



HUBBLE

hangouts

How Can We Directly Image Exoplanets?

Thursday, July 31 2014, 3pm EDT, 7pm UTC

1
00:00:05,990 --> 00:00:04,100
there we go hello everybody welcome to

2
00:00:07,460 --> 00:00:06,000
our latest Hubble hangout my name is

3
00:00:09,890 --> 00:00:07,470
Tony Darnell work at the Space Telescope

4
00:00:11,570 --> 00:00:09,900
Science Institute and we've got a really

5
00:00:13,070 --> 00:00:11,580
interesting hangout plan for you today

6
00:00:15,409 --> 00:00:13,080
we have dr. mark clamping from the

7
00:00:18,109 --> 00:00:15,419
Goddard Space Flight Center here to talk

8
00:00:21,080 --> 00:00:18,119
to us about exoplanet observations both

9
00:00:24,080 --> 00:00:21,090
past present and the future and so we're

10
00:00:26,960 --> 00:00:24,090
looking very interesting hang out so we

11
00:00:29,509 --> 00:00:26,970
hope you will bring lots of questions

12
00:00:31,939 --> 00:00:29,519
and comments which brings me to how you

13
00:00:33,740 --> 00:00:31,949

can interact with us we hope we hope you

14

00:00:36,440 --> 00:00:33,750

will send us questions with the Q&A app

15

00:00:38,330 --> 00:00:36,450

on YouTube as well and the Google+ event

16

00:00:41,630 --> 00:00:38,340

page we're also monitoring the Hubble

17

00:00:43,640 --> 00:00:41,640

hangout ash tagged on Twitter and you

18

00:00:45,860 --> 00:00:43,650

can also comment on the Google+ event

19

00:00:48,680 --> 00:00:45,870

page itself so we're monitoring all

20

00:00:50,540 --> 00:00:48,690

these different avenues for you to

21

00:00:52,550 --> 00:00:50,550

interact so we hope to get lots of great

22

00:00:55,520 --> 00:00:52,560

questions from you later in the Hangout

23

00:00:57,650 --> 00:00:55,530

with me also is dr. Carol Christian

24

00:00:59,300 --> 00:00:57,660

Christian she is from the Space

25

00:01:00,080 --> 00:00:59,310

Telescope Science Institute as well hi

26

00:01:03,680 --> 00:01:00,090

Carol

27

00:01:06,080 --> 00:01:03,690

hello I'm Scott Lewis how's it going

28

00:01:08,780 --> 00:01:06,090

Tony hey ready to drive the Internet I

29

00:01:11,270 --> 00:01:08,790

I'm always ready to drive I know you're

30

00:01:17,720 --> 00:01:11,280

expert driver NASCAR of the Internet

31

00:01:21,320 --> 00:01:17,730

drivers f1f1 known as car any new Thank

32

00:01:24,100 --> 00:01:21,330

You Peggy so as I mentioned our guest

33

00:01:26,480 --> 00:01:24,110

today is dr. mark clamp and he is the

34

00:01:28,310 --> 00:01:26,490

observatory project scientist for the

35

00:01:29,390 --> 00:01:28,320

James Webb Space Telescope at Goddard

36

00:01:32,990 --> 00:01:29,400

welcome mark

37

00:01:35,090 --> 00:01:33,000

hi thanks I'm really excited to get you

38

00:01:37,190 --> 00:01:35,100

in a hangout because you've got a lot of

39

00:01:38,870 --> 00:01:37,200

great research going on you're involved

40

00:01:41,180 --> 00:01:38,880

in all kinds of great things but first I

41

00:01:43,100 --> 00:01:41,190

have to ask you observatory project

42

00:01:45,380 --> 00:01:43,110

scientists how was that different what

43

00:01:47,149 --> 00:01:45,390

is it what is it what does that mean and

44

00:01:50,570 --> 00:01:47,159

how does that differ from say just a

45

00:01:51,950 --> 00:01:50,580

regular project science well it comes

46

00:01:54,980 --> 00:01:51,960

down to the fact that James Webb Space

47

00:01:58,190 --> 00:01:54,990

Telescope is such a massive project and

48

00:01:59,840 --> 00:01:58,200

it's a very large telescope so my job is

49

00:02:03,410 --> 00:01:59,850

to be responsible for the observatory

50

00:02:06,440 --> 00:02:03,420

which is three pieces the telescope the

51
00:02:08,809 --> 00:02:06,450
Sun shield and then the spacecraft bus

52
00:02:10,130 --> 00:02:08,819
so my job is to work with the engineers

53
00:02:12,830 --> 00:02:10,140
to make sure that the science

54
00:02:14,390 --> 00:02:12,840
requirements for the telescope for the

55
00:02:17,240 --> 00:02:14,400
observatory are met

56
00:02:19,729 --> 00:02:17,250
or preferably exceeded and when they

57
00:02:21,710 --> 00:02:19,739
have problems I I'm the guy that gets to

58
00:02:23,750 --> 00:02:21,720
sit down with them and help them figure

59
00:02:26,059 --> 00:02:23,760
out how they can meet our requirements

60
00:02:28,430 --> 00:02:26,069
and still you know meet the budget or

61
00:02:30,050 --> 00:02:28,440
the schedule also really not not very

62
00:02:36,860 --> 00:02:30,060
much then you don't really have much to

63
00:02:44,089 --> 00:02:36,870

do they keep me very busy like an

64

00:02:45,140 --> 00:02:44,099

achiever there okay well that sounds

65

00:02:47,210 --> 00:02:45,150

great we're hope to get some more

66

00:02:49,250 --> 00:02:47,220

insights into the status of JWST a

67

00:02:50,390 --> 00:02:49,260

little bit later on in the Hangout but

68

00:02:51,949 --> 00:02:50,400

before we do that I want to talk a

69

00:02:54,170 --> 00:02:51,959

little bit about your research interest

70

00:02:56,330 --> 00:02:54,180

before you were building the James

71

00:02:58,910 --> 00:02:56,340

whatever coordinating all these efforts

72

00:03:01,580 --> 00:02:58,920

so what's your primary research interest

73

00:03:04,880 --> 00:03:01,590

so my primary research interest has

74

00:03:07,130 --> 00:03:04,890

always been direct imaging or taking

75

00:03:09,289 --> 00:03:07,140

pictures of debris disks which of the

76
00:03:11,869 --> 00:03:09,299
early stages of the formation of planets

77
00:03:14,809 --> 00:03:11,879
and then actually trying to directly

78
00:03:18,259 --> 00:03:14,819
image planets themselves so I started

79
00:03:20,839 --> 00:03:18,269
off 20 years ago building an instrument

80
00:03:22,780 --> 00:03:20,849
called a chronograph and I guess we'll

81
00:03:26,569 --> 00:03:22,790
get into how chronograph work later on

82
00:03:30,740 --> 00:03:26,579
for tellus telescopes that would be put

83
00:03:31,460 --> 00:03:30,750
on the chilean telescopes down in at

84
00:03:34,159 --> 00:03:31,470
lasya

85
00:03:36,470 --> 00:03:34,169
and then la serena and then i slowly

86
00:03:38,089 --> 00:03:36,480
evolved to working on flight hardware

87
00:03:39,740 --> 00:03:38,099
and I actually helped build the advanced

88
00:03:42,710 --> 00:03:39,750

camera for surveys which had a

89

00:03:44,599 --> 00:03:42,720

chronograph that's on double that's on

90

00:03:46,369 --> 00:03:44,609

Hubble so I've always kind of worked on

91

00:03:48,979 --> 00:03:46,379

building hardware to do this kind of

92

00:03:51,229 --> 00:03:48,989

problem and we started off as I said you

93

00:03:53,390 --> 00:03:51,239

know studying debris disks and the more

94

00:03:54,800 --> 00:03:53,400

you get into imaging debris disks the

95

00:03:57,140 --> 00:03:54,810

more you want to sort of go the next

96

00:03:59,420 --> 00:03:57,150

step and actually be able to direct the

97

00:04:01,069 --> 00:03:59,430

image the planets so that's what I've

98

00:04:02,960 --> 00:04:01,079

been kind of working on with Hubble on

99

00:04:05,629 --> 00:04:02,970

and off for the last you know 10 15

100

00:04:07,849 --> 00:04:05,639

years right so today's today's hangout

101
00:04:10,069 --> 00:04:07,859
topic obviously is about exoplanets but

102
00:04:14,659 --> 00:04:10,079
one of the things that really amazes me

103
00:04:17,659 --> 00:04:14,669
about this this branch of astronomy or

104
00:04:20,120 --> 00:04:17,669
research is that this really is a pretty

105
00:04:21,800 --> 00:04:20,130
brand-new research area isn't it you

106
00:04:24,440 --> 00:04:21,810
said yourself 20 years ago that pretty

107
00:04:25,580 --> 00:04:24,450
much marks the beginning of exoplanet

108
00:04:27,800 --> 00:04:25,590
research doesn't it I mean we have been

109
00:04:28,220 --> 00:04:27,810
doing this for very long no that's

110
00:04:31,010 --> 00:04:28,230
correct

111
00:04:34,400 --> 00:04:31,020
it's about 20 years and this is just a

112
00:04:35,990 --> 00:04:34,410
rapidly expanding field a lot of the new

113
00:04:38,240 --> 00:04:36,000

young people coming into astronomy

114

00:04:39,950 --> 00:04:38,250

they're all sort of coming into this

115

00:04:42,710 --> 00:04:39,960

field because there's just so much going

116

00:04:44,360 --> 00:04:42,720

on there's you know new planets being

117

00:04:46,670 --> 00:04:44,370

discovered every day it's just a really

118

00:04:48,320 --> 00:04:46,680

exciting and dynamic field right now and

119

00:04:50,210 --> 00:04:48,330

correct me if I'm wrong but if this

120

00:04:52,580 --> 00:04:50,220

field the exoplanet research really had

121

00:04:54,500 --> 00:04:52,590

I think pretty humble beginnings from my

122

00:04:57,080 --> 00:04:54,510

understanding I mean I remember at the

123

00:04:59,990 --> 00:04:57,090

high altitude observatory

124

00:05:02,330 --> 00:05:00,000

there was people there observing a

125

00:05:05,060 --> 00:05:02,340

project called stare sta re which

126

00:05:07,910 --> 00:05:05,070

basically used Mead telescopes in a

127

00:05:12,260 --> 00:05:07,920

parking lot to and this was with dr.

128

00:05:15,080 --> 00:05:12,270

carbon oh and and is it it was at Mike

129

00:05:18,490 --> 00:05:15,090

Brown it was old gosh I'm dating myself

130

00:05:21,430 --> 00:05:18,500

now but anyway they were looking at

131

00:05:23,390 --> 00:05:21,440

exoplanets or trying to find exoplanets

132

00:05:24,200 --> 00:05:23,400

presumably with the transit method which

133

00:05:29,390 --> 00:05:24,210

we'll get to in a minute

134

00:05:31,340 --> 00:05:29,400

with amateur grade instruments exactly I

135

00:05:33,530 --> 00:05:31,350

mean this well as you say well talk

136

00:05:35,240 --> 00:05:33,540

about transiting exoplanets in a minute

137

00:05:37,910 --> 00:05:35,250

but I think one of the amazing things

138

00:05:39,950 --> 00:05:37,920

about studying transits is you can

139

00:05:41,930 --> 00:05:39,960

actually stand in a car park like they

140

00:05:45,170 --> 00:05:41,940

Charbonneau did with a Celestron

141

00:05:46,940 --> 00:05:45,180

telescope and take data that you know

142

00:05:52,610 --> 00:05:46,950

shows you there's an exoplanet orbiting

143

00:05:55,550 --> 00:05:52,620

a star that's pretty amazing yeah we - a

144

00:05:58,250 --> 00:05:55,560

year and a half ago I held a hangout on

145

00:06:00,890 --> 00:05:58,260

here where I had one of our amateur

146

00:06:04,250 --> 00:06:00,900

astronomers that works with the AP a VSO

147

00:06:05,930 --> 00:06:04,260

and we did a live observation of a

148

00:06:07,940 --> 00:06:05,940

transiting exoplanets we were able to

149

00:06:10,520 --> 00:06:07,950

get the data there and show the curve

150

00:06:11,990 --> 00:06:10,530

going on afterwards and talk about what

151
00:06:14,690 --> 00:06:12,000
was going on these are things that can

152
00:06:17,030 --> 00:06:14,700
be done by every month and it's it's

153
00:06:19,940 --> 00:06:17,040
amazing and that this is real we're

154
00:06:22,910 --> 00:06:19,950
using advanced telescopes you know it

155
00:06:24,800 --> 00:06:22,920
you know orbiting in space and also very

156
00:06:28,670 --> 00:06:24,810
large telescopes here on earth to

157
00:06:30,590 --> 00:06:28,680
discover completely new worlds exactly

158
00:06:33,230 --> 00:06:30,600
they're transiting exoplanet method is

159
00:06:35,360 --> 00:06:33,240
great because it just scales from you

160
00:06:37,040 --> 00:06:35,370
know your telescope in the car park all

161
00:06:40,310 --> 00:06:37,050
the way up to James Webb Space Telescope

162
00:06:42,020 --> 00:06:40,320
and that every step or every scale you

163
00:06:44,060 --> 00:06:42,030

can make lots of really amazing

164

00:06:47,120 --> 00:06:44,070

discoveries all right well let's go

165

00:06:49,340 --> 00:06:47,130

ahead and bring that up so I believe

166

00:06:50,600 --> 00:06:49,350

you've got a good illustration of what

167

00:06:52,820 --> 00:06:50,610

the transit method is so let's talk

168

00:06:54,620 --> 00:06:52,830

about before we get to the future of

169

00:06:55,910 --> 00:06:54,630

exoplanet observations let's talk about

170

00:06:57,920 --> 00:06:55,920

how it's been done in the past as we

171

00:07:00,860 --> 00:06:57,930

talked about ahead relatively exoplanet

172

00:07:03,230 --> 00:07:00,870

research has been is a new field very

173

00:07:06,170 --> 00:07:03,240

young very exciting red hot right now in

174

00:07:08,390 --> 00:07:06,180

astronomy and and

175

00:07:12,080 --> 00:07:08,400

the observations have been done

176

00:07:14,150 --> 00:07:12,090

primarily by looking at very very tiny

177

00:07:17,300 --> 00:07:14,160

dips in brightness of a star and Scott

178

00:07:20,600 --> 00:07:17,310

has this up now basically when a planet

179

00:07:23,240 --> 00:07:20,610

passes in front of a star it gets just a

180

00:07:25,760 --> 00:07:23,250

little tiny bit dimmer and as the buzz

181

00:07:28,190 --> 00:07:25,770

up as the light is blocked from the star

182

00:07:29,120 --> 00:07:28,200

and Dave out I mean I'm sorry mark I'll

183

00:07:31,220 --> 00:07:29,130

let you go ahead and explain this

184

00:07:33,620 --> 00:07:31,230

animation a little bit okay so the

185

00:07:36,650 --> 00:07:33,630

animation is just showing what happens

186

00:07:39,470 --> 00:07:36,660

when you look at a star where the planet

187

00:07:42,170 --> 00:07:39,480

is actually moving across the face of

188

00:07:44,570 --> 00:07:42,180

the star as it orbit it's that star and

189

00:07:46,880 --> 00:07:44,580

so what happens is you see a very tiny

190

00:07:49,760 --> 00:07:46,890

dip in the amount of light coming from

191

00:07:52,430 --> 00:07:49,770

the star as the planet orbits across the

192

00:07:54,830 --> 00:07:52,440

face of the star and the dip is

193

00:07:56,540 --> 00:07:54,840

basically a function of the area of the

194

00:08:01,760 --> 00:07:56,550

star that you're looking at in the area

195

00:08:04,580 --> 00:08:01,770

of the planet so large gas giant planets

196

00:08:07,040 --> 00:08:04,590

like Jupiter z-- might produce a dip of

197

00:08:09,110 --> 00:08:07,050

a few percent whereas if you were

198

00:08:11,120 --> 00:08:09,120

looking at a terrestrial earth-like

199

00:08:14,360 --> 00:08:11,130

planet then the dip is much smaller it's

200

00:08:16,910 --> 00:08:14,370

about 0.05 percent and then it becomes

201
00:08:18,980 --> 00:08:16,920
very challenging measurement but just

202
00:08:21,290 --> 00:08:18,990
looking at some of these big Jupiter

203
00:08:22,820 --> 00:08:21,300
planets that's the kind of stuff you can

204
00:08:25,160 --> 00:08:22,830
do with a you know it's very simple

205
00:08:27,740 --> 00:08:25,170
telescope as we were talking about a few

206
00:08:29,210 --> 00:08:27,750
minutes ago Ryan this was the first

207
00:08:31,100 --> 00:08:29,220
measurements we made out of the first

208
00:08:33,320 --> 00:08:31,110
ways in which we detected exoplanets and

209
00:08:34,610 --> 00:08:33,330
this is an indirect method a meaning

210
00:08:37,220 --> 00:08:34,620
that we're not seeing the planet

211
00:08:39,440 --> 00:08:37,230
directly we're seeing we're seeing the

212
00:08:41,960 --> 00:08:39,450
the effect of that planet in orbit

213
00:08:44,270 --> 00:08:41,970

around the star and inferring the

214

00:08:45,890 --> 00:08:44,280

existence of that planet being there how

215

00:08:47,120 --> 00:08:45,900

hard is instamate how hard is this to

216

00:08:49,160 --> 00:08:47,130

make I mean we said we can do it with

217

00:08:51,350 --> 00:08:49,170

with amateur great instruments but we

218

00:08:53,540 --> 00:08:51,360

can do better jobs with with bigger

219

00:08:55,970 --> 00:08:53,550

telescopes correct I mean how how hard

220

00:08:58,310 --> 00:08:55,980

is this measurement it is

221

00:09:00,319 --> 00:08:58,320

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

222

00:09:01,910 --> 00:09:00,329

trying to just do gas giant planets

223

00:09:04,430 --> 00:09:01,920

where you're looking for a you know a

224

00:09:07,009 --> 00:09:04,440

few percent dip as you start trying to

225

00:09:09,439 --> 00:09:07,019

look for terrestrial planets it becomes

226

00:09:12,259 --> 00:09:09,449

a real problem because you need to have

227

00:09:14,360 --> 00:09:12,269

extremely precise photometry and that's

228

00:09:16,610 --> 00:09:14,370

why we've had to go into space to really

229

00:09:18,379 --> 00:09:16,620

look for the earth sized planets and

230

00:09:19,970 --> 00:09:18,389

that's as you know that's what the

231

00:09:22,639 --> 00:09:19,980

Kepler mission has been doing for the

232

00:09:25,430 --> 00:09:22,649

last you know six or seven years it's

233

00:09:27,710 --> 00:09:25,440

just been staring at 150,000 stars

234

00:09:30,860 --> 00:09:27,720

trying to find the ones that have

235

00:09:32,900 --> 00:09:30,870

transits that are directly traceable to

236

00:09:36,889 --> 00:09:32,910

something the size of a sort of small

237

00:09:39,350 --> 00:09:36,899

rocky planet so it it gets very easy to

238

00:09:42,470 --> 00:09:39,360

very very hard here's an example

239

00:09:44,629 --> 00:09:42,480

Kepler - and you'll be able to see I'll

240

00:09:46,759 --> 00:09:44,639

have it pop up here in a second where

241

00:09:48,980 --> 00:09:46,769

we're seeing those dips and brightness

242

00:09:52,210 --> 00:09:48,990

that's being detected I'm on the lower

243

00:09:59,829 --> 00:09:52,220

right-hand side of the screen right here

244

00:10:04,610 --> 00:10:02,629

right and when you look at real data

245

00:10:06,439 --> 00:10:04,620

you know without doing the analysis of

246

00:10:08,629 --> 00:10:06,449

the data and the processing it's very

247

00:10:11,329 --> 00:10:08,639

hard especially for the small planets to

248

00:10:15,019 --> 00:10:11,339

see any dip at all you need any planet

249

00:10:17,480 --> 00:10:15,029

to give you a so it's this technique

250

00:10:19,340 --> 00:10:17,490

really thrives on especially when you're

251
00:10:21,530 --> 00:10:19,350
trying to do the small planets on having

252
00:10:24,110 --> 00:10:21,540
as much light as possible even from very

253
00:10:26,480 --> 00:10:24,120
bright stars so this is one of the

254
00:10:28,129 --> 00:10:26,490
reasons why JWST is going to be such a

255
00:10:31,040 --> 00:10:28,139
powerful tool for doing this kind of

256
00:10:32,990 --> 00:10:31,050
science yes we're getting into that a

257
00:10:35,990 --> 00:10:33,000
little more detail in a bit but then we

258
00:10:39,710 --> 00:10:36,000
have used to do this I mean people did

259
00:10:42,319 --> 00:10:39,720
want to try and just go for an HST sized

260
00:10:44,600 --> 00:10:42,329
telescope what could be done it's not a

261
00:10:47,569 --> 00:10:44,610
primary thing that we do because these

262
00:10:49,809 --> 00:10:47,579
other observatories will concentrate on

263
00:10:53,329 --> 00:10:49,819

that but a few observations were taken

264

00:10:54,829 --> 00:10:53,339

with HST just to to make sure we knew

265

00:10:56,360 --> 00:10:54,839

what we're up against yeah I think

266

00:10:58,490 --> 00:10:56,370

Carolyn correct me if I'm wrong but the

267

00:11:00,439 --> 00:10:58,500

the reason HST is an ideally suited for

268

00:11:02,269 --> 00:11:00,449

this kind of work is that it takes

269

00:11:04,519 --> 00:11:02,279

generally these light curves take many

270

00:11:06,620 --> 00:11:04,529

days to sometimes depending on the

271

00:11:08,179 --> 00:11:06,630

period of the planet to create right so

272

00:11:09,199 --> 00:11:08,189

you really kind of need to take up a lot

273

00:11:11,809 --> 00:11:09,209

of Hubble time

274

00:11:14,090 --> 00:11:11,819

to do to get a decent curb right right

275

00:11:18,650 --> 00:11:14,100

and that's why as mark says the strategy

276

00:11:20,540 --> 00:11:18,660

that Kepler is using is so important so

277

00:11:22,210 --> 00:11:20,550

you can take a long time to make sure

278

00:11:23,359 --> 00:11:22,220

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

279

00:11:24,980 --> 00:11:23,369

sample

280

00:11:26,359 --> 00:11:24,990

you can't just see it once to say oh

281

00:11:28,669 --> 00:11:26,369

there must be a planet no you're gonna

282

00:11:30,559 --> 00:11:28,679

it has to be periodic he has to keep

283

00:11:33,829 --> 00:11:30,569

coming back it has to be similar every

284

00:11:36,350 --> 00:11:33,839

time right and and so you you need that

285

00:11:39,319 --> 00:11:36,360

and so Kepler and staring for many years

286

00:11:42,619 --> 00:11:39,329

at the same region of the sky can then

287

00:11:44,960 --> 00:11:42,629

do that and as they acquire more and

288

00:11:47,960 --> 00:11:44,970

more data they can as Mark said get to

289

00:11:50,419 --> 00:11:47,970

some tinier and tinier planets that they

290

00:11:52,220 --> 00:11:50,429

can discover because initially the data

291

00:11:54,350 --> 00:11:52,230

is a little noisy so you have to keep

292

00:11:56,150 --> 00:11:54,360

accumulating the data until you get good

293

00:11:59,150 --> 00:11:56,160

statistics and you're confident about

294

00:12:00,949 --> 00:11:59,160

that you've detected a transit oh yeah

295

00:12:02,629 --> 00:12:00,959

this is a great segue into the past of

296

00:12:04,069 --> 00:12:02,639

observations hope Kepler was designed

297

00:12:05,869 --> 00:12:04,079

I'm just gonna fill in the gaps what we

298

00:12:07,609 --> 00:12:05,879

what we didn't say about Kepler is it's

299

00:12:10,609 --> 00:12:07,619

staring at one spot this guy looking at

300

00:12:12,350 --> 00:12:10,619

over 150,000 stars for a very very long

301
00:12:14,869 --> 00:12:12,360
time five years I believe was wouldn't

302
00:12:16,699 --> 00:12:14,879
was it Sun was its mission it went a

303
00:12:19,759 --> 00:12:16,709
little bit past that before it stopped

304
00:12:22,309 --> 00:12:19,769
being able to point precisely but for so

305
00:12:24,350 --> 00:12:22,319
we got five years of Kepler data looking

306
00:12:26,780 --> 00:12:24,360
at the same hundred and fifty some odd

307
00:12:29,030 --> 00:12:26,790
thousand stars and as Carol said we

308
00:12:30,769 --> 00:12:29,040
built this up over time to get these

309
00:12:32,720 --> 00:12:30,779
tiny dips and brightness and eight uses

310
00:12:35,389 --> 00:12:32,730
the transit method but that's not the

311
00:12:37,100 --> 00:12:35,399
only method to find these exoplanets

312
00:12:39,829 --> 00:12:37,110
it's just what Kepler uses and it was

313
00:12:41,960 --> 00:12:39,839

the beginning it was the way we started

314

00:12:43,220 --> 00:12:41,970

finding exoplanets in the first place

315

00:12:45,799 --> 00:12:43,230

but there's another method it's called

316

00:12:48,470 --> 00:12:45,809

the radial velocity method and Scott has

317

00:12:50,600 --> 00:12:48,480

a an animation that sort of illustrates

318

00:12:52,549 --> 00:12:50,610

that and Mark can you give us some

319

00:12:55,039 --> 00:12:52,559

insight into what that method is and and

320

00:12:58,609 --> 00:12:55,049

what are the best ways of making that

321

00:13:00,949 --> 00:12:58,619

kind of measurement okay so the radial

322

00:13:04,129 --> 00:13:00,959

velocity method was actually the first

323

00:13:06,169 --> 00:13:04,139

one that made up exoplanet discovery oh

324

00:13:10,519 --> 00:13:06,179

that was first I had it wrong on my ipod

325

00:13:12,410 --> 00:13:10,529

and it was me show my odd Geoff Marcy

326

00:13:15,109 --> 00:13:12,420

some of the early pioneers in this field

327

00:13:19,549 --> 00:13:15,119

and the basic idea is that if you have a

328

00:13:22,970 --> 00:13:19,559

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

329

00:13:25,939 --> 00:13:22,980

planet you as the planet orbits

330

00:13:27,769 --> 00:13:25,949

start the combine center gravity of the

331

00:13:30,980 --> 00:13:27,779

two is just slightly offset from the

332

00:13:33,319 --> 00:13:30,990

center of the star and so you see the

333

00:13:36,110 --> 00:13:33,329

Stars and you know essentially orbit a

334

00:13:37,939 --> 00:13:36,120

very small amount and thus it's coming

335

00:13:40,610 --> 00:13:37,949

towards you and going away from you and

336

00:13:44,389 --> 00:13:40,620

you can actually measure that velocity

337

00:13:47,540 --> 00:13:44,399

in the dispersed light from the star you

338

00:13:48,800 --> 00:13:47,550

need extremely high sensitivity to do

339

00:13:52,160 --> 00:13:48,810

that because you're talking about

340

00:13:55,189 --> 00:13:52,170

measuring the order of kilometers or

341

00:13:57,439 --> 00:13:55,199

second differences in the lines as they

342

00:13:58,939 --> 00:13:57,449

move backwards and forwards so to do

343

00:14:02,120 --> 00:13:58,949

that you need very large ground-based

344

00:14:04,910 --> 00:14:02,130

telescopes that disperse the light you

345

00:14:06,560 --> 00:14:04,920

know a very large amount but a large

346

00:14:08,240 --> 00:14:06,570

number of the original planet

347

00:14:10,939 --> 00:14:08,250

discoveries were found using this

348

00:14:12,650 --> 00:14:10,949

technique and then we realize that some

349

00:14:14,990 --> 00:14:12,660

of these stars were probably transiting

350

00:14:16,840 --> 00:14:15,000

and we started to follow up the

351
00:14:19,490 --> 00:14:16,850
observations using the transit technique

352
00:14:21,170 --> 00:14:19,500
right so let's bring them together real

353
00:14:23,090 --> 00:14:21,180
quick so there's each of these methods

354
00:14:24,410 --> 00:14:23,100
has their own strengths and weaknesses

355
00:14:26,629 --> 00:14:24,420
and we can get different information

356
00:14:28,610 --> 00:14:26,639
about the exoplanet from each one you

357
00:14:30,290 --> 00:14:28,620
want to tell us what what can we learn

358
00:14:33,319 --> 00:14:30,300
from transit methods about exoplanets

359
00:14:35,240 --> 00:14:33,329
versus a radial velocity yeah I think

360
00:14:38,569 --> 00:14:35,250
that the story really is that when you

361
00:14:40,519 --> 00:14:38,579
put the two together you if you combine

362
00:14:42,910 --> 00:14:40,529
a system where you've got radial

363
00:14:47,720 --> 00:14:42,920

velocity measurements which give you the

364

00:14:51,470 --> 00:14:47,730

the mass times M_{Sinai} or the with the

365

00:14:53,809 --> 00:14:51,480

inclination and the transit method which

366

00:14:55,730 --> 00:14:53,819

gives you some idea of the radius of the

367

00:14:58,370 --> 00:14:55,740

star when you combine those together you

368

00:15:00,949 --> 00:14:58,380

can actually back out the mass the

369

00:15:03,019 --> 00:15:00,959

radius and then you've got some idea of

370

00:15:04,819 --> 00:15:03,029

the density and since you know the

371

00:15:06,889 --> 00:15:04,829

radius of the star you can start making

372

00:15:08,990 --> 00:15:06,899

inferences about the composition of the

373

00:15:10,730 --> 00:15:09,000

planet so when you put these two

374

00:15:13,250 --> 00:15:10,740

techniques together you start to get

375

00:15:14,930 --> 00:15:13,260

really useful data you know the kind of

376

00:15:17,750 --> 00:15:14,940

stuff astronomers like where you plot

377

00:15:19,759 --> 00:15:17,760

mass and radius on a on a chart and you

378

00:15:23,329 --> 00:15:19,769

can start to categorize these different

379

00:15:24,889 --> 00:15:23,339

planets does not do that right that it

380

00:15:26,930 --> 00:15:24,899

just does the radio or the transit

381

00:15:28,730 --> 00:15:26,940

method correct right so Kepler was

382

00:15:32,319 --> 00:15:28,740

designed to answer one very simple

383

00:15:35,090 --> 00:15:32,329

question what fraction of stars have a

384

00:15:36,889 --> 00:15:35,100

terrestrial or rocky planet orbiting

385

00:15:39,619 --> 00:15:36,899

them so it's really a

386

00:15:42,009 --> 00:15:39,629

Society in statistics but that's a very

387

00:15:44,449 --> 00:15:42,019

important number to know because

388

00:15:47,179 --> 00:15:44,459

ultimately we would like to directly

389

00:15:49,759 --> 00:15:47,189

image earth-like planets around other

390

00:15:51,710 --> 00:15:49,769

stars and even gets better of them but

391

00:15:54,290 --> 00:15:51,720

we can't really build a telescope to do

392

00:15:56,359 --> 00:15:54,300

that until we know what the probability

393

00:15:58,699 --> 00:15:56,369

that if we look at a given star it's

394

00:16:01,069 --> 00:15:58,709

gonna have a terrestrial planet it

395

00:16:03,169 --> 00:16:01,079

really determines how big your your

396

00:16:04,699 --> 00:16:03,179

mirror has to be so that's a very

397

00:16:06,859 --> 00:16:04,709

important number that we need to

398

00:16:11,840 --> 00:16:06,869

understand and that's what Kepler was

399

00:16:13,189 --> 00:16:11,850

designed to do so we got transit method

400

00:16:15,889 --> 00:16:13,199

will show you something about the radius

401

00:16:17,150 --> 00:16:15,899

of the planet and the radial velocity

402

00:16:19,340 --> 00:16:17,160

method will give you some idea of how

403

00:16:20,660 --> 00:16:19,350

massive the planet is so yeah he knows

404

00:16:24,169 --> 00:16:20,670

together we can get a pretty complete

405

00:16:27,319 --> 00:16:24,179

indirect picture of the the exoplanet

406

00:16:28,579 --> 00:16:27,329

itself but we're not satisfied with that

407

00:16:31,100 --> 00:16:28,589

either I mean this is how it's been done

408

00:16:32,389 --> 00:16:31,110

with the past and now we want to look at

409

00:16:33,859 --> 00:16:32,399

these things directly you said at the

410

00:16:36,439 --> 00:16:33,869

beginning that one of your research

411

00:16:38,720 --> 00:16:36,449

interest is to observe exoplanets

412

00:16:43,160 --> 00:16:38,730

directly can we do that now

413

00:16:44,809 --> 00:16:43,170

yes we can so observing exoplanet is

414

00:16:47,929 --> 00:16:44,819

directly it's a real challenge because

415

00:16:49,939 --> 00:16:47,939

they are extremely faint and they're

416

00:16:53,059 --> 00:16:49,949

orbiting very close to stars that are

417

00:16:55,160 --> 00:16:53,069

extremely bright and contrast so this

418

00:16:58,160 --> 00:16:55,170

whole field we call high dynamic range

419

00:17:00,169 --> 00:16:58,170

imaging or high contrast imaging and the

420

00:17:03,530 --> 00:17:00,179

basic idea is that you need to figure

421

00:17:05,750 --> 00:17:03,540

out a way whereby you can essentially

422

00:17:08,000 --> 00:17:05,760

suppress the light from the star you're

423

00:17:10,340 --> 00:17:08,010

looking at so that you can increase the

424

00:17:13,039 --> 00:17:10,350

region of contrast around the star and

425

00:17:17,210 --> 00:17:13,049

be able to direct the image of planet

426
00:17:19,579 --> 00:17:17,220
and just to give you an example if you

427
00:17:22,340 --> 00:17:19,589
were looking at our Sun from another

428
00:17:25,069 --> 00:17:22,350
solar system Jupiter will be about a

429
00:17:27,289 --> 00:17:25,079
billion times fainter than the star and

430
00:17:29,480 --> 00:17:27,299
if you were looking at the earth it will

431
00:17:32,269 --> 00:17:29,490
be about ten billion times fainter but

432
00:17:34,190 --> 00:17:32,279
also much closer and it's it's a very

433
00:17:36,139 --> 00:17:34,200
difficult very challenging problem it

434
00:17:38,539 --> 00:17:36,149
you have to think about a lot of

435
00:17:40,370 --> 00:17:38,549
different optical aspects of your

436
00:17:43,130 --> 00:17:40,380
telescope design when you try to do this

437
00:17:47,240 --> 00:17:43,140
so I was I was just going to comment and

438
00:17:50,210 --> 00:17:47,250

jump in here is that in the initial in

439

00:17:50,600 --> 00:17:50,220

any of these studies especially the

440

00:17:53,750 --> 00:17:50,610

trends

441

00:17:55,640 --> 00:17:53,760

method initially they were large planets

442

00:17:57,620 --> 00:17:55,650

that were found for the reasons that

443

00:17:59,510 --> 00:17:57,630

Mark was talking about is you need a big

444

00:18:02,330 --> 00:17:59,520

dip but you needed to go around several

445

00:18:05,990 --> 00:18:02,340

times where you needed to do that you

446

00:18:08,990 --> 00:18:06,000

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

447

00:18:11,840 --> 00:18:09,000

that is going to take ten years you know

448

00:18:15,830 --> 00:18:11,850

to cross in front of its star from your

449

00:18:21,350 --> 00:18:15,840

perspective so what happened was that

450

00:18:24,530 --> 00:18:21,360

many of the Jupiter Saturn type planets

451
00:18:26,600 --> 00:18:24,540
that were found were relatively close to

452
00:18:28,280 --> 00:18:26,610
their parent star which is not the

453
00:18:30,470 --> 00:18:28,290
situation that we have in our solar

454
00:18:33,320 --> 00:18:30,480
system so that was a puzzle for a while

455
00:18:36,590 --> 00:18:33,330
but it it's an artifact to the fact that

456
00:18:39,140 --> 00:18:36,600
that's how the transit observations work

457
00:18:41,240 --> 00:18:39,150
is that they are predisposed to find

458
00:18:43,430 --> 00:18:41,250
things that block a lot of light and are

459
00:18:46,190 --> 00:18:43,440
close to the parent star and go around a

460
00:18:49,700 --> 00:18:46,200
lot but that doesn't mean those are the

461
00:18:51,080 --> 00:18:49,710
only planets around other stars yeah

462
00:18:52,940 --> 00:18:51,090
there's a but there's an inherent bias

463
00:18:54,680 --> 00:18:52,950

in that observation because yeah it has

464

00:18:56,840 --> 00:18:54,690

to it has to pass the night it has to

465

00:18:58,250 --> 00:18:56,850

pass between us and the star of the even

466

00:19:00,380 --> 00:18:58,260

know it's there we don't get those other

467

00:19:02,510 --> 00:19:00,390

right and also Mark had mentioned

468

00:19:06,230 --> 00:19:02,520

inclination so if you have an

469

00:19:08,510 --> 00:19:06,240

inclination which is close to what we

470

00:19:11,000 --> 00:19:08,520

call edge onto the planet when it does

471

00:19:13,490 --> 00:19:11,010

orbit it crosses in front of the disk of

472

00:19:16,159 --> 00:19:13,500

the star we can see that dip but if it's

473

00:19:19,190 --> 00:19:16,169

or if the our vantage point is different

474

00:19:22,400 --> 00:19:19,200

we may not ever see that there are stars

475

00:19:23,900 --> 00:19:22,410

that don't know that have planets that

476
00:19:25,970 --> 00:19:23,910
we just haven't seen them so we need

477
00:19:28,070 --> 00:19:25,980
these other techniques so if anything

478
00:19:29,690 --> 00:19:28,080
Kepler has undercounted its region of

479
00:19:30,950 --> 00:19:29,700
the sky that is looking at because it's

480
00:19:32,480 --> 00:19:30,960
only counting those with the

481
00:19:36,049 --> 00:19:32,490
line-of-sight issues that we just talked

482
00:19:38,510 --> 00:19:36,059
about i Scott can you put that and that

483
00:19:40,970 --> 00:19:38,520
one animation back up where the worth of

484
00:19:45,950 --> 00:19:40,980
the planet going around the star and

485
00:19:47,840 --> 00:19:45,960
while he's doing - they're all through

486
00:19:49,520 --> 00:19:47,850
the one the first one the first one you

487
00:19:51,770 --> 00:19:49,530
show us one yes come by the transit

488
00:19:56,710 --> 00:19:51,780

method and the route of import

489

00:20:10,860 --> 00:19:56,720

planet going around all right all right

490

00:20:16,120 --> 00:20:14,890

that one okay you gotta read my mind

491

00:20:20,560 --> 00:20:16,130

Scott I thought that's what that's what

492

00:20:22,720 --> 00:20:20,570

you did so I'm not too directly so to

493

00:20:25,149 --> 00:20:22,730

directly see this planet we're gonna

494

00:20:27,880 --> 00:20:25,159

need to block the light out from the

495

00:20:30,010 --> 00:20:27,890

star somehow and to do that we use

496

00:20:33,310 --> 00:20:30,020

something you know we use something

497

00:20:36,520 --> 00:20:33,320

called a coronagraph to see things close

498

00:20:38,020 --> 00:20:36,530

to the Sun to see for example the the

499

00:20:41,560 --> 00:20:38,030

atmosphere of the Sun we block out the

500

00:20:45,460 --> 00:20:41,570

disk using just a you know Anna Coulter

501
00:20:47,470 --> 00:20:45,470
here is it better to when we in order to

502
00:20:49,149 --> 00:20:47,480
see this exoplanet directly the one that

503
00:20:51,460 --> 00:20:49,159
Scott is currently showing we would have

504
00:20:54,970 --> 00:20:51,470
to somehow block the light from That

505
00:20:57,640 --> 00:20:54,980
star and we would see it like stuck if

506
00:20:59,470 --> 00:20:57,650
we Scott stopped it when it gets off to

507
00:21:01,390 --> 00:20:59,480
the limb of the star like right there if

508
00:21:02,919 --> 00:21:01,400
you can stop it somewhere when it gets

509
00:21:03,850 --> 00:21:02,929
to the side there you go yeah well

510
00:21:05,770 --> 00:21:03,860
that's close enough

511
00:21:07,210 --> 00:21:05,780
it's okay in order to see that we'd have

512
00:21:09,940 --> 00:21:07,220
to block the light out from that star

513
00:21:12,130 --> 00:21:09,950

right that is correct yes but we need

514

00:21:13,870 --> 00:21:12,140

the orientation to be such that it's

515

00:21:17,440 --> 00:21:13,880

either off to one side or the other this

516

00:21:21,700 --> 00:21:17,450

is only for exoplanets that are within

517

00:21:24,159 --> 00:21:21,710

our society exactly and so Scott's just

518

00:21:25,630 --> 00:21:24,169

put up a picture of a system called

519

00:21:28,169 --> 00:21:25,640

formal heart which is one I actually

520

00:21:31,600 --> 00:21:28,179

studied with Hubble Space Telescope and

521

00:21:33,279 --> 00:21:31,610

in this one you can actually see how of

522

00:21:37,600 --> 00:21:33,289

the coronagraph on the advanced camera

523

00:21:39,789 --> 00:21:37,610

and subsequently Stace worked so we

524

00:21:41,560 --> 00:21:39,799

block out the light from the central

525

00:21:43,480 --> 00:21:41,570

star in this case former heart which is

526

00:21:45,580 --> 00:21:43,490

extremely bright star in the southern

527

00:21:50,080 --> 00:21:45,590

hemisphere and what you see in that

528

00:21:54,190 --> 00:21:50,090

image is a ring of dust very analogous

529

00:21:57,880 --> 00:21:54,200

to the Kuiper belt disc in our own solar

530

00:22:01,529 --> 00:21:57,890

system and then just inside it's

531

00:22:04,029 --> 00:22:01,539

highlighted in a box several different

532

00:22:06,370 --> 00:22:04,039

observations of a planet that's actually

533

00:22:09,070 --> 00:22:06,380

orbit informal heart and this we were

534

00:22:10,630 --> 00:22:09,080

able to do using direct imaging high

535

00:22:14,169 --> 00:22:10,640

contrast imaging with the Hubble Space

536

00:22:16,930 --> 00:22:14,179

Telescope yeah I know you said it

537

00:22:18,880 --> 00:22:16,940

yourself the debris disc around that is

538

00:22:20,650 --> 00:22:18,890

very visible here huh yeah so how is

539

00:22:23,410 --> 00:22:20,660

this done how do you block out the light

540

00:22:27,510 --> 00:22:23,420

from these from these stars so put very

541

00:22:30,790 --> 00:22:27,520

simply you put very simply you have a

542

00:22:34,090 --> 00:22:30,800

some kind of mask in your optical system

543

00:22:36,790 --> 00:22:34,100

so you focus the light from the image

544

00:22:39,610 --> 00:22:36,800

down onto a very small mask and then you

545

00:22:41,590 --> 00:22:39,620

re have to reimage that light and also

546

00:22:43,840 --> 00:22:41,600

block out a lot of the scattered light

547

00:22:47,590 --> 00:22:43,850

that's produced by optical effects in

548

00:22:50,350 --> 00:22:47,600

the system once you've done that you can

549

00:22:53,080 --> 00:22:50,360

then re image the picture again and it

550

00:22:55,000 --> 00:22:53,090

it gives you a pretty good what we call

551
00:22:57,370 --> 00:22:55,010
circumstellar image an image of the

552
00:23:00,100 --> 00:22:57,380
region around the star you don't always

553
00:23:02,920 --> 00:23:00,110
get to remove most the light from the

554
00:23:04,870 --> 00:23:02,930
central star so certainly in the case of

555
00:23:07,630 --> 00:23:04,880
Hubble which cannot achieve the kind of

556
00:23:11,320 --> 00:23:07,640
contrasts I mentioned so Hubble we can

557
00:23:14,290 --> 00:23:11,330
get contrasts of about a thousand to ten

558
00:23:15,820 --> 00:23:14,300
thousand maybe so to do Hubble

559
00:23:18,070 --> 00:23:15,830
observations we actually take a picture

560
00:23:20,230 --> 00:23:18,080
of our system and then we take a picture

561
00:23:22,870 --> 00:23:20,240
of a star that we don't think has a

562
00:23:24,400 --> 00:23:22,880
planet or several stars that we don't

563
00:23:27,490 --> 00:23:24,410

think have a planet and we actually have

564

00:23:29,590 --> 00:23:27,500

to do a subtraction of one from the

565

00:23:31,810 --> 00:23:29,600

other to remove the residual halo of

566

00:23:35,170 --> 00:23:31,820

light so that we can actually find these

567

00:23:36,580 --> 00:23:35,180

planets oh wow okay so I understand in

568

00:23:38,920 --> 00:23:36,590

this diagram that that's up right now I

569

00:23:40,540 --> 00:23:38,930

understand the occulting spot part I get

570

00:23:42,490 --> 00:23:40,550

I get what's going on there but I don't

571

00:23:45,540 --> 00:23:42,500

understand the leo stop what is that

572

00:23:48,460 --> 00:23:45,550

doing so the Leo stop is to deal with

573

00:23:50,650 --> 00:23:48,470

what we call diffraction so every edge

574

00:23:52,870 --> 00:23:50,660

in the optical system the telescope

575

00:23:55,150 --> 00:23:52,880

spider that holds a secondary mirror the

576

00:23:57,220 --> 00:23:55,160

edge of the secondary mirror the edge of

577

00:23:59,950 --> 00:23:57,230

the primary mirror is diffracting light

578

00:24:03,010 --> 00:23:59,960

and you can first order think of that as

579

00:24:05,860 --> 00:24:03,020

just scattering light and so that light

580

00:24:07,600 --> 00:24:05,870

needs to be suppressed so the leo filter

581

00:24:10,030 --> 00:24:07,610

just removes although that scattered

582

00:24:12,550 --> 00:24:10,040

light in what we call the pupil plane

583

00:24:14,890 --> 00:24:12,560

and then when you re image you don't get

584

00:24:17,310 --> 00:24:14,900

all of that additional stray light or

585

00:24:21,310 --> 00:24:17,320

scattered light contaminating your image

586

00:24:24,100 --> 00:24:21,320

now this is a very simple coronagraph

587

00:24:25,750 --> 00:24:24,110

design it's the original EO design that

588

00:24:27,910 --> 00:24:25,760

I showed you there are lots more now

589

00:24:30,670 --> 00:24:27,920

which are infinitely more complicated

590

00:24:32,890 --> 00:24:30,680

that use bending mirrors the

591

00:24:35,740 --> 00:24:32,900

for mobile mirrors and there are also

592

00:24:38,560 --> 00:24:35,750

designs use you know very small

593

00:24:40,240 --> 00:24:38,570

interferometers to interfere pieces of

594

00:24:42,460 --> 00:24:40,250

the light in the focal plane with each

595

00:24:44,500 --> 00:24:42,470

other to block out the light from the

596

00:24:47,650 --> 00:24:44,510

central star so there's a there's a

597

00:24:49,450 --> 00:24:47,660

whole universe of different approaches

598

00:24:51,790 --> 00:24:49,460

to doing choreography now based on

599

00:24:53,860 --> 00:24:51,800

different optical techniques right so

600

00:24:56,710 --> 00:24:53,870

the future of exoplanet observations is

601
00:24:59,470 --> 00:24:56,720
to see them directly and let's talk

602
00:25:02,650 --> 00:24:59,480
about what JWST is planning on doing

603
00:25:04,510 --> 00:25:02,660
they have is it correct me if I'm wrong

604
00:25:05,680 --> 00:25:04,520
but is that what the micro shutters are

605
00:25:07,690 --> 00:25:05,690
supposed to be for there's these things

606
00:25:10,030 --> 00:25:07,700
called micro shutters on JWST that are

607
00:25:13,330 --> 00:25:10,040
designed I think to block out light from

608
00:25:16,060 --> 00:25:13,340
stars is that correct the micro shutters

609
00:25:18,550 --> 00:25:16,070
are actually allowed to allow us to look

610
00:25:21,220 --> 00:25:18,560
at multiple objects at the same time so

611
00:25:25,480 --> 00:25:21,230
they're more geared towards the deep

612
00:25:28,870 --> 00:25:25,490
imaging of galaxies problem but several

613
00:25:31,210 --> 00:25:28,880

of the JWST instruments have

614

00:25:33,400 --> 00:25:31,220

coronagraphs built into them that will

615

00:25:35,800 --> 00:25:33,410

give us different levels of performance

616

00:25:38,320 --> 00:25:35,810

in near-infrared and then the medium

617

00:25:41,500 --> 00:25:38,330

Freret so in the near-infrared we use

618

00:25:44,350 --> 00:25:41,510

very traditional coronagraphs much like

619

00:25:46,480 --> 00:25:44,360

the one we just saw in the figure in the

620

00:25:48,460 --> 00:25:46,490

mid infrared at longer wavelengths we

621

00:25:50,680 --> 00:25:48,470

actually use a small interferometer

622

00:25:53,770 --> 00:25:50,690

where we divide the focal plane into

623

00:25:56,470 --> 00:25:53,780

four and in to interfere pieces against

624

00:26:00,010 --> 00:25:56,480

each other to block out on now the light

625

00:26:02,950 --> 00:26:00,020

from the central star so JWST has some

626
00:26:05,380 --> 00:26:02,960
extremely capable coronagraphs and they

627
00:26:07,990 --> 00:26:05,390
will allow us to really study that

628
00:26:09,970 --> 00:26:08,000
parameter space that isn't sort of met

629
00:26:12,550 --> 00:26:09,980
by doing transit observations to further

630
00:26:15,150 --> 00:26:12,560
out objects but all bits of you know

631
00:26:17,860 --> 00:26:15,160
roughly akin to jupiter and further out

632
00:26:19,300 --> 00:26:17,870
ok well that you brought up the topic I

633
00:26:21,910 --> 00:26:19,310
want to get to it whereas as an

634
00:26:24,310 --> 00:26:21,920
exoplanet researcher what most excites

635
00:26:25,600 --> 00:26:24,320
you about JWST I mean what kinds of

636
00:26:29,950 --> 00:26:25,610
planets are we going to be able to image

637
00:26:32,200 --> 00:26:29,960
with that so I I think for me the two

638
00:26:34,780 --> 00:26:32,210

most exciting things are one being able

639

00:26:36,520 --> 00:26:34,790

to take images of systems like formal

640

00:26:40,270 --> 00:26:36,530

hearts at different wavelengths I think

641

00:26:42,910 --> 00:26:40,280

we all really be able to stop the piece

642

00:26:44,140 --> 00:26:42,920

apart that system now by imaging at

643

00:26:44,680 --> 00:26:44,150

different wavelengths we can see

644

00:26:49,780 --> 00:26:44,690

different

645

00:26:51,850 --> 00:26:49,790

are dust within the system and we can

646

00:26:53,650 --> 00:26:51,860

also hunt for the other planets that we

647

00:26:57,400 --> 00:26:53,660

think might be there that we can't right

648

00:27:00,130 --> 00:26:57,410

now see as far as the transiting systems

649

00:27:02,830 --> 00:27:00,140

goes that's where I think JWST is going

650

00:27:04,450 --> 00:27:02,840

to be the killer application it just has

651
00:27:07,540 --> 00:27:04,460
everything you need to do really

652
00:27:09,220 --> 00:27:07,550
fantastic transiting exoplanet science

653
00:27:12,010 --> 00:27:09,230
and we haven't actually talked much

654
00:27:14,230 --> 00:27:12,020
about doing spectroscopy but the next

655
00:27:16,960 --> 00:27:14,240
step in doing transit transiting

656
00:27:19,480 --> 00:27:16,970
observations is to disperse the light as

657
00:27:21,280 --> 00:27:19,490
you measure the transit and by doing

658
00:27:23,470 --> 00:27:21,290
that you can actually back out the

659
00:27:25,900 --> 00:27:23,480
spectrum or the dispersed light

660
00:27:27,910 --> 00:27:25,910
signature of the planet's atmosphere and

661
00:27:29,410 --> 00:27:27,920
once you can do that then you can start

662
00:27:31,750 --> 00:27:29,420
studying lots of different planets

663
00:27:34,810 --> 00:27:31,760

looking at their atmospheres and really

664

00:27:37,720 --> 00:27:34,820

doing a lot more comparison of different

665

00:27:40,390 --> 00:27:37,730

types of planets so can you can you

666

00:27:42,430 --> 00:27:40,400

quantify that a little bit how we work

667

00:27:44,200 --> 00:27:42,440

presumably we're doing are we able to

668

00:27:45,820 --> 00:27:44,210

wobble to me back up are we able to do

669

00:27:48,010 --> 00:27:45,830

this now with anything that currently

670

00:27:51,190 --> 00:27:48,020

exists get these get the composition of

671

00:27:55,140 --> 00:27:51,200

exoplanet atmospheres so we can do this

672

00:27:57,220 --> 00:27:55,150

now with HST is they're extremely hard

673

00:27:59,680 --> 00:27:57,230

observations as you said because a

674

00:28:02,290 --> 00:27:59,690

single transit can last many hours and

675

00:28:04,930 --> 00:28:02,300

you know Hubble goes around the earth

676
00:28:06,910 --> 00:28:04,940
every 90 minutes so you only get half of

677
00:28:08,800 --> 00:28:06,920
90 minutes to actually do science you

678
00:28:11,770 --> 00:28:08,810
have to piece together several transits

679
00:28:13,690 --> 00:28:11,780
and Hubble doesn't work out into the

680
00:28:16,980 --> 00:28:13,700
full range of the near-infrared you know

681
00:28:20,320 --> 00:28:16,990
it does you know what one to 1.7 microns

682
00:28:23,500 --> 00:28:20,330
rather than one to five which JW can do

683
00:28:26,680 --> 00:28:23,510
and then JW can also do the 5 to 30

684
00:28:31,620 --> 00:28:26,690
range W it's kind of like you're on

685
00:28:36,070 --> 00:28:34,330
that's right yeah I called me on the

686
00:28:39,370 --> 00:28:36,080
breast ice and NDT cuz we're like that

687
00:28:41,470 --> 00:28:39,380
so yeah and and the other thing is that

688
00:28:44,110 --> 00:28:41,480

spits has also started to do this but

689

00:28:46,690 --> 00:28:44,120

it's has to build up a spectrum by

690

00:28:48,730 --> 00:28:46,700

taking images and then you get a

691

00:28:51,160 --> 00:28:48,740

spectrum with what we call a spectral

692

00:28:52,930 --> 00:28:51,170

energy distribution four or five data

693

00:28:55,270 --> 00:28:52,940

points and you're trying to fit to those

694

00:28:57,580 --> 00:28:55,280

so being able to get a real spectrum

695

00:28:58,570 --> 00:28:57,590

with a very high resolution in a single

696

00:29:00,759 --> 00:28:58,580

transit which is

697

00:29:02,830 --> 00:29:00,769

James Webb will give you is that going

698

00:29:04,000 --> 00:29:02,840

to be very powerful okay that brings to

699

00:29:05,230 --> 00:29:04,010

the question I initially wanted to ask

700

00:29:07,419 --> 00:29:05,240

you which we can you quantify it a

701
00:29:09,460 --> 00:29:07,429
little bit how much better JWST might do

702
00:29:12,370 --> 00:29:09,470
then how these current observations are

703
00:29:15,940 --> 00:29:12,380
being done or I don't know maybe orders

704
00:29:17,680 --> 00:29:15,950
of magnitude estimate that's tough but

705
00:29:20,740 --> 00:29:17,690
you know you know the bottom line is

706
00:29:23,710 --> 00:29:20,750
that most of the observations we're

707
00:29:25,539 --> 00:29:23,720
doing now the resolutions may be the

708
00:29:28,210 --> 00:29:25,549
order of spectral resolution of a

709
00:29:30,190 --> 00:29:28,220
hundred with jwe we can go to two

710
00:29:32,590 --> 00:29:30,200
thousand three thousand spectral

711
00:29:34,810 --> 00:29:32,600
resolution and we can get get a full

712
00:29:37,570 --> 00:29:34,820
transit in one visit for a lot of gas

713
00:29:39,310 --> 00:29:37,580

giant planets so you've said that the

714

00:29:42,810 --> 00:29:39,320

the transit method is going to be one of

715

00:29:49,720 --> 00:29:42,820

the bread-and-butter uh applications of

716

00:29:52,509 --> 00:29:49,730

JWST or you said JW yeah so what did did

717

00:29:55,480 --> 00:29:52,519

the results from Kepler surprised you at

718

00:29:59,500 --> 00:29:55,490

all as a scientist just how many planets

719

00:30:02,950 --> 00:29:59,510

Kepler found I know I think one of the

720

00:30:04,720 --> 00:30:02,960

thing I know I was I have actually one

721

00:30:06,610 --> 00:30:04,730

of the believers who was expecting that

722

00:30:09,159 --> 00:30:06,620

Kepler would find a lot of planets and

723

00:30:11,529 --> 00:30:09,169

it has I think it's been one of the

724

00:30:14,409 --> 00:30:11,539

surprising things is just how many small

725

00:30:17,440 --> 00:30:14,419

planets and also planets in the sort of

726
00:30:20,200 --> 00:30:17,450
super earth range midway between the

727
00:30:23,560 --> 00:30:20,210
size of our earth and uranus and neptune

728
00:30:25,870 --> 00:30:23,570
so it's discovered i for me one of its

729
00:30:29,620 --> 00:30:25,880
big discoveries is just how many super s

730
00:30:31,360 --> 00:30:29,630
and small rocky there are out there yeah

731
00:30:33,730 --> 00:30:31,370
i bring that up because one of the big

732
00:30:35,740 --> 00:30:33,740
things that I always hear JWST project

733
00:30:37,090 --> 00:30:35,750
members talk about is that one of the

734
00:30:39,220 --> 00:30:37,100
most exciting things about the James

735
00:30:41,470 --> 00:30:39,230
Webb Space Telescope isn't the kinds of

736
00:30:43,210 --> 00:30:41,480
science that we are we know we can do

737
00:30:44,560 --> 00:30:43,220
with Jay are the kinds of answers are

738
00:30:47,560 --> 00:30:44,570

two questions we know we're going to get

739

00:30:49,360 --> 00:30:47,570

but the answers to questions that we do

740

00:30:52,180 --> 00:30:49,370

haven't even thought to answer ask yet

741

00:30:54,700 --> 00:30:52,190

and so there's a whole unknown area of

742

00:30:56,680 --> 00:30:54,710

things that we expect JWST will show us

743

00:30:59,440 --> 00:30:56,690

and from Kay and I use Kepler as an

744

00:31:01,180 --> 00:30:59,450

example because from my mind I think

745

00:31:03,310 --> 00:31:01,190

it's just blown everybody away I mean

746

00:31:06,639 --> 00:31:03,320

staring at one spot in the sky for years

747

00:31:09,100 --> 00:31:06,649

and years is a pretty simple thing to do

748

00:31:11,620 --> 00:31:09,110

and it blew us away with what it is

749

00:31:13,870 --> 00:31:11,630

about our place in the universe so

750

00:31:16,810 --> 00:31:13,880

I'm just excited about JWST coming out

751

00:31:18,460 --> 00:31:16,820

but that's not all let's talk about some

752

00:31:20,620 --> 00:31:18,470

other things well real quick before we

753

00:31:25,270 --> 00:31:20,630

do that for those that aren't aware of

754

00:31:27,610 --> 00:31:25,280

the just how spectacular JWST is I mean

755

00:31:30,040 --> 00:31:27,620

I know you and I've done some outreach

756

00:31:33,360 --> 00:31:30,050

with the full-scale model but here's a

757

00:31:40,300 --> 00:31:33,370

wonderful animation just showing how

758

00:31:44,410 --> 00:31:40,310

fantastic de WS t is so it's going to be

759

00:31:46,360 --> 00:31:44,420

owned at the the I2 point and it is what

760

00:31:48,220 --> 00:31:46,370

the area of a tennis court and four

761

00:31:54,010 --> 00:31:48,230

stories tall is that about accurate

762

00:31:56,230 --> 00:31:54,020

that's right it's the best rent and I

763

00:31:58,630 --> 00:31:56,240

was as I was telling you earlier Tony I

764

00:32:01,270 --> 00:31:58,640

just participated in the first-ever

765

00:32:03,220 --> 00:32:01,280

deployment of those five layers on the

766

00:32:05,740 --> 00:32:03,230

ground and it's really amazing when

767

00:32:07,030 --> 00:32:05,750

you're standing inside the tennis I know

768

00:32:08,470 --> 00:32:07,040

and I want to do and I want to get you

769

00:32:10,150 --> 00:32:08,480

back and another hangout to talk about

770

00:32:11,920 --> 00:32:10,160

that specifically because I want to know

771

00:32:13,600 --> 00:32:11,930

how it went maybe everything's on track

772

00:32:15,640 --> 00:32:13,610

if you guys learned anything on you

773

00:32:17,230 --> 00:32:15,650

doing that deployment but unfortunately

774

00:32:19,210 --> 00:32:17,240

we don't have time because I want to get

775

00:32:21,100 --> 00:32:19,220

to so many other things so mark your

776

00:32:25,200 --> 00:32:21,110

calendar and for another for another

777

00:32:29,590 --> 00:32:25,210

hangout where we'll go into this okay so

778

00:32:30,730 --> 00:32:29,600

a Coulter well what's the next I'll let

779

00:32:32,020 --> 00:32:30,740

you drive this part of the conversation

780

00:32:33,070 --> 00:32:32,030

yeah what do you want to talk about

781

00:32:34,600 --> 00:32:33,080

knife you've got all these different

782

00:32:37,540 --> 00:32:34,610

missions coming up we've got something

783

00:32:42,100 --> 00:32:37,550

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

784

00:32:46,000 --> 00:32:42,110

we've got star shades coming up what

785

00:32:49,780 --> 00:32:46,010

would pick your pick one so let me start

786

00:32:51,730 --> 00:32:49,790

with test so as you said Kepler has done

787

00:32:54,130 --> 00:32:51,740

a great job of answering the question

788

00:32:56,260 --> 00:32:54,140

you know what's the probability if I

789

00:32:58,870 --> 00:32:56,270

look at a star it's got a planet the

790

00:33:01,510 --> 00:32:58,880

terrestrial planet around it but a lot

791

00:33:03,490 --> 00:33:01,520

of the targets that Kepler is

792

00:33:06,040 --> 00:33:03,500

identifying forests are just way too

793

00:33:08,860 --> 00:33:06,050

faint to be able to do good spectroscopy

794

00:33:10,510 --> 00:33:08,870

with James Webb so it turns out that

795

00:33:12,820 --> 00:33:10,520

even though James Webb is six and a half

796

00:33:14,620 --> 00:33:12,830

meters across the kind of signal

797

00:33:16,360 --> 00:33:14,630

strengths you need to in order to be

798

00:33:19,210 --> 00:33:16,370

able to back out the spectrum in these

799

00:33:20,830 --> 00:33:19,220

planets you need much brighter power and

800

00:33:24,280 --> 00:33:20,840

Stiles to be able to do the observations

801
00:33:25,510 --> 00:33:24,290
so my colleague George Ricker at MIT

802
00:33:28,780 --> 00:33:25,520
came up with a mission

803
00:33:31,570 --> 00:33:28,790
which I'm participating called Tess and

804
00:33:35,830 --> 00:33:31,580
the basic idea of Tess is we're going to

805
00:33:39,010 --> 00:33:35,840
go find nearby transiting exoplanet Airy

806
00:33:42,370 --> 00:33:39,020
systems around bright stars that people

807
00:33:44,200 --> 00:33:42,380
can study using JWST or even the next

808
00:33:48,700 --> 00:33:44,210
generation of very large ground-based

809
00:33:51,040 --> 00:33:48,710
telescopes so that raises a problem how

810
00:33:53,590 --> 00:33:51,050
you know you've heard you have to stare

811
00:33:55,420 --> 00:33:53,600
for a long time so if you wanted to map

812
00:33:57,850 --> 00:33:55,430
all the bright stars in the sky how do

813
00:34:01,600 --> 00:33:57,860

you do that and George came up with this

814

00:34:03,760 --> 00:34:01,610

very neat approach using tests where we

815

00:34:06,400 --> 00:34:03,770

will map out the whole sky over two

816

00:34:08,770 --> 00:34:06,410

years and basically study most of the

817

00:34:10,810 --> 00:34:08,780

bright stars to see which ones would

818

00:34:13,210 --> 00:34:10,820

make great candidates follow up with

819

00:34:14,770 --> 00:34:13,220

JWST and again that's a transit

820

00:34:17,380 --> 00:34:14,780

telescope brightest looking at transits

821

00:34:20,440 --> 00:34:17,390

exactly it's a transit telescope it has

822

00:34:21,940 --> 00:34:20,450

four cameras and they basically scan the

823

00:34:23,830 --> 00:34:21,950

whole of the Northern Hemisphere and

824

00:34:27,280 --> 00:34:23,840

then the whole of the Sun Hemisphere and

825

00:34:30,730 --> 00:34:27,290

we get close to the ecliptic equator

826
00:34:33,880 --> 00:34:30,740
something like a continuous period of 27

827
00:34:35,830 --> 00:34:33,890
days up to the ecliptic poles where Tess

828
00:34:39,610 --> 00:34:35,840
actually gets your four years coverage

829
00:34:41,620 --> 00:34:39,620
in the JWST continuous viewing zone so

830
00:34:44,500 --> 00:34:41,630
it's really geared towards finding

831
00:34:48,159 --> 00:34:44,510
targets wins it wins it launching so

832
00:34:52,090 --> 00:34:48,169
that one will launch in 2017 2017 right

833
00:34:54,210 --> 00:34:52,100
before the JWST goes up so that'll then

834
00:34:56,320 --> 00:34:54,220
that's an entire sky survey of

835
00:34:58,660 --> 00:34:56,330
transiting exoplanets so that's going to

836
00:35:00,220 --> 00:34:58,670
be exciting and but it will not image

837
00:35:01,830 --> 00:35:00,230
directly that's one of the things even

838
00:35:03,610 --> 00:35:01,840

though we said it's the future of

839

00:35:04,960 --> 00:35:03,620

exoplanet observations that's not

840

00:35:08,830 --> 00:35:04,970

necessarily something the tests will be

841

00:35:11,320 --> 00:35:08,840

able to do right there of tests and the

842

00:35:12,520 --> 00:35:11,330

four cameras going on - ah okay there's

843

00:35:13,740 --> 00:35:12,530

an image of the spacecraft so that's

844

00:35:23,890 --> 00:35:13,750

cool

845

00:35:25,480 --> 00:35:23,900

at last so the the ultimate goal I think

846

00:35:28,360 --> 00:35:25,490

of a lot of people working in the field

847

00:35:32,920 --> 00:35:28,370

of exoplanets right now is to find earth

848

00:35:35,620 --> 00:35:32,930

2.0 an earth-like planet orbiting a star

849

00:35:38,440 --> 00:35:35,630

like star and what they would like to be

850

00:35:39,400 --> 00:35:38,450

able to do is take images or conduct a

851
00:35:41,230 --> 00:35:39,410
survey and take

852
00:35:43,990 --> 00:35:41,240
images of these planets and then follow

853
00:35:45,400 --> 00:35:44,000
up by doing spectroscopy are the ones

854
00:35:47,800 --> 00:35:45,410
that are interesting to look for

855
00:35:49,810 --> 00:35:47,810
biomarkers you know the usual things

856
00:35:51,730 --> 00:35:49,820
that we would look for there's evidence

857
00:35:54,640 --> 00:35:51,740
that there might be the possibility of

858
00:35:57,490 --> 00:35:54,650
life on that planet and to do that you

859
00:36:00,070 --> 00:35:57,500
need to have a very large telescope so

860
00:36:03,250 --> 00:36:00,080
there are two approaches one is to build

861
00:36:05,980 --> 00:36:03,260
a 1012 metre telescope with a

862
00:36:08,860 --> 00:36:05,990
coronagraph and another is to build a

863
00:36:11,950 --> 00:36:08,870

large telescope and use this external a

864

00:36:14,230 --> 00:36:11,960

Coulter that you mentioned so in both

865

00:36:17,350 --> 00:36:14,240

cases they're very challenging problems

866

00:36:19,300 --> 00:36:17,360

because you're trying to measure planets

867

00:36:21,850 --> 00:36:19,310

that are extremely close to their bright

868

00:36:24,970 --> 00:36:21,860

central star and a 10 million times

869

00:36:28,090 --> 00:36:24,980

fainter so you've got to knock down 10

870

00:36:30,070 --> 00:36:28,100

billion times the light of the star so

871

00:36:31,720 --> 00:36:30,080

that you can bring up the contrast in

872

00:36:34,270 --> 00:36:31,730

the surrounding region enough to be able

873

00:36:36,160 --> 00:36:34,280

to identify the planets what's the

874

00:36:37,750 --> 00:36:36,170

acronym stand for I always forget what

875

00:36:40,630 --> 00:36:37,760

does that last stand for do you know a

876

00:36:44,620 --> 00:36:40,640

Bond technology large aperture Space

877

00:36:48,460 --> 00:36:44,630

Telescope okay and that that was not one

878

00:36:53,560 --> 00:36:48,470

of the ones that use the NRO chassis is

879

00:36:56,340 --> 00:36:53,570

it or my no so the the ones that use the

880

00:37:00,490 --> 00:36:56,350

those chassis czar is after which is

881

00:37:02,820 --> 00:37:00,500

also being called w first that that's

882

00:37:06,780 --> 00:37:02,830

the next mission that will come after

883

00:37:09,340 --> 00:37:06,790

JWST and is another step where they will

884

00:37:12,370 --> 00:37:09,350

include a chronograph that would allow

885

00:37:15,250 --> 00:37:12,380

them to take images of gas giant planets

886

00:37:18,430 --> 00:37:15,260

and possibly some super Earths right so

887

00:37:22,000 --> 00:37:18,440

at last is kind of the end of the road

888

00:37:23,410 --> 00:37:22,010

if you like okay studying a 2.0 and

889

00:37:26,890 --> 00:37:23,420

there are a number of steps along the

890

00:37:31,290 --> 00:37:26,900

way you know JWST then this mission

891

00:37:34,810 --> 00:37:31,300

called w first and then this big

892

00:37:36,790 --> 00:37:34,820

flagship later on good so that with a

893

00:37:38,500 --> 00:37:36,800

lotta i just can't believe how many

894

00:37:40,300 --> 00:37:38,510

things are on the pipeline right now

895

00:37:42,340 --> 00:37:40,310

being built and and ready to be launched

896

00:37:45,280 --> 00:37:42,350

one of them I'm most excited about is

897

00:37:47,980 --> 00:37:45,290

this thing that uses talked about a coal

898

00:37:50,050 --> 00:37:47,990

ting star so that we can see the planets

899

00:37:52,810 --> 00:37:50,060

directly is uses this thing called a

900

00:37:54,190 --> 00:37:52,820

star shade and Scott

901
00:37:56,980 --> 00:37:54,200
have some pretty cool animations can you

902
00:37:58,990 --> 00:37:56,990
put one of those up for us I can so I'm

903
00:38:01,680 --> 00:37:59,000
gonna look the first one first just to

904
00:38:04,300 --> 00:38:01,690
show it unfurling yeah yeah it's

905
00:38:05,920 --> 00:38:04,310
fantastic yeah so mark while he's doing

906
00:38:06,460 --> 00:38:05,930
that why don't you describe what what

907
00:38:11,080 --> 00:38:06,470
this is

908
00:38:13,930 --> 00:38:11,090
so the ACOTA is one of the concepts that

909
00:38:17,290 --> 00:38:13,940
people are looking at for doing this

910
00:38:19,930 --> 00:38:17,300
earth 2.0 measurement and the basic idea

911
00:38:22,470 --> 00:38:19,940
is that you can either make the Large

912
00:38:26,470 --> 00:38:22,480
Telescope with the internal chronograph

913
00:38:28,060 --> 00:38:26,480

to extremely demanding specifications in

914

00:38:31,120 --> 00:38:28,070

terms of its stability we're talking

915

00:38:34,000 --> 00:38:31,130

about tens of Pico meters here you know

916

00:38:36,640 --> 00:38:34,010

and holding a big structure 1012 meters

917

00:38:39,670 --> 00:38:36,650

wide to that kind of tolerance an

918

00:38:42,370 --> 00:38:39,680

alternate approach is to go with this

919

00:38:45,640 --> 00:38:42,380

external occulta which is basically a

920

00:38:48,130 --> 00:38:45,650

mask that you fly something like a

921

00:38:50,560 --> 00:38:48,140

hundred to 150,000 kilometers from the

922

00:38:53,290 --> 00:38:50,570

telescope then you align the two so that

923

00:38:56,610 --> 00:38:53,300

this free flying mask or a Coulter

924

00:38:59,380 --> 00:38:56,620

blocks out the light from the star and

925

00:39:01,960 --> 00:38:59,390

allows you to image the planets around

926
00:39:03,670 --> 00:39:01,970
the star with the coronagraph and the

927
00:39:06,070 --> 00:39:03,680
nice thing about this approach is that

928
00:39:08,890 --> 00:39:06,080
it doesn't put any demanding

929
00:39:11,050 --> 00:39:08,900
requirements on the telescope instead

930
00:39:13,330 --> 00:39:11,060
the demanding requirements of the mask

931
00:39:15,700 --> 00:39:13,340
which is you know extremely big you know

932
00:39:18,970 --> 00:39:15,710
we're talking 20 to 30 metres wide and

933
00:39:21,400 --> 00:39:18,980
you have to fly in formation with the

934
00:39:22,690 --> 00:39:21,410
telescope to keep them aligned and then

935
00:39:24,820 --> 00:39:22,700
when you're ready to go to your next

936
00:39:27,490 --> 00:39:24,830
target you have to fly it around the sky

937
00:39:29,680 --> 00:39:27,500
to align with your next target I don't

938
00:39:33,490 --> 00:39:29,690

look if it swings around abouts

939

00:39:35,680 --> 00:39:33,500

yeah I thought I did oh yes he was it

940

00:39:37,930 --> 00:39:35,690

was intricate look at that thing I mean

941

00:39:39,660 --> 00:39:37,940

that's amazing and you said it was how

942

00:39:41,950 --> 00:39:39,670

big again I'm sorry you said 30

943

00:39:44,550 --> 00:39:41,960

depending on the size of the telescope

944

00:39:46,930 --> 00:39:44,560

today it can be 20 to 30 meters diameter

945

00:39:49,180 --> 00:39:46,940

okay so this is a big thing we were

946

00:39:51,490 --> 00:39:49,190

talking about up in space so yeah and

947

00:39:53,440 --> 00:39:51,500

this is this is the this is showing this

948

00:39:54,970 --> 00:39:53,450

animation showing how it blocks the

949

00:39:58,150 --> 00:39:54,980

light light from the stars and you can

950

00:40:00,040 --> 00:39:58,160

see these planets becoming visible once

951
00:40:01,930 --> 00:40:00,050
that's been done because they are all

952
00:40:04,060 --> 00:40:01,940
that extraneous light as being as being

953
00:40:06,339 --> 00:40:04,070
blocked out what's up with that shape

954
00:40:09,719 --> 00:40:06,349
how come is shaped that way

955
00:40:12,819 --> 00:40:09,729
the shape is basically designed again to

956
00:40:16,929 --> 00:40:12,829
optimize the or minimize the diffracted

957
00:40:19,719 --> 00:40:16,939
light from the edge of the mask itself

958
00:40:22,059 --> 00:40:19,729
if you just use a circular aperture that

959
00:40:24,759 --> 00:40:22,069
circular edge you know creates a lot of

960
00:40:26,439 --> 00:40:24,769
scattered light or diffracted light that

961
00:40:28,449 --> 00:40:26,449
you don't want right where the planets

962
00:40:30,880 --> 00:40:28,459
will be but by using this fully

963
00:40:32,709 --> 00:40:30,890

optimized shape you can basically decide

964

00:40:36,279 --> 00:40:32,719

where you want the diffracted light to

965

00:40:38,409 --> 00:40:36,289

finish up so it puts the scattered light

966

00:40:40,329 --> 00:40:38,419

where it's not going to interfere with

967

00:40:43,659 --> 00:40:40,339

your imaging of the planet saying it's a

968

00:40:45,549 --> 00:40:43,669

simple way of sort of putting it so how

969

00:40:47,319 --> 00:40:45,559

is this thing going to be pointed I mean

970

00:40:48,939 --> 00:40:47,329

you've got this thing flowing floating

971

00:40:53,140 --> 00:40:48,949

out in space I mean how do you point

972

00:40:54,759 --> 00:40:53,150

this thing very carefully right so this

973

00:40:56,769 --> 00:40:54,769

is one of the challenges that people are

974

00:40:59,319 --> 00:40:56,779

working on right now as I said that

975

00:41:02,229 --> 00:40:59,329

these things are still in the probably

976

00:41:04,209 --> 00:41:02,239

Bacoor the tray stage so we're trading

977

00:41:06,489 --> 00:41:04,219

off the benefits of the occult of us the

978

00:41:08,829 --> 00:41:06,499

benefits of the internal coronagraph and

979

00:41:11,649 --> 00:41:08,839

they each have their pros and cons and

980

00:41:14,679 --> 00:41:11,659

the idea is to figure out which one wins

981

00:41:17,140 --> 00:41:14,689

out at the end of the day ok in you know

982

00:41:20,199 --> 00:41:17,150

to align these things you have to have a

983

00:41:22,239 --> 00:41:20,209

way of the telescope knowing exactly

984

00:41:24,029 --> 00:41:22,249

where your coultter is and being able to

985

00:41:26,469 --> 00:41:24,039

stay aligned with respect to the ACOTA

986

00:41:29,349 --> 00:41:26,479

okay so as you so you just pointed out

987

00:41:33,159 --> 00:41:29,359

this is still being in the design stage

988

00:41:34,899 --> 00:41:33,169

or early early so no timelines or

989

00:41:37,659 --> 00:41:34,909

anything like that for when this might

990

00:41:39,329 --> 00:41:37,669

get deployed no yeah this is you know

991

00:41:42,549 --> 00:41:39,339

we're still in the sort of early days

992

00:41:44,559 --> 00:41:42,559

phase I would say okay but that's

993

00:41:46,089 --> 00:41:44,569

something definitely that's gonna wait

994

00:41:48,279 --> 00:41:46,099

and we're what well we know where it'll

995

00:41:51,339 --> 00:41:48,289

go right roughly it'll will go out to I2

996

00:41:53,409 --> 00:41:51,349

well well yeah but right most of these

997

00:41:55,569 --> 00:41:53,419

missions now are looking at going to our

998

00:41:58,599 --> 00:41:55,579

- in fact they actually all be I2

999

00:42:01,929 --> 00:41:58,609

they're not at I2 and let's talk real

1000

00:42:05,079 --> 00:42:01,939

quick what I was gonna okay I'll go for

1001
00:42:09,189 --> 00:42:05,089
Scott so we're talking about Lagrangian

1002
00:42:11,649 --> 00:42:09,199
points which are a balance as far as the

1003
00:42:14,109 --> 00:42:11,659
were the gravity and the mass are within

1004
00:42:16,809 --> 00:42:14,119
system so this is a particular point

1005
00:42:19,299 --> 00:42:16,819
that's where Jamie's WSC is going and

1006
00:42:20,140 --> 00:42:19,309
where we had other things go as well and

1007
00:42:22,089 --> 00:42:20,150
so we have different

1008
00:42:24,130 --> 00:42:22,099
points between us and the moon and the

1009
00:42:26,710 --> 00:42:24,140
Sun and the way things are balanced out

1010
00:42:28,630 --> 00:42:26,720
within the gravity field we can hold

1011
00:42:32,380 --> 00:42:28,640
them there with very minimal adjustments

1012
00:42:34,329 --> 00:42:32,390
and that's why with JWST for instance we

1013
00:42:36,010 --> 00:42:34,339

do need have some fuel on board to

1014

00:42:38,920 --> 00:42:36,020

adjust but it's going to be staying

1015

00:42:40,870 --> 00:42:38,930

there primarily fairly easily and just

1016

00:42:43,930 --> 00:42:40,880

at those balancing points between

1017

00:42:46,599 --> 00:42:43,940

objects right it's it's a spot where it

1018

00:42:49,599 --> 00:42:46,609

will match Earth's orbit as it goes

1019

00:42:50,829 --> 00:42:49,609

around the Sun and will always be you

1020

00:42:52,839 --> 00:42:50,839

know we'll be able to look in the same

1021

00:42:54,910 --> 00:42:52,849

region to be able to communicate with it

1022

00:42:56,950 --> 00:42:54,920

and things like that so it's a really

1023

00:43:00,670 --> 00:42:56,960

important area in the solar system it's

1024

00:43:02,470 --> 00:43:00,680

also gonna get really crowded there any

1025

00:43:03,760 --> 00:43:02,480

worries about that mark any I mean we're

1026

00:43:06,160 --> 00:43:03,770

launching all this stuff and putting it

1027

00:43:09,940 --> 00:43:06,170

at I2 is there any any worries about

1028

00:43:12,250 --> 00:43:09,950

crowding you nodded I2 I mean that's an

1029

00:43:14,529 --> 00:43:12,260

extremely large volume of space I mean

1030

00:43:18,339 --> 00:43:14,539

as you know there's certainly growing

1031

00:43:20,710 --> 00:43:18,349

worries about the number of satellites

1032

00:43:23,920 --> 00:43:20,720

in low Earth orbit and the impact that

1033

00:43:25,720 --> 00:43:23,930

you know debris when when you launch and

1034

00:43:28,559 --> 00:43:25,730

when you operate these satellites might

1035

00:43:31,240 --> 00:43:28,569

have on the you you know standard

1036

00:43:33,760 --> 00:43:31,250

operational modes of low Earth orbit

1037

00:43:36,519 --> 00:43:33,770

ones but out Adel - it's just not an

1038

00:43:40,150 --> 00:43:36,529

issue because it's such a big volume so

1039

00:43:42,010 --> 00:43:40,160

yeah so I guess exoplanets are probably

1040

00:43:43,510 --> 00:43:42,020

one of the most exciting areas of

1041

00:43:46,059 --> 00:43:43,520

astronomy right now it's certainly one

1042

00:43:48,220 --> 00:43:46,069

of the biggest growing and we've got a

1043

00:43:50,529 --> 00:43:48,230

lot not only in the building stages

1044

00:43:52,150 --> 00:43:50,539

coming up and how we plan to observe

1045

00:43:53,589 --> 00:43:52,160

exoplanets directly and we've given you

1046

00:43:55,390 --> 00:43:53,599

a brief overview about some of those

1047

00:43:57,339 --> 00:43:55,400

different ways and plans of the future

1048

00:43:59,109 --> 00:43:57,349

but I want to get to a couple of

1049

00:44:01,329 --> 00:43:59,119

comments here first of all Craig Landon

1050

00:44:06,940 --> 00:44:01,339

on YouTube is saying why doesn't anyone

1051
00:44:08,799 --> 00:44:06,950
mention Tess I think we did yeah there

1052
00:44:11,380 --> 00:44:08,809
you go Craig so we talked about Tess

1053
00:44:14,519 --> 00:44:11,390
it's coming up 2017 like Mark said it's

1054
00:44:17,230 --> 00:44:14,529
going to be a really great really great

1055
00:44:21,870 --> 00:44:17,240
piece of the exoplanet research puzzle

1056
00:44:26,289 --> 00:44:21,880
and here's one from let me see here I

1057
00:44:30,130 --> 00:44:26,299
went oops I just lost it there it is me

1058
00:44:33,009 --> 00:44:30,140
hello me hello Jeannot Jeannot Vic from

1059
00:44:35,409 --> 00:44:33,019
YouTube what do we need to do

1060
00:44:38,620 --> 00:44:35,419
to get images of exoplanets similar to

1061
00:44:40,899 --> 00:44:38,630
those of series or Pluto by Hubble do we

1062
00:44:43,509 --> 00:44:40,909
need to get 50 meter space-based mirror

1063
00:44:45,759 --> 00:44:43,519

or do we need much better camera

1064

00:44:50,679 --> 00:44:45,769

technology or even both so eight

1065

00:44:52,889 --> 00:44:50,689

unicorns space unicorns so what we do is

1066

00:44:57,389 --> 00:44:52,899

so what do we need to be able to see

1067

00:44:59,979 --> 00:44:57,399

smaller exoplanets like Pluto and Ceres

1068

00:45:02,769 --> 00:44:59,989

in order to do that you just need an

1069

00:45:04,269 --> 00:45:02,779

extremely large aperture because that's

1070

00:45:06,849 --> 00:45:04,279

the only way you can actually resolve

1071

00:45:09,130 --> 00:45:06,859

them I mean the better cameras might go

1072

00:45:11,259 --> 00:45:09,140

to better contrast but you'll never have

1073

00:45:15,069 --> 00:45:11,269

enough spatial resolution to really be

1074

00:45:18,089 --> 00:45:15,079

able to get the kind of resolution that

1075

00:45:20,259 --> 00:45:18,099

this question is asking for right so a

1076
00:45:21,699 --> 00:45:20,269
resolution with whether you can resolve

1077
00:45:23,319 --> 00:45:21,709
something as a function of two things

1078
00:45:27,279 --> 00:45:23,329
the wavelength you're looking at and the

1079
00:45:29,589 --> 00:45:27,289
diameter of the collecting surface and

1080
00:45:31,149 --> 00:45:29,599
so once you have depending on what

1081
00:45:32,709 --> 00:45:31,159
wavelength you're trying to look at it

1082
00:45:36,009 --> 00:45:32,719
at you can actually hope to resolve it

1083
00:45:37,899 --> 00:45:36,019
but these things are so small that to

1084
00:45:39,549 --> 00:45:37,909
look at them and other systems would

1085
00:45:41,409 --> 00:45:39,559
need an enormous telescope one that I

1086
00:45:44,949 --> 00:45:41,419
think is not even in the planning stages

1087
00:45:46,149 --> 00:45:44,959
right now so there's one here's a

1088
00:45:49,359 --> 00:45:46,159

comment here that I want to just bring

1089

00:45:52,749 --> 00:45:49,369

up on the Q&A app that has to do with

1090

00:45:55,959 --> 00:45:52,759

the extremely large telescope this is

1091

00:45:58,959 --> 00:45:55,969

from Mike Mike Oh Mike Oh Sarah I think

1092

00:46:01,899 --> 00:45:58,969

is how you pronounce it with the new

1093

00:46:04,599 --> 00:46:01,909

forty millimeter European extremely

1094

00:46:07,749 --> 00:46:04,609

large telescope which is a tremendously

1095

00:46:10,359 --> 00:46:07,759

imaginative name he says will it be able

1096

00:46:12,129 --> 00:46:10,369

to directly observe extrasolar planets

1097

00:46:15,370 --> 00:46:12,139

or EDD is Space Telescope with a star

1098

00:46:17,349 --> 00:46:15,380

shade so the extremely large extremely

1099

00:46:21,339 --> 00:46:17,359

large scale let's go as opposed to the

1100

00:46:23,919 --> 00:46:21,349

ESO has a very large telescope will it

1101

00:46:25,929 --> 00:46:23,929

be able to see anything so that they

1102

00:46:28,089 --> 00:46:25,939

will be able to do direct imaging of

1103

00:46:30,219 --> 00:46:28,099

guest's gas giant planets very easily I

1104

00:46:31,899 --> 00:46:30,229

think with that kind of aperture and

1105

00:46:33,789 --> 00:46:31,909

they'll be using additional techniques

1106

00:46:36,099 --> 00:46:33,799

that we didn't really mention today such

1107

00:46:39,759 --> 00:46:36,109

as adaptive optics which allow you to

1108

00:46:41,559 --> 00:46:39,769

correct for some of the aberrations that

1109

00:46:43,539 --> 00:46:41,569

you get in your optics from the

1110

00:46:46,269 --> 00:46:43,549

atmosphere so yes they'll be able to do

1111

00:46:46,930 --> 00:46:46,279

something I'm not sure they will be able

1112

00:46:50,620 --> 00:46:46,940

to dare

1113

00:46:55,089 --> 00:46:50,630

imager sighs planets may be super us in

1114

00:46:57,910 --> 00:46:55,099

special cases right and so here's

1115

00:46:59,500 --> 00:46:57,920

something from Adam synergy also on the

1116

00:47:01,809 --> 00:46:59,510

Q&A app he's asking what is the

1117

00:47:04,000 --> 00:47:01,819

scientific value of direct imaging of

1118

00:47:05,819 --> 00:47:04,010

exoplanets beyond producing a pretty

1119

00:47:10,900 --> 00:47:05,829

picture

1120

00:47:12,700 --> 00:47:10,910

so by getting direct images you can do a

1121

00:47:15,700 --> 00:47:12,710

number of things you can get the orbit

1122

00:47:17,410 --> 00:47:15,710

which is always very useful and there

1123

00:47:20,890 --> 00:47:17,420

are other things that we also didn't

1124

00:47:23,349 --> 00:47:20,900

really get into such as doing time

1125

00:47:25,920 --> 00:47:23,359

monitoring you can time monitor these

1126

00:47:28,270 --> 00:47:25,930

images and maybe see evidence of

1127

00:47:30,460 --> 00:47:28,280

continents or different structures on

1128

00:47:34,750 --> 00:47:30,470

the surface of the planet in this kind

1129

00:47:36,849 --> 00:47:34,760

of world our Becca you're telling me

1130

00:47:39,970 --> 00:47:36,859

that we'll be able to see we might be

1131

00:47:42,040 --> 00:47:39,980

able to see comments well you can't see

1132

00:47:44,250 --> 00:47:42,050

them but you can see variations in the

1133

00:47:50,550 --> 00:47:44,260

amount of light coming from the planet

1134

00:47:56,920 --> 00:47:54,339

people who are trying to do in a very

1135

00:47:59,650 --> 00:47:56,930

you know very coarse way try to

1136

00:48:02,589 --> 00:47:59,660

understand variations of the atmospheres

1137

00:48:04,510 --> 00:48:02,599

of Jupiter sized planets using Hubble

1138

00:48:06,370 --> 00:48:04,520

but if you have these larger telescopes

1139

00:48:09,819 --> 00:48:06,380

that are much more capable and the

1140

00:48:11,950 --> 00:48:09,829

infrared extended in Fred you might be

1141

00:48:13,240 --> 00:48:11,960

able to do that so yeah you're not going

1142

00:48:16,630 --> 00:48:13,250

to see the little continent swirling

1143

00:48:19,740 --> 00:48:16,640

around but changes but it's very similar

1144

00:48:22,839 --> 00:48:19,750

to the old Pluto observation same idea

1145

00:48:25,720 --> 00:48:22,849

okay so the idea the reflectivity of a

1146

00:48:27,819 --> 00:48:25,730

planet might change might be slightly

1147

00:48:30,309 --> 00:48:27,829

darker slightly brighter in some spots

1148

00:48:32,440 --> 00:48:30,319

depending on the topographic features it

1149

00:48:34,329 --> 00:48:32,450

has exactly and there was actually a

1150

00:48:36,690 --> 00:48:34,339

very nice demonstration of this by the

1151

00:48:38,950 --> 00:48:36,700

EPOXI mission which looked back at Earth

1152

00:48:42,190 --> 00:48:38,960

when they were on their way to their

1153

00:48:45,730 --> 00:48:42,200

last target and they actually do see

1154

00:48:47,710 --> 00:48:45,740

some of the some of those some of this

1155

00:48:50,200 --> 00:48:47,720

structure in the time monitoring that

1156

00:48:52,030 --> 00:48:50,210

they were able to do yeah who says we

1157

00:49:00,020 --> 00:48:52,040

don't have creative names or imaginative

1158

00:49:03,859 --> 00:49:00,030

name I'm thinking up those names right

1159

00:49:05,990 --> 00:49:03,869

yeah over beer I was just going to

1160

00:49:09,370 --> 00:49:06,000

mention we were talking about very large

1161

00:49:12,500 --> 00:49:09,380

telescopes as you've seen in the

1162

00:49:15,950 --> 00:49:12,510

animations Jay James Webb telescope does

1163

00:49:18,620 --> 00:49:15,960

not have a solid mirror and so when

1164

00:49:21,320 --> 00:49:18,630

you're talking about imagining and

1165

00:49:23,330 --> 00:49:21,330

having discussion over here about how

1166

00:49:26,900 --> 00:49:23,340

large those telescopes would have to be

1167

00:49:31,460 --> 00:49:26,910

to image you know and asked a very minor

1168

00:49:33,170 --> 00:49:31,470

planet those part of the idea that many

1169

00:49:35,359 --> 00:49:33,180

people think that if we ever do this

1170

00:49:37,910 --> 00:49:35,369

they'll have to be in segments there's

1171

00:49:39,950 --> 00:49:37,920

no way that a monolithic mirror is going

1172

00:49:41,960 --> 00:49:39,960

to be sent up there it's going to be in

1173

00:49:44,660 --> 00:49:41,970

pieces and James Webb is a pathfinder

1174

00:49:47,270 --> 00:49:44,670

for that because we have these great

1175

00:49:49,720 --> 00:49:47,280

segments that are going to be aligned

1176

00:49:52,490 --> 00:49:49,730

and work fantastic

1177

00:49:54,800 --> 00:49:52,500

okay so Carol I think I have one for you

1178

00:49:56,300 --> 00:49:54,810

here from Michel job and he goes when I

1179

00:49:58,609 --> 00:49:56,310

first read this question it was like I

1180

00:50:04,130 --> 00:49:58,619

was thinking of the Greek sandwich so

1181

00:50:05,810 --> 00:50:04,140

how are the gyros doing I guess on HST

1182

00:50:08,510 --> 00:50:05,820

how are the gyroscopes yeah they are

1183

00:50:11,150 --> 00:50:08,520

doing okay we had a problem with one

1184

00:50:15,230 --> 00:50:11,160

which is not working there's this

1185

00:50:18,980 --> 00:50:15,240

there's a second one which was monitor

1186

00:50:21,440 --> 00:50:18,990

we have like six and the second one did

1187

00:50:25,099 --> 00:50:21,450

not fail but I think they're resting it

1188

00:50:26,810 --> 00:50:25,109

and so an and in addition so we have

1189

00:50:28,700 --> 00:50:26,820

plenty of gyros left because we have

1190

00:50:32,120 --> 00:50:28,710

redundancy in the system and the other

1191

00:50:35,060 --> 00:50:32,130

thing is there have been studies done of

1192

00:50:36,650 --> 00:50:35,070

what if what if you only have three

1193

00:50:38,500 --> 00:50:36,660

waves you only have two that kind of

1194

00:50:41,060 --> 00:50:38,510

thing can we still do science but

1195

00:50:43,280 --> 00:50:41,070

because of the redundancy of the gyros

1196

00:50:45,470 --> 00:50:43,290

we're doing great it's just he's doing

1197

00:50:47,390 --> 00:50:45,480

just great yeah and I think that

1198

00:50:49,550 --> 00:50:47,400

probably would have done better science

1199

00:51:03,770 --> 00:50:49,560

if we had launched it with euros instead

1200

00:51:08,359 --> 00:51:03,780

but you know I so there was a question

1201
00:51:11,960 --> 00:51:08,369
of why does mark call James Webb

1202
00:51:19,210 --> 00:51:11,970
telescope JW and it's because he's very

1203
00:51:24,680 --> 00:51:21,860
this is a great picture of haha

1204
00:51:27,050 --> 00:51:24,690
but actually and it was pretty awesome

1205
00:51:28,670 --> 00:51:27,060
that well you can see a person standing

1206
00:51:31,250 --> 00:51:28,680
so that gives you the idea of the size

1207
00:51:33,740 --> 00:51:31,260
and this was during some testing when

1208
00:51:38,900 --> 00:51:33,750
Mark got to stand right there and be

1209
00:51:40,730 --> 00:51:38,910
imaged all over the place it just shows

1210
00:51:45,950 --> 00:51:40,740
that we really are involved in every

1211
00:52:01,010 --> 00:51:45,960
asset ok you can get rid of that image

1212
00:52:06,080 --> 00:52:01,020
now ok so let's see me good see if I can

1213
00:52:10,160 --> 00:52:06,090

find a couple more here ok so this was

1214

00:52:12,740 --> 00:52:10,170

from Michael let lit light Luther Houser

1215

00:52:15,620 --> 00:52:12,750

from the Q&A app are there any other

1216

00:52:17,570 --> 00:52:15,630

solar systems similar to us in the Milky

1217

00:52:22,550 --> 00:52:17,580

Way if so where are they now

1218

00:52:24,170 --> 00:52:22,560

I I think this would be the the context

1219

00:52:26,480 --> 00:52:24,180

of this is you know maybe what Kepler

1220

00:52:27,980 --> 00:52:26,490

has found something like that so what do

1221

00:52:30,740 --> 00:52:27,990

you say mark any other solar system

1222

00:52:33,590 --> 00:52:30,750

similar to ours if you're talking about

1223

00:52:36,320 --> 00:52:33,600

an exact copy I think not

1224

00:52:38,300 --> 00:52:36,330

Kepler's finding solar systems with lots

1225

00:52:40,850 --> 00:52:38,310

of planets there are several that have

1226
00:52:43,220 --> 00:52:40,860
almost as many as our solar system we're

1227
00:52:45,350 --> 00:52:43,230
starting to find earth-size planets in

1228
00:52:47,930 --> 00:52:45,360
the same region as Earth what we call

1229
00:52:49,280 --> 00:52:47,940
the habitable zone so as we refine more

1230
00:52:52,250 --> 00:52:49,290
and more of these systems they're

1231
00:52:54,920 --> 00:52:52,260
starting to look more and more like our

1232
00:52:57,410 --> 00:52:54,930
solar system in some ways and different

1233
00:53:00,050 --> 00:52:57,420
in others so as I said a lot of these

1234
00:53:02,600 --> 00:53:00,060
systems have a different distribution of

1235
00:53:04,130 --> 00:53:02,610
planet sizes to our own solar system so

1236
00:53:05,810 --> 00:53:04,140
I think what we're really seeing is that

1237
00:53:08,420 --> 00:53:05,820
there's a very large diversity of

1238
00:53:11,210 --> 00:53:08,430

different kinds of systems as we look

1239

00:53:13,160 --> 00:53:11,220

around with kappa ok here's a good one

1240

00:53:16,520 --> 00:53:13,170

also from the Q&A app from Iman our

1241

00:53:19,100 --> 00:53:16,530

Ayman Fantin who's going they do zit who

1242

00:53:21,100 --> 00:53:19,110

asks they declare planets of a specific

1243

00:53:24,350 --> 00:53:21,110

mass at a specific distance from a star

1244

00:53:27,130 --> 00:53:24,360

how can they be so sure they know the

1245

00:53:28,990 --> 00:53:27,140

planets is there by the star wobble

1246

00:53:32,170 --> 00:53:29,000

but they have no idea of the total mass

1247

00:53:33,960 --> 00:53:32,180

of all planets orbiting how can it be

1248

00:53:37,090 --> 00:53:33,970

so percent how can they be so precise

1249

00:53:38,830 --> 00:53:37,100

and so there's kind of an embedded thing

1250

00:53:40,510 --> 00:53:38,840

in there when you when you see a star

1251
00:53:42,550 --> 00:53:40,520
wobbling because of a planet in orbit

1252
00:53:44,650 --> 00:53:42,560
around it how can you be so sure it's

1253
00:53:45,820 --> 00:53:44,660
just that due to that one planet not a

1254
00:53:47,800 --> 00:53:45,830
whole bunch of others that we don't

1255
00:53:52,720 --> 00:53:47,810
necessarily see how can you be so

1256
00:53:54,190 --> 00:53:52,730
precise well the answer to take the last

1257
00:53:56,110 --> 00:53:54,200
part of that question the longer you

1258
00:53:58,480 --> 00:53:56,120
look the more likely you are to find

1259
00:54:02,350 --> 00:53:58,490
evidence of additional planets in these

1260
00:54:04,450 --> 00:54:02,360
systems so you know back in the late 90s

1261
00:54:07,150 --> 00:54:04,460
people were announcing individual

1262
00:54:09,580 --> 00:54:07,160
planets as time has gone by these radial

1263
00:54:11,980 --> 00:54:09,590

velocity surveys have started to add

1264

00:54:14,320 --> 00:54:11,990

additional planets to those systems in

1265

00:54:16,120 --> 00:54:14,330

in answer to the question about

1266

00:54:18,610 --> 00:54:16,130

precision well that comes from adding

1267

00:54:20,200 --> 00:54:18,620

the transits in as well as I said once

1268

00:54:21,280 --> 00:54:20,210

you've got the transits for these

1269

00:54:23,200 --> 00:54:21,290

systems and the radio velocity

1270

00:54:25,420 --> 00:54:23,210

measurements you've got the masts you've

1271

00:54:27,670 --> 00:54:25,430

got the orbit you can be extremely

1272

00:54:30,970 --> 00:54:27,680

precise about what you're seeing because

1273

00:54:34,480 --> 00:54:30,980

you've got data that prove the numbers

1274

00:54:37,780 --> 00:54:34,490

yeah so in the specific distance does

1275

00:54:39,730 --> 00:54:37,790

that come from this the speed with which

1276

00:54:42,310 --> 00:54:39,740

the the planet goes across the service

1277

00:54:44,530 --> 00:54:42,320

are transits or is that how you get that

1278

00:54:46,780 --> 00:54:44,540

information yeah I mean it can come from

1279

00:54:49,330 --> 00:54:46,790

the transits if you have a transit every

1280

00:54:51,370 --> 00:54:49,340

four days then you can figure out what

1281

00:54:55,150 --> 00:54:51,380

the orbit is especially once you know

1282

00:55:01,960 --> 00:54:55,160

the size of the planet as well okay tell

1283

00:55:05,410 --> 00:55:01,970

my friends it's just physics it's only

1284

00:55:09,790 --> 00:55:05,420

physics it also asks a guy Michael asks

1285

00:55:12,760 --> 00:55:09,800

where's Hubble data the archive you want

1286

00:55:14,710 --> 00:55:12,770

to answer that Carol sure so there's

1287

00:55:17,140 --> 00:55:14,720

lots of imagery that's available through

1288

00:55:20,950 --> 00:55:17,150

Hubble site org so if you go to Hubble

1289

00:55:23,230 --> 00:55:20,960

site s ite Hubble's s ite or there's

1290

00:55:25,690 --> 00:55:23,240

lots of images and explanations of the

1291

00:55:31,270 --> 00:55:25,700

images and the press releases and then

1292

00:55:33,120 --> 00:55:31,280

the actual science data from Hubble we

1293

00:55:36,550 --> 00:55:33,130

will also have the James Webb telescope

1294

00:55:39,820 --> 00:55:36,560

data when it comes down we have some we

1295

00:55:40,990 --> 00:55:39,830

have the Kepler data we we will have the

1296

00:55:45,010 --> 00:55:41,000

test data

1297

00:55:49,080 --> 00:55:45,020

we have ten other satellite which have

1298

00:55:52,800 --> 00:55:49,090

data in our archive and it's archived at

1299

00:55:55,360 --> 00:55:52,810

stsci that's our institution Space

1300

00:55:59,800 --> 00:55:55,370

Telescope Science Institute

1301
00:56:01,750 --> 00:55:59,810
edu archive stsci edu but you can say

1302
00:56:03,610 --> 00:56:01,760
Space Telescope archive on Google and

1303
00:56:07,630 --> 00:56:03,620
you can find it and there is an

1304
00:56:10,030 --> 00:56:07,640
interface into that data you can get

1305
00:56:11,650 --> 00:56:10,040
gifts of some of the data now it's

1306
00:56:15,610 --> 00:56:11,660
science data and it needs to be

1307
00:56:17,770 --> 00:56:15,620
processed carefully so that all the

1308
00:56:19,960 --> 00:56:17,780
instrument signature is taken care of

1309
00:56:21,970 --> 00:56:19,970
the cosmic rays are removed but that

1310
00:56:24,430 --> 00:56:21,980
data is all there and it's made public

1311
00:56:26,560 --> 00:56:24,440
in a timely fashion after the

1312
00:56:28,330 --> 00:56:26,570
observations have been taken yeah we

1313
00:56:30,520 --> 00:56:28,340

have done a hangouts in the past on how

1314

00:56:32,800 --> 00:56:30,530

together and done some done some

1315

00:56:34,420 --> 00:56:32,810

preliminary processing on it result

1316

00:56:35,770 --> 00:56:34,430

LaVey we are Scott and I were talking

1317

00:56:38,200 --> 00:56:35,780

today about maybe doing another one

1318

00:56:40,510 --> 00:56:38,210

there's another one right so look for

1319

00:56:43,120 --> 00:56:40,520

more Hangouts on how to get Hubble data

1320

00:56:46,720 --> 00:56:43,130

in the future and I think you did one on

1321

00:56:48,940 --> 00:56:46,730

the Hubble legacy archive as well there

1322

00:56:51,640 --> 00:56:48,950

are two hangouts already in the archive

1323

00:56:53,470 --> 00:56:51,650

where we've we have and a hangout

1324

00:56:56,320 --> 00:56:53,480

archive where we have discussed how you

1325

00:56:58,570 --> 00:56:56,330

get the data right so Scott am I missing

1326
00:57:01,300 --> 00:56:58,580
anything I'm looking you can't wait you

1327
00:57:03,610 --> 00:57:01,310
just like it's like Skye Lewis is owning

1328
00:57:05,580 --> 00:57:03,620
Hubble hangout hash tag here Twitter

1329
00:57:09,460 --> 00:57:05,590
sorry everybody

1330
00:57:13,080 --> 00:57:09,470
it's because you can't tweet as Hubble

1331
00:57:15,880 --> 00:57:13,090
while you're hosting the show sorry

1332
00:57:17,530 --> 00:57:15,890
yeah let's work out some technical I

1333
00:57:20,680 --> 00:57:17,540
can't do too many things at once or

1334
00:57:24,300 --> 00:57:20,690
outside my head explodes but babe I miss

1335
00:57:27,690 --> 00:57:24,310
anything but yeah I do have some here so

1336
00:57:33,220 --> 00:57:27,700
exoplanets in general so a one from

1337
00:57:36,730 --> 00:57:33,230
Eliseo mangonia it was in relation to

1338
00:57:38,830 --> 00:57:36,740

the radio velocity image I put up there

1339

00:57:41,230 --> 00:57:38,840

and they could the stars orbit really be

1340

00:57:43,270 --> 00:57:41,240

affected by the exoplanets gravity I

1341

00:57:45,310 --> 00:57:43,280

mean if the inspectors finger prick

1342

00:57:47,440 --> 00:57:45,320

changes in time wouldn't it be too

1343

00:57:50,920 --> 00:57:47,450

subtle for ladies to the exoplanets full

1344

00:57:53,680 --> 00:57:50,930

on the star so I mean first of all with

1345

00:57:54,520 --> 00:57:53,690

that we know that they have they both

1346

00:57:56,680 --> 00:57:54,530

have mass

1347

00:57:59,710 --> 00:57:56,690

and so there will be a center of mass

1348

00:58:01,210 --> 00:57:59,720

between them it's not as if one takes

1349

00:58:02,830 --> 00:58:01,220

all the mass and the other ones massless

1350

00:58:04,420 --> 00:58:02,840

so they have to have a center of mass

1351

00:58:05,859 --> 00:58:04,430

between them and that's the biggest

1352

00:58:09,550 --> 00:58:05,869

point of a while were able to see them

1353

00:58:11,680 --> 00:58:09,560

shift and so if if you did have if you

1354

00:58:14,170 --> 00:58:11,690

could detect the spectrum both spectra

1355

00:58:15,490 --> 00:58:14,180

on top of each other one of the star and

1356

00:58:18,609 --> 00:58:15,500

the other of the planet if it was bright

1357

00:58:21,010 --> 00:58:18,619

enough then you could see the shift in

1358

00:58:23,410 --> 00:58:21,020

both objects and in fact we do in binary

1359

00:58:26,290 --> 00:58:23,420

stars that are similar in brightness yes

1360

00:58:29,410 --> 00:58:26,300

you would see the shifting because the

1361

00:58:32,589 --> 00:58:29,420

the object's orbit each other and so

1362

00:58:36,310 --> 00:58:32,599

that spectroscopic shift would manifest

1363

00:58:40,080 --> 00:58:36,320

itself in the planet and the star too

1364

00:58:42,190 --> 00:58:40,090

but we just keep the planets too faint

1365

00:58:43,750 --> 00:58:42,200

petaflop sighs want to make mention his

1366

00:58:45,490 --> 00:58:43,760

comment he goes I want an earth-sized

1367

00:58:53,020 --> 00:58:45,500

mirror in orbit yeah wouldn't that be

1368

00:59:01,290 --> 00:58:53,030

cool after we get our Dyson Sphere set

1369

00:59:03,490 --> 00:59:01,300

up 2019 after okay I have another one -

1370

00:59:05,320 --> 00:59:03,500

and it's more about exoplanets in

1371

00:59:08,849 --> 00:59:05,330

general so I'm this was from Eamon

1372

00:59:11,109 --> 00:59:08,859

Fenton on on Google+ and a webpage and

1373

00:59:13,300 --> 00:59:11,119

you know we're told that we found

1374

00:59:15,550 --> 00:59:13,310

exoplanets of a certain mass and at

1375

00:59:18,460 --> 00:59:15,560

certain distance from their parent star

1376

00:59:20,470 --> 00:59:18,470

but how can we be so sure what what

1377

00:59:25,750 --> 00:59:20,480

gives us that information we know their

1378

00:59:28,690 --> 00:59:25,760

distance again it comes down to for

1379

00:59:30,579 --> 00:59:28,700

instance the transit date - you see you

1380

00:59:34,300 --> 00:59:30,589

see the dip in the light coming from the

1381

00:59:37,420 --> 00:59:34,310

star as on a very regular basis and you

1382

00:59:39,940 --> 00:59:37,430

can calculate the size of the body

1383

00:59:42,099 --> 00:59:39,950

that's causing that dip so it's just

1384

00:59:44,410 --> 00:59:42,109

physics as Carol said very simple

1385

00:59:47,200 --> 00:59:44,420

physics to you directly so we're just

1386

00:59:49,050 --> 00:59:47,210

studying the orbits are able to know the

1387

00:59:53,200 --> 00:59:49,060

mass and everything like that so yeah

1388

00:59:55,120 --> 00:59:53,210

right okay well mark this has been

1389

00:59:57,310 --> 00:59:55,130

awesome thank you so much for joining us

1390

00:59:59,560 --> 00:59:57,320

fantastic you're gonna come back right

1391

01:00:02,109 --> 00:59:59,570

talk about JWST in the deployment of the

1392

01:00:04,599 --> 01:00:02,119

sunscreen sunscreen or those yeah this

1393

01:00:07,720 --> 01:00:04,609

green I'd be happy to do that and I've

1394

01:00:10,770 --> 01:00:07,730

also just by way of advertising

1395

01:00:15,220 --> 01:00:10,780

tell people that if they go to the JWST

1396

01:00:16,960 --> 01:00:15,230

tsfc nasa.gov website over the next two

1397

01:00:20,470 --> 01:00:16,970

months they'll be able to watch mirrors

1398

01:00:24,250 --> 01:00:20,480

being mounted into the back plane of the

1399

01:00:26,890 --> 01:00:24,260

telescope that's right there's a lot

1400

01:00:31,300 --> 01:00:26,900

I'll be sharing up those links later

1401
01:00:33,609 --> 01:00:31,310
through plus it's really cool see the

1402
01:00:35,730 --> 01:00:33,619
whole thing going on and that is pretty

1403
01:00:39,370 --> 01:00:35,740
much live isn't it or is there delay

1404
01:00:42,340 --> 01:00:39,380
sorry those are pretty much live images

1405
01:00:46,210 --> 01:00:42,350
right or is there a delay no no they are

1406
01:00:48,700 --> 01:00:46,220
live images okay Ron yeah they take an

1407
01:00:51,130 --> 01:00:48,710
image every few seconds that's amazing

1408
01:00:52,540 --> 01:00:51,140
okay so keep an eye out for that hangout

1409
01:00:54,580 --> 01:00:52,550
and you may be asking how do I know

1410
01:00:57,910 --> 01:00:54,590
where these hangouts are it's all in

1411
01:01:00,340 --> 01:00:57,920
Hubble site that org slash Explorer are

1412
01:01:02,170 --> 01:01:00,350
get involved slash Hubble hangouts

1413
01:01:04,300 --> 01:01:02,180

that's where I'm putting all of the the

1414

01:01:08,160 --> 01:01:04,310

schedule you can also follow us on

1415

01:01:11,230 --> 01:01:08,170

twitter at hubble telescope you can also

1416

01:01:13,810 --> 01:01:11,240

add us on circles on the Google G+ page

1417

01:01:15,099 --> 01:01:13,820

we also post on our Facebook page as

1418

01:01:17,560 --> 01:01:15,109

well and that's where all of the

1419

01:01:19,300 --> 01:01:17,570

hangouts will be announced next week

1420

01:01:22,180 --> 01:01:19,310

Carol Scott and I will be talking with

1421

01:01:23,620 --> 01:01:22,190

niku Mott who I was his name is longer

1422

01:01:25,960 --> 01:01:23,630

than that but I was told to just go

1423

01:01:28,690 --> 01:01:25,970

ahead and cut it short who has been

1424

01:01:31,480 --> 01:01:28,700

using Hubble to to look at some

1425

01:01:33,280 --> 01:01:31,490

exoplanets jupiter-sized exoplanets he's

1426

01:01:35,170 --> 01:01:33,290

found they were looking at three of them

1427

01:01:38,620 --> 01:01:35,180

and they were looking at the water vapor

1428

01:01:40,900 --> 01:01:38,630

on those exoplanets and found them to be

1429

01:01:43,480 --> 01:01:40,910

surprisingly dry so that was a press

1430

01:01:45,940 --> 01:01:43,490

release that came out last week and we

1431

01:01:47,080 --> 01:01:45,950

will be talking with the with principal

1432

01:01:50,080 --> 01:01:47,090

investigators who made that observation

1433

01:01:52,210 --> 01:01:50,090

so more on exoplanets next week that's

1434

01:01:55,890 --> 01:01:52,220

Thursday at 3 o'clock eastern time 7

1435

01:02:04,330 --> 01:01:55,900

o'clock Universal Time so I'm ending

1436

01:02:05,890 --> 01:02:04,340

Pacific per for me in LA about me so

1437

01:02:09,400 --> 01:02:05,900

Carol thank you it's been a lot of fun

1438

01:02:11,349 --> 01:02:09,410

as always and Scott thank you excellent

1439

01:02:14,349 --> 01:02:11,359

driving we didn't crash once so good job

1440

01:02:15,849 --> 01:02:14,359

once alright alright folks so thank you

1441

01:02:20,050 --> 01:02:15,859

all for watching and thanks very much

1442

01:02:21,250 --> 01:02:20,060

mark yeah you're awesome thanks

1443

01:02:22,960 --> 01:02:21,260

alright thanks