,959
think is not even in the planning stages

1091
00:45:41,418 --> 00:45:46,158
right now so there's one here's a

1092
00:45:44,958 --> 00:45:49,368
comment here that I want to just bring

1093
00:45:46,159 --> 00:45:52,759
up on the Q&A app that has to do with

1094
00:45:49,369 --> 00:45:55,969
the extremely large telescope this is

1095
00:45:52,759 --> 00:45:58,969
from Mike Mike Oh Mike Oh Sarah I think

1096
00:45:55,969 --> 00:46:01,909
is how you pronounce it with the new

1097
00:45:58,969 --> 00:46:04,608
forty millimeter European extremely

1098
00:46:01,909 --> 00:46:07,759
large telescope which is a tremendously

1099
00:46:04,608 --> 00:46:10,369
imaginative name he says will it be able

1100
00:46:07,759 --> 00:46:12,139
to directly observe extrasolar planets

1101
00:46:10,369 --> 00:46:15,380
or EDD is Space Telescope with a star

1102
00:46:12,139 --> 00:46:17,358
shade so the extremely large extremely

1103
00:46:15,380 --> 00:46:21,349
large scale let's go as opposed to the

1104
00:46:17,358 --> 00:46:23,929
ESO has a very large telescope will it

1105
00:46:21,349 --> 00:46:25,939
be able to see anything so that they

1106
00:46:23,929 --> 00:46:28,099
will be able to do direct imaging of

1107
00:46:25,938 --> 00:46:30,228
guest's gas giant planets very easily I

1108
00:46:28,099 --> 00:46:31,909
think with that kind of aperture and

1109
00:46:30,228 --> 00:46:33,798
they'll be using additional techniques

1110
00:46:31,909 --> 00:46:36,108
that we didn't really mention today such

1111
00:46:33,798 --> 00:46:39,768
as adaptive optics which allow you to

1112

00:46:36,108 --> 00:46:41,568
correct for some of the aberrations that

1113
00:46:39,768 --> 00:46:43,548
you get in your optics from the

1114
00:46:41,568 --> 00:46:46,278
atmosphere so yes they'll be able to do

1115
00:46:43,548 --> 00:46:46,940
something I'm not sure they will be able

1116
00:46:46,278 --> 00:46:50,630
to dare

1117
00:46:46,940 --> 00:46:55,099
imager sighs planets may be super us in

1118
00:46:50,630 --> 00:46:57,920
special cases right and so here's

1119
00:46:55,099 --> 00:46:59,510
something from Adam synergy also on the

1120
00:46:57,920 --> 00:47:01,818
Q&A app he's asking what is the

1121
00:46:59,510 --> 00:47:04,010
scientific value of direct imaging of

1122
00:47:01,818 --> 00:47:05,829
exoplanets beyond producing a pretty

1123
00:47:04,010 --> 00:47:10,910
picture

1124
00:47:05,829 --> 00:47:12,710
so by getting direct images you can do a

1125
00:47:10,909 --> 00:47:15,710
number of things you can get the orbit

1126
00:47:12,710 --> 00:47:17,420

which is always very useful and there

1127

00:47:15,710 --> 00:47:20,900

are other things that we also didn't

1128

00:47:17,420 --> 00:47:23,358

really get into such as doing time

1129

00:47:20,900 --> 00:47:25,930

monitoring you can time monitor these

1130

00:47:23,358 --> 00:47:28,279

images and maybe see evidence of

1131

00:47:25,929 --> 00:47:30,469

continents or different structures on

1132

00:47:28,280 --> 00:47:34,760

the surface of the planet in this kind

1133

00:47:30,469 --> 00:47:36,858

of world our Becca you're telling me

1134

00:47:34,760 --> 00:47:39,980

that we'll be able to see we might be

1135

00:47:36,858 --> 00:47:42,049

able to see comments well you can't see

1136

00:47:39,980 --> 00:47:44,260

them but you can see variations in the

1137

00:47:42,050 --> 00:47:48,550

amount of light coming from the planet

1138

00:47:44,260 --> 00:47:48,550

it's kind of like that map of Pluto that

1139

00:47:50,559 --> 00:47:56,929

people who are trying to do in a very

1140

00:47:54,349 --> 00:47:59,660

you know very coarse way try to

1141
00:47:56,929 --> 00:48:02,598
understand variations of the atmospheres

1142
00:47:59,659 --> 00:48:04,519
of Jupiter sized planets using Hubble

1143
00:48:02,599 --> 00:48:06,380
but if you have these larger telescopes

1144
00:48:04,519 --> 00:48:09,829
that are much more capable and the

1145
00:48:06,380 --> 00:48:11,960
infrared extended in Fred you might be

1146
00:48:09,829 --> 00:48:13,250
able to do that so yeah you're not going

1147
00:48:11,960 --> 00:48:16,639
to see the little continent swirling

1148
00:48:13,250 --> 00:48:19,750
around but changes but it's very similar

1149
00:48:16,639 --> 00:48:22,848
to the old Pluto observation same idea

1150
00:48:19,750 --> 00:48:25,730
okay so the idea the reflectivity of a

1151
00:48:22,849 --> 00:48:27,829
planet might change might be slightly

1152
00:48:25,730 --> 00:48:30,318
darker slightly brighter in some spots

1153
00:48:27,829 --> 00:48:32,450
depending on the topographic features it

1154
00:48:30,318 --> 00:48:34,338
has exactly and there was actually a

1155
00:48:32,449 --> 00:48:36,699
very nice demonstration of this by the

1156
00:48:34,338 --> 00:48:38,960
EPOXI mission which looked back at Earth

1157
00:48:36,699 --> 00:48:42,199
when they were on their way to their

1158
00:48:38,960 --> 00:48:45,740
last target and they actually do see

1159
00:48:42,199 --> 00:48:47,719
some of the some of those some of this

1160
00:48:45,739 --> 00:48:50,209
structure in the time monitoring that

1161
00:48:47,719 --> 00:48:52,039
they were able to do yeah who says we

1162
00:48:50,210 --> 00:49:00,030
don't have creative names or imaginative

1163
00:48:52,039 --> 00:49:03,869
name I'm thinking up those names right

1164
00:49:00,030 --> 00:49:06,000
yeah over beer I was just going to

1165
00:49:03,869 --> 00:49:09,380
mention we were talking about very large

1166
00:49:06,000 --> 00:49:12,510
telescopes as you've seen in the

1167
00:49:09,380 --> 00:49:15,960
animations Jay James Webb telescope does

1168
00:49:12,510 --> 00:49:18,630
not have a solid mirror and so when

1169

00:49:15,960 --> 00:49:21,329
you're talking about imagining and

1170
00:49:18,630 --> 00:49:23,340
having discussion over here about how

1171
00:49:21,329 --> 00:49:26,909
large those telescopes would have to be

1172
00:49:23,340 --> 00:49:31,470
to image you know and asked a very minor

1173
00:49:26,909 --> 00:49:33,179
planet those part of the idea that many

1174
00:49:31,469 --> 00:49:35,368
people think that if we ever do this

1175
00:49:33,179 --> 00:49:37,919
they'll have to be in segments there's

1176
00:49:35,369 --> 00:49:39,960
no way that a monolithic mirror is going

1177
00:49:37,920 --> 00:49:41,970
to be sent up there it's going to be in

1178
00:49:39,960 --> 00:49:44,670
pieces and James Webb is a pathfinder

1179
00:49:41,969 --> 00:49:47,279
for that because we have these great

1180
00:49:44,670 --> 00:49:49,730
segments that are going to be aligned

1181
00:49:47,280 --> 00:49:52,500
and work fantastic

1182
00:49:49,730 --> 00:49:54,809
okay so Carol I think I have one for you

1183
00:49:52,500 --> 00:49:56,309

here from Michel job and he goes when I

1184

00:49:54,809 --> 00:49:58,619

first read this question it was like I

1185

00:49:56,309 --> 00:50:04,139

was thinking of the Greek sandwich so

1186

00:49:58,619 --> 00:50:05,820

how are the gyros doing I guess on HST

1187

00:50:04,139 --> 00:50:08,519

how are the gyroscopes yeah they are

1188

00:50:05,820 --> 00:50:11,160

doing okay we had a problem with one

1189

00:50:08,519 --> 00:50:15,239

which is not working there's this

1190

00:50:11,159 --> 00:50:18,989

there's a second one which was monitor

1191

00:50:15,239 --> 00:50:21,449

we have like six and the second one did

1192

00:50:18,989 --> 00:50:25,108

not fail but I think they're resting it

1193

00:50:21,449 --> 00:50:26,819

and so an and in addition so we have

1194

00:50:25,108 --> 00:50:28,710

plenty of gyros left because we have

1195

00:50:26,820 --> 00:50:32,130

redundancy in the system and the other

1196

00:50:28,710 --> 00:50:35,070

thing is there have been studies done of

1197

00:50:32,130 --> 00:50:36,660

what if what if you only have three

1198
00:50:35,070 --> 00:50:38,510
waves you only have two that kind of

1199
00:50:36,659 --> 00:50:41,069
thing can we still do science but

1200
00:50:38,510 --> 00:50:43,290
because of the redundancy of the gyros

1201
00:50:41,070 --> 00:50:45,480
we're doing great it's just he's doing

1202
00:50:43,289 --> 00:50:47,400
just great yeah and I think that

1203
00:50:45,480 --> 00:50:49,559
probably would have done better science

1204
00:50:47,400 --> 00:51:03,780
if we had launched it with euros instead

1205
00:50:49,559 --> 00:51:08,369
but you know I so there was a question

1206
00:51:03,780 --> 00:51:11,970
of why does mark call James Webb

1207
00:51:08,369 --> 00:51:14,930
telescope JW and it's because he's very

1208
00:51:11,969 --> 00:51:14,929
close friends with it

1209
00:51:19,219 --> 00:51:24,689
this is a great picture of haha

1210
00:51:21,869 --> 00:51:27,059
but actually and it was pretty awesome

1211
00:51:24,690 --> 00:51:28,679
that well you can see a person standing

1212
00:51:27,059 --> 00:51:31,259
so that gives you the idea of the size

1213
00:51:28,679 --> 00:51:33,750
and this was during some testing when

1214
00:51:31,260 --> 00:51:38,910
Mark got to stand right there and be

1215
00:51:33,750 --> 00:51:40,739
imaged all over the place it just shows

1216
00:51:38,909 --> 00:51:45,960
that we really are involved in every

1217
00:51:40,739 --> 00:52:01,019
asset ok you can get rid of that image

1218
00:51:45,960 --> 00:52:06,090
now ok so let's see me good see if I can

1219
00:52:01,019 --> 00:52:10,170
find a couple more here ok so this was

1220
00:52:06,090 --> 00:52:12,750
from Michael let lit light Luther Houser

1221
00:52:10,170 --> 00:52:15,630
from the Q&A app are there any other

1222
00:52:12,750 --> 00:52:17,579
solar systems similar to us in the Milky

1223
00:52:15,630 --> 00:52:22,559
Way if so where are they now

1224
00:52:17,579 --> 00:52:24,179
I I think this would be the the context

1225
00:52:22,559 --> 00:52:26,489
of this is you know maybe what Kepler

1226

00:52:24,179 --> 00:52:27,989
has found something like that so what do

1227
00:52:26,489 --> 00:52:30,750
you say mark any other solar system

1228
00:52:27,989 --> 00:52:33,599
similar to ours if you're talking about

1229
00:52:30,750 --> 00:52:36,329
an exact copy I think not

1230
00:52:33,599 --> 00:52:38,309
Kepler's finding solar systems with lots

1231
00:52:36,329 --> 00:52:40,860
of planets there are several that have

1232
00:52:38,309 --> 00:52:43,230
almost as many as our solar system we're

1233
00:52:40,860 --> 00:52:45,360
starting to find earth-size planets in

1234
00:52:43,230 --> 00:52:47,940
the same region as Earth what we call

1235
00:52:45,360 --> 00:52:49,289
the habitable zone so as we refine more

1236
00:52:47,940 --> 00:52:52,260
and more of these systems they're

1237
00:52:49,289 --> 00:52:54,929
starting to look more and more like our

1238
00:52:52,260 --> 00:52:57,420
solar system in some ways and different

1239
00:52:54,929 --> 00:53:00,059
in others so as I said a lot of these

1240
00:52:57,420 --> 00:53:02,610

systems have a different distribution of

1241
00:53:00,059 --> 00:53:04,139
planet sizes to our own solar system so

1242
00:53:02,610 --> 00:53:05,820
I think what we're really seeing is that

1243
00:53:04,139 --> 00:53:08,429
there's a very large diversity of

1244
00:53:05,820 --> 00:53:11,220
different kinds of systems as we look

1245
00:53:08,429 --> 00:53:13,169
around with kappa ok here's a good one

1246
00:53:11,219 --> 00:53:16,529
also from the Q&A app from Iman our

1247
00:53:13,170 --> 00:53:19,110
Ayman Fantin who's going they do zit who

1248
00:53:16,530 --> 00:53:21,110
asks they declare planets of a specific

1249
00:53:19,110 --> 00:53:24,360
mass at a specific distance from a star

1250
00:53:21,110 --> 00:53:27,140
how can they be so sure they know the

1251
00:53:24,360 --> 00:53:29,000
planets is there by the star wobble

1252
00:53:27,139 --> 00:53:32,179
but they have no idea of the total mass

1253
00:53:29,000 --> 00:53:33,969
of all planets orbiting how can it be

1254
00:53:32,179 --> 00:53:37,099
so percent how can they be so precise

1255
00:53:33,969 --> 00:53:38,839
and so there's kind of an embedded thing

1256
00:53:37,099 --> 00:53:40,519
in there when you when you see a star

1257
00:53:38,840 --> 00:53:42,559
wobbling because of a planet in orbit

1258
00:53:40,519 --> 00:53:44,659
around it how can you be so sure it's

1259
00:53:42,559 --> 00:53:45,829
just that due to that one planet not a

1260
00:53:44,659 --> 00:53:47,809
whole bunch of others that we don't

1261
00:53:45,829 --> 00:53:52,730
necessarily see how can you be so

1262
00:53:47,809 --> 00:53:54,199
precise well the answer to take the last

1263
00:53:52,730 --> 00:53:56,119
part of that question the longer you

1264
00:53:54,199 --> 00:53:58,489
look the more likely you are to find

1265
00:53:56,119 --> 00:54:02,359
evidence of additional planets in these

1266
00:53:58,489 --> 00:54:04,459
systems so you know back in the late 90s

1267
00:54:02,360 --> 00:54:07,160
people were announcing individual

1268
00:54:04,460 --> 00:54:09,590
planets as time has gone by these radial

1269
00:54:07,159 --> 00:54:11,989
velocity surveys have started to add

1270
00:54:09,590 --> 00:54:14,329
additional planets to those systems in

1271
00:54:11,989 --> 00:54:16,129
in answer to the question about

1272
00:54:14,329 --> 00:54:18,619
precision well that comes from adding

1273
00:54:16,130 --> 00:54:20,210
the transits in as well as I said once

1274
00:54:18,619 --> 00:54:21,289
you've got the transits for these

1275
00:54:20,210 --> 00:54:23,210
systems and the radio velocity

1276
00:54:21,289 --> 00:54:25,429
measurements you've got the masts you've

1277
00:54:23,210 --> 00:54:27,679
got the orbit you can be extremely

1278
00:54:25,429 --> 00:54:30,980
precise about what you're seeing because

1279
00:54:27,679 --> 00:54:34,489
you've got data that prove the numbers

1280
00:54:30,980 --> 00:54:37,789
yeah so in the specific distance does

1281
00:54:34,489 --> 00:54:39,739
that come from this the speed with which

1282
00:54:37,789 --> 00:54:42,320
the the planet goes across the service

1283

00:54:39,739 --> 00:54:44,539
are transits or is that how you get that

1284
00:54:42,320 --> 00:54:46,789
information yeah I mean it can come from

1285
00:54:44,539 --> 00:54:49,340
the transits if you have a transit every

1286
00:54:46,789 --> 00:54:51,380
four days then you can figure out what

1287
00:54:49,340 --> 00:54:55,160
the orbit is especially once you know

1288
00:54:51,380 --> 00:55:01,970
the size of the planet as well okay tell

1289
00:54:55,159 --> 00:55:05,420
my friends it's just physics it's only

1290
00:55:01,969 --> 00:55:09,799
physics it also asks a guy Michael asks

1291
00:55:05,420 --> 00:55:12,769
where's Hubble data the archive you want

1292
00:55:09,800 --> 00:55:14,720
to answer that Carol sure so there's

1293
00:55:12,769 --> 00:55:17,150
lots of imagery that's available through

1294
00:55:14,719 --> 00:55:20,959
Hubble site org so if you go to Hubble

1295
00:55:17,150 --> 00:55:23,240
site s ite Hubble's s ite or there's

1296
00:55:20,960 --> 00:55:25,699
lots of images and explanations of the

1297
00:55:23,239 --> 00:55:31,279

images and the press releases and then

1298

00:55:25,699 --> 00:55:33,129

the actual science data from Hubble we

1299

00:55:31,280 --> 00:55:36,560

will also have the James Webb telescope

1300

00:55:33,130 --> 00:55:39,829

data when it comes down we have some we

1301

00:55:36,559 --> 00:55:41,000

have the Kepler data we we will have the

1302

00:55:39,829 --> 00:55:45,019

test data

1303

00:55:41,000 --> 00:55:49,090

we have ten other satellite which have

1304

00:55:45,019 --> 00:55:52,809

data in our archive and it's archived at

1305

00:55:49,090 --> 00:55:55,370

stsci that's our institution Space

1306

00:55:52,809 --> 00:55:59,809

Telescope Science Institute

1307

00:55:55,369 --> 00:56:01,759

edu archive stsci edu but you can say

1308

00:55:59,809 --> 00:56:03,619

Space Telescope archive on Google and

1309

00:56:01,760 --> 00:56:07,640

you can find it and there is an

1310

00:56:03,619 --> 00:56:10,039

interface into that data you can get

1311

00:56:07,639 --> 00:56:11,659

gifts of some of the data now it's

1312
00:56:10,039 --> 00:56:15,619
science data and it needs to be

1313
00:56:11,659 --> 00:56:17,779
processed carefully so that all the

1314
00:56:15,619 --> 00:56:19,969
instrument signature is taken care of

1315
00:56:17,780 --> 00:56:21,980
the cosmic rays are removed but that

1316
00:56:19,969 --> 00:56:24,439
data is all there and it's made public

1317
00:56:21,980 --> 00:56:26,570
in a timely fashion after the

1318
00:56:24,440 --> 00:56:28,340
observations have been taken yeah we

1319
00:56:26,570 --> 00:56:30,530
have done a hangouts in the past on how

1320
00:56:28,340 --> 00:56:32,809
together and done some done some

1321
00:56:30,530 --> 00:56:34,430
preliminary processing on it result

1322
00:56:32,809 --> 00:56:35,779
LaVey we are Scott and I were talking

1323
00:56:34,429 --> 00:56:38,210
today about maybe doing another one

1324
00:56:35,780 --> 00:56:40,519
there's another one right so look for

1325
00:56:38,210 --> 00:56:43,130
more Hangouts on how to get Hubble data

1326
00:56:40,519 --> 00:56:46,730
in the future and I think you did one on

1327
00:56:43,130 --> 00:56:48,950
the Hubble legacy archive as well there

1328
00:56:46,730 --> 00:56:51,650
are two hangouts already in the archive

1329
00:56:48,949 --> 00:56:53,480
where we've we have and a hangout

1330
00:56:51,650 --> 00:56:56,329
archive where we have discussed how you

1331
00:56:53,480 --> 00:56:58,579
get the data right so Scott am I missing

1332
00:56:56,329 --> 00:57:01,309
anything I'm looking you can't wait you

1333
00:56:58,579 --> 00:57:03,619
just like it's like Skye Lewis is owning

1334
00:57:01,309 --> 00:57:05,590
Hubble hangout hash tag here Twitter

1335
00:57:03,619 --> 00:57:09,469
sorry everybody

1336
00:57:05,590 --> 00:57:13,090
it's because you can't tweet as Hubble

1337
00:57:09,469 --> 00:57:15,889
while you're hosting the show sorry

1338
00:57:13,090 --> 00:57:17,539
yeah let's work out some technical I

1339
00:57:15,889 --> 00:57:20,690
can't do too many things at once or

1340

00:57:17,539 --> 00:57:24,309
outside my head explodes but babe I miss

1341
00:57:20,690 --> 00:57:27,700
anything but yeah I do have some here so

1342
00:57:24,309 --> 00:57:33,230
exoplanets in general so a one from

1343
00:57:27,699 --> 00:57:36,739
Eliseo mangonia it was in relation to

1344
00:57:33,230 --> 00:57:38,840
the radio velocity image I put up there

1345
00:57:36,739 --> 00:57:41,239
and they could the stars orbit really be

1346
00:57:38,840 --> 00:57:43,280
affected by the exoplanets gravity I

1347
00:57:41,239 --> 00:57:45,319
mean if the inspectors finger prick

1348
00:57:43,280 --> 00:57:47,450
changes in time wouldn't it be too

1349
00:57:45,320 --> 00:57:50,930
subtle for ladies to the exoplanets full

1350
00:57:47,449 --> 00:57:53,689
on the star so I mean first of all with

1351
00:57:50,929 --> 00:57:54,529
that we know that they have they both

1352
00:57:53,690 --> 00:57:56,690
have mass

1353
00:57:54,530 --> 00:57:59,720
and so there will be a center of mass

1354
00:57:56,690 --> 00:58:01,220

between them it's not as if one takes

1355

00:57:59,719 --> 00:58:02,839

all the mass and the other ones massless

1356

00:58:01,219 --> 00:58:04,429

so they have to have a center of mass

1357

00:58:02,840 --> 00:58:05,869

between them and that's the biggest

1358

00:58:04,429 --> 00:58:09,559

point of a while were able to see them

1359

00:58:05,869 --> 00:58:11,690

shift and so if if you did have if you

1360

00:58:09,559 --> 00:58:14,179

could detect the spectrum both spectra

1361

00:58:11,690 --> 00:58:15,500

on top of each other one of the star and

1362

00:58:14,179 --> 00:58:18,618

the other of the planet if it was bright

1363

00:58:15,500 --> 00:58:21,019

enough then you could see the shift in

1364

00:58:18,619 --> 00:58:23,420

both objects and in fact we do in binary

1365

00:58:21,019 --> 00:58:26,300

stars that are similar in brightness yes

1366

00:58:23,420 --> 00:58:29,420

you would see the shifting because the

1367

00:58:26,300 --> 00:58:32,599

the object's orbit each other and so

1368

00:58:29,420 --> 00:58:36,320

that spectroscopic shift would manifest

1369
00:58:32,599 --> 00:58:40,090
itself in the planet and the star too

1370
00:58:36,320 --> 00:58:42,200
but we just keep the planets too faint

1371
00:58:40,090 --> 00:58:43,760
petaflop sighs want to make mention his

1372
00:58:42,199 --> 00:58:45,500
comment he goes I want an earth-sized

1373
00:58:43,760 --> 00:58:53,030
mirror in orbit yeah wouldn't that be

1374
00:58:45,500 --> 00:59:01,300
cool after we get our Dyson Sphere set

1375
00:58:53,030 --> 00:59:03,500
up 2019 after okay I have another one -

1376
00:59:01,300 --> 00:59:05,330
and it's more about exoplanets in

1377
00:59:03,500 --> 00:59:08,858
general so I'm this was from Eamon

1378
00:59:05,329 --> 00:59:11,119
Fenton on on Google+ and a webpage and

1379
00:59:08,858 --> 00:59:13,309
you know we're told that we found

1380
00:59:11,119 --> 00:59:15,559
exoplanets of a certain mass and at

1381
00:59:13,309 --> 00:59:18,469
certain distance from their parent star

1382
00:59:15,559 --> 00:59:20,480
but how can we be so sure what what

1383
00:59:18,469 --> 00:59:25,759
gives us that information we know their

1384
00:59:20,480 --> 00:59:28,699
distance again it comes down to for

1385
00:59:25,760 --> 00:59:30,589
instance the transit date - you see you

1386
00:59:28,699 --> 00:59:34,309
see the dip in the light coming from the

1387
00:59:30,588 --> 00:59:37,429
star as on a very regular basis and you

1388
00:59:34,309 --> 00:59:39,949
can calculate the size of the body

1389
00:59:37,429 --> 00:59:42,108
that's causing that dip so it's just

1390
00:59:39,949 --> 00:59:44,419
physics as Carol said very simple

1391
00:59:42,108 --> 00:59:47,210
physics to you directly so we're just

1392
00:59:44,420 --> 00:59:49,059
studying the orbits are able to know the

1393
00:59:47,210 --> 00:59:53,210
mass and everything like that so yeah

1394
00:59:49,059 --> 00:59:55,130
right okay well mark this has been

1395
00:59:53,210 --> 00:59:57,320
awesome thank you so much for joining us

1396
00:59:55,130 --> 00:59:59,570
fantastic you're gonna come back right

1397

00:59:57,320 --> 01:00:02,119
talk about JWST in the deployment of the

1398
00:59:59,570 --> 01:00:04,609
sunscreen sunscreen or those yeah this

1399
01:00:02,119 --> 01:00:07,730
green I'd be happy to do that and I've

1400
01:00:04,608 --> 01:00:10,779
also just by way of advertising

1401
01:00:07,730 --> 01:00:15,230
tell people that if they go to the JWST

1402
01:00:10,780 --> 01:00:16,970
tsfc nasa.gov website over the next two

1403
01:00:15,230 --> 01:00:20,480
months they'll be able to watch mirrors

1404
01:00:16,969 --> 01:00:24,259
being mounted into the back plane of the

1405
01:00:20,480 --> 01:00:26,900
telescope that's right there's a lot

1406
01:00:24,260 --> 01:00:31,310
I'll be sharing up those links later

1407
01:00:26,900 --> 01:00:33,619
through plus it's really cool see the

1408
01:00:31,309 --> 01:00:35,739
whole thing going on and that is pretty

1409
01:00:33,619 --> 01:00:39,380
much live isn't it or is there delay

1410
01:00:35,739 --> 01:00:42,349
sorry those are pretty much live images

1411
01:00:39,380 --> 01:00:46,220

right or is there a delay no no they are

1412
01:00:42,349 --> 01:00:48,710
live images okay Ron yeah they take an

1413
01:00:46,219 --> 01:00:51,139
image every few seconds that's amazing

1414
01:00:48,710 --> 01:00:52,550
okay so keep an eye out for that hangout

1415
01:00:51,139 --> 01:00:54,589
and you may be asking how do I know

1416
01:00:52,550 --> 01:00:57,920
where these hangouts are it's all in

1417
01:00:54,590 --> 01:01:00,350
Hubble site that org slash Explorer are

1418
01:00:57,920 --> 01:01:02,180
get involved slash Hubble hangouts

1419
01:01:00,349 --> 01:01:04,309
that's where I'm putting all of the the

1420
01:01:02,179 --> 01:01:08,169
schedule you can also follow us on

1421
01:01:04,309 --> 01:01:11,239
twitter at hubble telescope you can also

1422
01:01:08,170 --> 01:01:13,820
add us on circles on the Google G+ page

1423
01:01:11,239 --> 01:01:15,108
we also post on our Facebook page as

1424
01:01:13,820 --> 01:01:17,570
well and that's where all of the

1425
01:01:15,108 --> 01:01:19,309
hangouts will be announced next week

1426
01:01:17,570 --> 01:01:22,190
Carol Scott and I will be talking with

1427
01:01:19,309 --> 01:01:23,630
niku Mott who I was his name is longer

1428
01:01:22,190 --> 01:01:25,970
than that but I was told to just go

1429
01:01:23,630 --> 01:01:28,700
ahead and cut it short who has been

1430
01:01:25,969 --> 01:01:31,489
using Hubble to to look at some

1431
01:01:28,699 --> 01:01:33,289
exoplanets jupiter-sized exoplanets he's

1432
01:01:31,489 --> 01:01:35,179
found they were looking at three of them

1433
01:01:33,289 --> 01:01:38,630
and they were looking at the water vapor

1434
01:01:35,179 --> 01:01:40,909
on those exoplanets and found them to be

1435
01:01:38,630 --> 01:01:43,490
surprisingly dry so that was a press

1436
01:01:40,909 --> 01:01:45,949
release that came out last week and we

1437
01:01:43,489 --> 01:01:47,089
will be talking with the with principal

1438
01:01:45,949 --> 01:01:50,089
investigators who made that observation

1439
01:01:47,090 --> 01:01:52,220
so more on exoplanets next week that's

1440
01:01:50,090 --> 01:01:55,900
Thursday at 3 o'clock eastern time 7

1441
01:01:52,219 --> 01:02:04,339
o'clock Universal Time so I'm ending

1442
01:01:55,900 --> 01:02:05,900
Pacific per for me in LA about me so

1443
01:02:04,340 --> 01:02:09,410
Carol thank you it's been a lot of fun

1444
01:02:05,900 --> 01:02:11,358
as always and Scott thank you excellent

1445
01:02:09,409 --> 01:02:14,358
driving we didn't crash once so good job

1446
01:02:11,358 --> 01:02:15,858
once alright alright folks so thank you

1447
01:02:14,358 --> 01:02:20,059
all for watching and thanks very much

1448
01:02:15,858 --> 01:02:21,259
mark yeah you're awesome thanks

1449
01:02:20,059 --> 01:02:22,969
alright thanks

1450
01:02:21,260 --> 01:02:25,480
thank you all for watching and as always

1451
01:02:22,969 --> 01:02:25,480
keep