

PUBLIC LECTURE SERIES

**Exploring Rocky Worlds:
On the Precipice of a New Frontier**

**Featuring Guest Speaker:
Katherine Bennett**

1
00:00:08,450 --> 00:00:04,910
welcome to the Space Telescope public

2
00:00:11,690 --> 00:00:08,460
lecture series tonight's talk exploring

3
00:00:13,129 --> 00:00:11,700
Rocky worlds on the precipice of a new

4
00:00:16,369 --> 00:00:13,139
frontier

5
00:00:19,490 --> 00:00:16,379
hold on a second ah

6
00:00:21,710 --> 00:00:19,500
there we go sorry I had a computer uh

7
00:00:24,050 --> 00:00:21,720
malfunctioned to my left here all right

8
00:00:26,990 --> 00:00:24,060
I am

9
00:00:28,429 --> 00:00:27,000
Dr Frank Summers your host uh an

10
00:00:30,830 --> 00:00:28,439
astronomer in the office of public

11
00:00:33,830 --> 00:00:30,840
Outreach here at the Space Telescope

12
00:00:36,470 --> 00:00:33,840
Science Institute I want to thank our

13
00:00:40,610 --> 00:00:36,480

amazing Tech Team Thomas murufu and

14

00:00:42,889 --> 00:00:40,620

Grant Justice for not only creating this

15

00:00:44,450 --> 00:00:42,899

uh the webcast but also streaming it

16

00:00:47,209 --> 00:00:44,460

live to YouTube

17

00:00:51,410 --> 00:00:47,219

as a reminder we will continue to be

18

00:00:56,029 --> 00:00:51,420

online only throughout 2023.

19

00:00:59,569 --> 00:00:56,039

our upcoming talks on May 2nd Galaxy

20

00:01:02,930 --> 00:00:59,579

clusters slash Frontier Fields Amanda

21

00:01:05,870 --> 00:01:02,940

hasn't given me an exact Topic at the

22

00:01:07,969 --> 00:01:05,880

title yet but our topic are these huge

23

00:01:10,910 --> 00:01:07,979

clusters of galaxies that cause

24

00:01:13,550 --> 00:01:10,920

gravitational lensing okay uh the

25

00:01:16,190 --> 00:01:13,560

largest uh bound structures in the

26
00:01:19,910 --> 00:01:16,200
universe and she will discuss those in

27
00:01:23,510 --> 00:01:19,920
May in June we have a very special

28
00:01:25,910 --> 00:01:23,520
presentation uh we will have a science

29
00:01:28,850 --> 00:01:25,920
conference for the Roman Space Telescope

30
00:01:31,730 --> 00:01:28,860
in June and they have brought in some

31
00:01:33,950 --> 00:01:31,740
special speakers for that conference and

32
00:01:37,190 --> 00:01:33,960
they will have speakers speaking on the

33
00:01:39,289 --> 00:01:37,200
Nancy Grace Roman Space Telescope but

34
00:01:42,469 --> 00:01:39,299
they haven't given me the full list of

35
00:01:45,050 --> 00:01:42,479
speakers yet one of them uh will be I

36
00:01:48,710 --> 00:01:45,060
believe Joan Gordon who will talk on the

37
00:01:51,350 --> 00:01:48,720
history of Nancy Grace Roman herself and

38
00:01:54,109 --> 00:01:51,360

the other speaker who is as yet undeter

39

00:01:56,389 --> 00:01:54,119

and we'll be speaking on the science

40

00:01:58,609 --> 00:01:56,399

that will be done with the Roman Space

41

00:02:02,090 --> 00:01:58,619

Telescope so I'll have more information

42

00:02:04,249 --> 00:02:02,100

for you next month as that gets firmed

43

00:02:05,990 --> 00:02:04,259

up but since it's going to be held

44

00:02:07,730 --> 00:02:06,000

during the conference it is not going to

45

00:02:10,249 --> 00:02:07,740

be on the first Tuesday like our usual

46

00:02:13,910 --> 00:02:10,259

talks are it's going to be I guess this

47

00:02:17,630 --> 00:02:13,920

is the third or fourth Thursday on June

48

00:02:19,130 --> 00:02:17,640

22nd and it'll be held at 4 30 P.M to

49

00:02:22,430 --> 00:02:19,140

coincide with their conference so their

50

00:02:23,570 --> 00:02:22,440

conference attendees can actually be

51

00:02:26,869 --> 00:02:23,580

part of it

52

00:02:30,410 --> 00:02:26,879

and then in July we have our Infamous

53

00:02:32,690 --> 00:02:30,420

TBD for title and TBD for speaker which

54

00:02:35,809 --> 00:02:32,700

means I haven't corralled somebody for

55

00:02:38,449 --> 00:02:35,819

the July Talk and actually I might be

56

00:02:41,690 --> 00:02:38,459

giving that talk myself uh speaking on

57

00:02:44,509 --> 00:02:41,700

one of our visualization projects stay

58

00:02:48,790 --> 00:02:44,519

tuned how you do you stay tuned you ask

59

00:02:54,589 --> 00:02:52,250

www.stsci.edu public hyphen lectures

60

00:02:57,170 --> 00:02:54,599

that's where you'll find this web page

61

00:03:00,410 --> 00:02:57,180

uh in the lower left you'll find a link

62

00:03:02,410 --> 00:03:00,420

to our webcasts uh both

63

00:03:05,930 --> 00:03:02,420

um our stsc l

64

00:03:08,089 --> 00:03:05,940

webcasting as well as the playlist on

65

00:03:09,949 --> 00:03:08,099

YouTube and if you want to get our

66

00:03:12,229 --> 00:03:09,959

announcements in the lower right you can

67

00:03:13,850 --> 00:03:12,239

enter your email address and hit that

68

00:03:16,369 --> 00:03:13,860

subscribe button

69

00:03:19,430 --> 00:03:16,379

also on that web page we have a list of

70

00:03:22,369 --> 00:03:19,440

our upcoming lectures and once a lecture

71

00:03:24,050 --> 00:03:22,379

has happened you will get the

72

00:03:26,330 --> 00:03:24,060

information about it the title the

73

00:03:28,490 --> 00:03:26,340

description the link to the stsci

74

00:03:30,410 --> 00:03:28,500

webcast and the link to the YouTube

75

00:03:33,410 --> 00:03:30,420

webcast

76

00:03:34,670 --> 00:03:33,420

as I said we have an email list of the

77

00:03:37,309 --> 00:03:34,680

now for the announcements that you can

78

00:03:39,890 --> 00:03:37,319

sign up on our website another way to

79

00:03:42,890 --> 00:03:39,900

get notifications is to subscribe to our

80

00:03:46,190 --> 00:03:42,900

YouTube channel [youtube.com Hubble Space](https://www.youtube.com/HubbleSpace)

81

00:03:48,289 --> 00:03:46,200

Telescope all one word you'll get the

82

00:03:51,470 --> 00:03:48,299

notices of new videos as well as

83

00:03:53,750 --> 00:03:51,480

reminders of Live Events such as this

84

00:03:56,270 --> 00:03:53,760

and if you have comments or questions

85

00:03:57,830 --> 00:03:56,280

you want to send me an email and tell me

86

00:03:59,990 --> 00:03:57,840

what we did right what we did wrong what

87

00:04:02,330 --> 00:04:00,000

you'd like to see send it to public

88

00:04:04,729 --> 00:04:02,340

lecture at stsci.edu

89

00:04:06,949 --> 00:04:04,739

[Music]

90

00:04:09,949 --> 00:04:06,959

I also would like to mention that we

91

00:04:11,570 --> 00:04:09,959

have social media for the we do social

92

00:04:13,490 --> 00:04:11,580

media for the Hubble Space Telescope for

93

00:04:15,949 --> 00:04:13,500

the web Space Telescope and for the

94

00:04:18,409 --> 00:04:15,959

Space Telescope Science Institute and

95

00:04:21,409 --> 00:04:18,419

here are the handles on Facebook Twitter

96

00:04:24,530 --> 00:04:21,419

Youtube and Instagram

97

00:04:26,810 --> 00:04:24,540

um your host me is not a social media

98

00:04:28,430 --> 00:04:26,820

Maven I only do a tiny bit mostly

99

00:04:31,969 --> 00:04:28,440

actually about the public lecture series

100

00:04:33,950 --> 00:04:31,979

uh but if you want those notices you can

101
00:04:36,950 --> 00:04:33,960
follow me on Facebook as Dr Frank

102
00:04:39,830 --> 00:04:36,960
Summers or on Twitter at Dr Frank

103
00:04:45,110 --> 00:04:42,710
the news from the universe for April

104
00:04:47,629 --> 00:04:45,120
2023

105
00:04:50,930 --> 00:04:47,639
our first story tonight

106
00:04:53,330 --> 00:04:50,940
stormy times on Jupiter

107
00:04:55,870 --> 00:04:53,340
we are going to be talking about the

108
00:04:58,909 --> 00:04:55,880
opal program the outer planets

109
00:05:01,490 --> 00:04:58,919
atmosphere's Legacy program and this is

110
00:05:04,670 --> 00:05:01,500
a multi-year program that has been

111
00:05:06,590 --> 00:05:04,680
running on Hubble it's Amy Simon and

112
00:05:09,710 --> 00:05:06,600
collaborators and you can see that the

113
00:05:13,070 --> 00:05:09,720

original paper was out in 2015 and so

114

00:05:15,530 --> 00:05:13,080

each year they get was as Earth swings

115

00:05:18,530 --> 00:05:15,540

by the outer planets a Jupiter Saturn

116

00:05:22,070 --> 00:05:18,540

Uranus and Neptune they get Hubble's

117

00:05:24,409 --> 00:05:22,080

best images of those planets in order to

118

00:05:27,050 --> 00:05:24,419

study changes in the atmosphere

119

00:05:30,950 --> 00:05:27,060

and this time we're going to take a look

120

00:05:33,490 --> 00:05:30,960

at the recent images of Jupiter so here

121

00:05:36,830 --> 00:05:33,500

is an image of Jupiter from November uh

122

00:05:38,749 --> 00:05:36,840

2022 all right when Earth swung past uh

123

00:05:41,029 --> 00:05:38,759

swung past Jupiter in its order because

124

00:05:43,430 --> 00:05:41,039

Earth is moving faster than Jupiter is

125

00:05:45,950 --> 00:05:43,440

moving slow and Earth is moving fast and

126

00:05:48,950 --> 00:05:45,960

so as Earth comes by they're at their

127

00:05:50,450 --> 00:05:48,960

closest okay and one of the things you

128

00:05:53,689 --> 00:05:50,460

notice about is you notice that black

129

00:05:56,270 --> 00:05:53,699

spot why is there a spot well that's

130

00:06:00,409 --> 00:05:56,280

because there is a moon in this image as

131

00:06:02,029 --> 00:06:00,419

well that is the moon IO uh the

132

00:06:05,810 --> 00:06:02,039

innermost of the Galilean moons of

133

00:06:08,510 --> 00:06:05,820

Jupiter and that is its shadow cast on

134

00:06:10,070 --> 00:06:08,520

the atmosphere of Jupiter so that's that

135

00:06:12,050 --> 00:06:10,080

definitely a change in Rupert's

136

00:06:14,270 --> 00:06:12,060

atmosphere but it's periodic okay

137

00:06:16,249 --> 00:06:14,280

actually it's kind of you know

138

00:06:19,189 --> 00:06:16,259

kind of cool that if you lived on

139

00:06:21,469 --> 00:06:19,199

Jupiter you'd get a lot more solar

140

00:06:24,170 --> 00:06:21,479

eclipses because you know IO goes around

141

00:06:26,330 --> 00:06:24,180

and that shadow goes across the face of

142

00:06:28,670 --> 00:06:26,340

Jupiter mostly every time the dial goes

143

00:06:30,710 --> 00:06:28,680

past so you know they get a lot more

144

00:06:32,990 --> 00:06:30,720

total solar eclipses than we do here on

145

00:06:35,270 --> 00:06:33,000

Earth okay but that's not what we're

146

00:06:37,790 --> 00:06:35,280

looking about uh we're looking at the

147

00:06:41,150 --> 00:06:37,800

atmosphere and we compare how the

148

00:06:45,290 --> 00:06:41,160

atmosphere changes and we also got this

149

00:06:47,050 --> 00:06:45,300

image from January 2023 and you can see

150

00:06:50,570 --> 00:06:47,060

that Jupiter has changed by getting

151
00:06:53,450 --> 00:06:50,580
smaller huh somehow unlike the rest of

152
00:06:55,670 --> 00:06:53,460
us it lost weight over the holidays

153
00:06:59,029 --> 00:06:55,680
no that is a joke

154
00:07:00,469 --> 00:06:59,039
um this is actually just due uh to a

155
00:07:02,629 --> 00:07:00,479
change in perspective

156
00:07:05,150 --> 00:07:02,639
so here is what we call the compass

157
00:07:08,210 --> 00:07:05,160
image and you can see those scale bars

158
00:07:12,350 --> 00:07:08,220
uh down here uh and over here right

159
00:07:14,749 --> 00:07:12,360
those scale bars are the same all right

160
00:07:17,390 --> 00:07:14,759
um and the problem is is that

161
00:07:20,809 --> 00:07:17,400
um what happened was between November

162
00:07:24,770 --> 00:07:20,819
and January Earth got

163
00:07:26,809 --> 00:07:24,780

20 percent further away okay it got uh

164

00:07:30,290 --> 00:07:26,819

went from like around 400 million miles

165

00:07:33,170 --> 00:07:30,300

to 480 Million Miles Away From Jupiter

166

00:07:36,650 --> 00:07:33,180

therefore Jupiter got 20 percent smaller

167

00:07:38,390 --> 00:07:36,660

okay so uh that's why Jupiter appears

168

00:07:41,450 --> 00:07:38,400

smaller in the general image because we

169

00:07:44,749 --> 00:07:41,460

kept them to the same angular scale

170

00:07:46,670 --> 00:07:44,759

um so uh you'll also note in the January

171

00:07:49,730 --> 00:07:46,680

image there is another moon this is

172

00:07:51,529 --> 00:07:49,740

Ganymede okay but again that's not what

173

00:07:54,469 --> 00:07:51,539

we're talking about I'm just we

174

00:07:56,270 --> 00:07:54,479

sometimes often get pictures allayan

175

00:07:58,610 --> 00:07:56,280

moons and we take pictures of Jupiter

176

00:08:00,950 --> 00:07:58,620

it's kind of cool all right what we're

177

00:08:03,409 --> 00:08:00,960

really talking about is this stuff over

178

00:08:05,450 --> 00:08:03,419

here you see all those ovals in the

179

00:08:09,050 --> 00:08:05,460

November image okay and they're how

180

00:08:10,909 --> 00:08:09,060

they're all lined up those are storms on

181

00:08:13,610 --> 00:08:10,919

Jupiter and look at just how many of

182

00:08:16,129 --> 00:08:13,620

those ovals there are especially in that

183

00:08:19,430 --> 00:08:16,139

one linear feature all right and this

184

00:08:21,710 --> 00:08:19,440

reminds me of what happened back in 2006

185

00:08:24,529 --> 00:08:21,720

2008

186

00:08:27,110 --> 00:08:24,539

um when three storms at this latitude

187

00:08:30,830 --> 00:08:27,120

merge to combine and form what's called

188

00:08:32,810 --> 00:08:30,840

oval ba all right and oval B8 is a

189

00:08:37,130 --> 00:08:32,820

larger storm that merged from three

190

00:08:38,870 --> 00:08:37,140

smaller storms okay at the time oval B A

191

00:08:41,089 --> 00:08:38,880

was red

192

00:08:42,829 --> 00:08:41,099

um and uh it was compared to the Great

193

00:08:45,410 --> 00:08:42,839

Red Spot which you see in the January

194

00:08:47,329 --> 00:08:45,420

image and so we called it red spot

195

00:08:50,509 --> 00:08:47,339

Junior

196

00:08:52,610 --> 00:08:50,519

um and uh it has since then ceased to be

197

00:08:54,769 --> 00:08:52,620

read so we're now back to calling it

198

00:08:57,590 --> 00:08:54,779

oval ba because red spot Junior doesn't

199

00:08:59,570 --> 00:08:57,600

really make much sense okay and so you

200

00:09:02,449 --> 00:08:59,580

can see there's a ton of storms in the

201
00:09:04,250 --> 00:09:02,459
southern part of Jupiter but what's

202
00:09:06,769 --> 00:09:04,260
really cool

203
00:09:09,530 --> 00:09:06,779
um is these storms in the northern

204
00:09:11,030 --> 00:09:09,540
latitudes of of Jupiter and this is

205
00:09:14,269 --> 00:09:11,040
something that the scientists that work

206
00:09:16,610 --> 00:09:14,279
on it call a Vortex Street and it's

207
00:09:18,230 --> 00:09:16,620
really really kind of cool okay all

208
00:09:20,389 --> 00:09:18,240
right so I'm gonna put some arrows here

209
00:09:22,310 --> 00:09:20,399
and you can see that um they've got some

210
00:09:24,590 --> 00:09:22,320
three white storms actually there's

211
00:09:26,509 --> 00:09:24,600
probably four or more and then there

212
00:09:29,870 --> 00:09:26,519
each of them have a corresponding Red

213
00:09:32,090 --> 00:09:29,880

Storm with it okay and the red storms

214

00:09:33,710 --> 00:09:32,100

are rotating counterclockwise in this

215

00:09:35,750 --> 00:09:33,720

picture and the white storms are

216

00:09:39,470 --> 00:09:35,760

rotating clockwise and the two are sort

217

00:09:42,290 --> 00:09:39,480

of reinforcing each other as they spin

218

00:09:44,449 --> 00:09:42,300

and you create this interleaving section

219

00:09:46,130 --> 00:09:44,459

of you know clockwise anti-clockwise

220

00:09:48,650 --> 00:09:46,140

clockwise anti-clockwise clockwise

221

00:09:52,190 --> 00:09:48,660

anti-clockwise this what they call this

222

00:09:54,889 --> 00:09:52,200

Vortex Street of of Storms and one of

223

00:09:58,970 --> 00:09:54,899

the cool things about it is that in the

224

00:10:02,030 --> 00:09:58,980

1990s these didn't exist okay these only

225

00:10:03,530 --> 00:10:02,040

have developed over the last 10 years

226

00:10:05,870 --> 00:10:03,540

now you say wait wait wait a minute

227

00:10:07,910 --> 00:10:05,880

Frank a storm that developed over 10

228

00:10:10,910 --> 00:10:07,920

years I mean we have storms that take

229

00:10:14,509 --> 00:10:10,920

maybe a few weeks or maybe a month to to

230

00:10:16,850 --> 00:10:14,519

fall but years well considering that the

231

00:10:20,990 --> 00:10:16,860

Great Red Spot has been around for like

232

00:10:22,970 --> 00:10:21,000

almost 300 years yeah 10 years is is a

233

00:10:25,130 --> 00:10:22,980

reasonable amount of time uh on Jupiter

234

00:10:28,130 --> 00:10:25,140

so they got storms that last for years

235

00:10:30,889 --> 00:10:28,140

and hence the opal project by taking

236

00:10:32,630 --> 00:10:30,899

pictures every year gets to monitor

237

00:10:34,790 --> 00:10:32,640

these

238

00:10:38,889 --> 00:10:34,800

um and really study the development of

239

00:10:47,389 --> 00:10:43,190

our second story tonight is an outburst

240

00:10:50,449 --> 00:10:47,399

of a hot luminous and massive star

241

00:10:53,030 --> 00:10:50,459

okay so how do we tell what is a hot

242

00:10:55,250 --> 00:10:53,040

luminous and massive star well in

243

00:10:57,650 --> 00:10:55,260

astronomy we use something called the HR

244

00:11:01,310 --> 00:10:57,660

diagram okay which is simply just a plot

245

00:11:03,230 --> 00:11:01,320

okay so on the x-axis is temperature and

246

00:11:05,150 --> 00:11:03,240

just to because we're astronomers and we

247

00:11:07,310 --> 00:11:05,160

want to be a pain in the butt uh it

248

00:11:09,470 --> 00:11:07,320

increases from right to left instead of

249

00:11:11,569 --> 00:11:09,480

the usual left to right okay at the

250

00:11:13,970 --> 00:11:11,579

Historical accident you don't need to

251
00:11:16,430 --> 00:11:13,980
know why but yeah temperature increases

252
00:11:18,650 --> 00:11:16,440
uh in the opposite direction and then

253
00:11:21,470 --> 00:11:18,660
brightness on the y-axis that increases

254
00:11:23,630 --> 00:11:21,480
going up okay so this is just a plot

255
00:11:26,269 --> 00:11:23,640
right a plot of characteristics of stars

256
00:11:27,829 --> 00:11:26,279
and naively you would think that stars

257
00:11:29,509 --> 00:11:27,839
could exist anywhere on this plot they

258
00:11:31,970 --> 00:11:29,519
could be scattered all over the place

259
00:11:34,670 --> 00:11:31,980
but when you do the plot for the stars

260
00:11:38,210 --> 00:11:34,680
we observe you actually find that they

261
00:11:41,269 --> 00:11:38,220
only exist in certain regions and the

262
00:11:43,490 --> 00:11:41,279
main region called the main sequence is

263
00:11:44,810 --> 00:11:43,500

this diagonal line from top left to

264

00:11:47,690 --> 00:11:44,820

lower right

265

00:11:49,970 --> 00:11:47,700

and this sequence actually reflects the

266

00:11:51,829 --> 00:11:49,980

physics of the nuclear fusion the

267

00:11:53,150 --> 00:11:51,839

hydrogen nuclear fusion that's going on

268

00:11:55,430 --> 00:11:53,160

in its core

269

00:11:57,350 --> 00:11:55,440

then you have that giant sequence that

270

00:11:59,630 --> 00:11:57,360

Sprouts off up to the toward the upper

271

00:12:01,850 --> 00:11:59,640

right and that actually represents the

272

00:12:04,009 --> 00:12:01,860

physics of what's happening in helium

273

00:12:07,670 --> 00:12:04,019

Fusion as these stars move from the main

274

00:12:09,650 --> 00:12:07,680

sequence uh that they move from hydrogen

275

00:12:11,930 --> 00:12:09,660

Fusion to helium fusion and then their

276

00:12:14,449 --> 00:12:11,940

characteristics change okay

277

00:12:16,130 --> 00:12:14,459

so if you're looking for the hottest

278

00:12:17,630 --> 00:12:16,140

stars you're looking to the left of this

279

00:12:19,130 --> 00:12:17,640

diagram if you're looking for the

280

00:12:23,269 --> 00:12:19,140

brightest stars you're looking to the

281

00:12:25,690 --> 00:12:23,279

top so the really extreme stars are up

282

00:12:28,610 --> 00:12:25,700

here they're hot bright and they're also

283

00:12:30,829 --> 00:12:28,620

incidentally massive and these are

284

00:12:32,449 --> 00:12:30,839

really the extreme stars and they're

285

00:12:35,509 --> 00:12:32,459

interesting to study because they're

286

00:12:38,210 --> 00:12:35,519

rare but also because they have

287

00:12:40,490 --> 00:12:38,220

outbursts they're unstable they actually

288

00:12:41,930 --> 00:12:40,500

have these huge winds and can blow off

289

00:12:45,170 --> 00:12:41,940

their outer layers

290

00:12:49,190 --> 00:12:45,180

and when they do that they can be

291

00:12:51,350 --> 00:12:49,200

gorgeous as in this image captured by

292

00:12:55,509 --> 00:12:51,360

the web Space Telescope

293

00:13:03,889 --> 00:12:59,930

isn't this gorgeous okay so this is the

294

00:13:07,009 --> 00:13:03,899

star named wolf Ray a124 and actually

295

00:13:10,610 --> 00:13:07,019

wolf Ray is a class of stars and so this

296

00:13:13,670 --> 00:13:10,620

is in some catalog the 124th entry uh in

297

00:13:15,350 --> 00:13:13,680

these catalog of wolfry a stars and the

298

00:13:17,150 --> 00:13:15,360

Stars at the center where you see the

299

00:13:19,129 --> 00:13:17,160

big six-pointed

300

00:13:20,569 --> 00:13:19,139

um uh diffraction spikes actually it's

301
00:13:22,550 --> 00:13:20,579
eight pointed because there's a little

302
00:13:24,590 --> 00:13:22,560
extra ones in the center

303
00:13:27,290 --> 00:13:24,600
um and then all this material has

304
00:13:30,470 --> 00:13:27,300
actually been blown away by this huge

305
00:13:34,069 --> 00:13:30,480
Stellar Wind of this very hot bright

306
00:13:35,870 --> 00:13:34,079
massive star all right and so the web

307
00:13:37,069 --> 00:13:35,880
Space Telescope of course observes an

308
00:13:39,650 --> 00:13:37,079
infrared light

309
00:13:43,129 --> 00:13:39,660
and it has both near infrared and

310
00:13:46,250 --> 00:13:43,139
mid-infrared detectors so this image is

311
00:13:48,829 --> 00:13:46,260
actually composed of observations from

312
00:13:51,590 --> 00:13:48,839
10 different filters six filters in the

313
00:13:54,290 --> 00:13:51,600

near infrared by near Cam and four

314

00:13:56,389 --> 00:13:54,300

filters in the mid infrared from from

315

00:13:59,030 --> 00:13:56,399

the instrument that's called Miri all

316

00:14:01,610 --> 00:13:59,040

right so if we just look at the mid

317

00:14:06,110 --> 00:14:01,620

infrared you can see a interesting

318

00:14:09,410 --> 00:14:06,120

contrast that stars are mostly in the

319

00:14:12,230 --> 00:14:09,420

near infrared and the gas and dust is

320

00:14:13,970 --> 00:14:12,240

mostly in the mid-infrared so this kind

321

00:14:15,410 --> 00:14:13,980

of gives you a feel for what you see in

322

00:14:17,569 --> 00:14:15,420

the near infrared what you see in the

323

00:14:19,670 --> 00:14:17,579

mid infrared because you know honestly

324

00:14:21,590 --> 00:14:19,680

we don't have that kind of our eyes

325

00:14:24,410 --> 00:14:21,600

don't see that so we don't really have

326

00:14:27,290 --> 00:14:24,420

that feel in our everyday experience but

327

00:14:29,210 --> 00:14:27,300

you can start to see that by having both

328

00:14:31,490 --> 00:14:29,220

near infrared and mid infrared and

329

00:14:33,590 --> 00:14:31,500

honestly the the range of wavelengths

330

00:14:35,870 --> 00:14:33,600

here is a factor of 18 it's from like

331

00:14:38,329 --> 00:14:35,880

one micron all the way up to 18 microns

332

00:14:40,550 --> 00:14:38,339

so it's a very large large range of

333

00:14:42,230 --> 00:14:40,560

wavelengths that you're covering to see

334

00:14:43,250 --> 00:14:42,240

lots and lots of different physics going

335

00:14:45,829 --> 00:14:43,260

on here

336

00:14:48,069 --> 00:14:45,839

and we can contrast that with just

337

00:14:50,590 --> 00:14:48,079

looking at the visible light from Hubble

338

00:14:53,990 --> 00:14:50,600

compared to the infrared light from web

339

00:14:56,389 --> 00:14:54,000

and so as I've said many times one of

340

00:14:58,069 --> 00:14:56,399

the best things we get to do now is we

341

00:15:00,050 --> 00:14:58,079

get to look and see what did Hubble see

342

00:15:02,990 --> 00:15:00,060

when it looked when Hubble looked at

343

00:15:04,730 --> 00:15:03,000

this object and what does webc when it

344

00:15:06,650 --> 00:15:04,740

looks at its object and we can try to do

345

00:15:08,750 --> 00:15:06,660

a comparison and I can sort of like I

346

00:15:11,689 --> 00:15:08,760

can blink back and forth to the mid

347

00:15:14,150 --> 00:15:11,699

infrared and Hubble and you can see some

348

00:15:17,829 --> 00:15:14,160

of the changes that you see by looking

349

00:15:20,530 --> 00:15:17,839

in these two different band passes

350

00:15:23,509 --> 00:15:20,540

yeah kind of cool

351
00:15:25,250 --> 00:15:23,519
multi-wavelength astronomy okay and we

352
00:15:27,889 --> 00:15:25,260
are lucky here at the Space Telescope

353
00:15:29,870 --> 00:15:27,899
Science Institute be the home of both of

354
00:15:31,970 --> 00:15:29,880
these telescopes and be able to see

355
00:15:35,210 --> 00:15:31,980
these different perspectives on objects

356
00:15:42,170 --> 00:15:38,629
our speaker tonight

357
00:15:43,189 --> 00:15:42,180
um is Catherine Bennett and let me stop

358
00:15:48,230 --> 00:15:43,199
my

359
00:15:51,110 --> 00:15:48,240
that there we go

360
00:15:54,530 --> 00:15:51,120
all right welcome Katie

361
00:15:57,050 --> 00:15:54,540
um Katie is not a PhD doctor astronomer

362
00:16:00,470 --> 00:15:57,060
yet she's on her way to becoming it

363
00:16:02,030 --> 00:16:00,480

she's in her first year as a graduate

364

00:16:03,470 --> 00:16:02,040

student at the Johns Hopkins University

365

00:16:06,110 --> 00:16:03,480

across the street from the Space

366

00:16:08,470 --> 00:16:06,120

Telescope Science Institute

367

00:16:10,850 --> 00:16:08,480

um and uh she is um you know

368

00:16:12,290 --> 00:16:10,860

enthusiastically volunteered to give a

369

00:16:14,569 --> 00:16:12,300

give a talk at the public lecture series

370

00:16:18,110 --> 00:16:14,579

and I said great I love these uh

371

00:16:20,090 --> 00:16:18,120

enthusiastic talks uh her history is

372

00:16:22,310 --> 00:16:20,100

kind of interesting okay because she did

373

00:16:25,970 --> 00:16:22,320

her undergraduate at the University of

374

00:16:30,230 --> 00:16:25,980

Florida not in physics not in astronomy

375

00:16:32,210 --> 00:16:30,240

but in exercise science yes

376

00:16:33,230 --> 00:16:32,220

um she came and then she worked in a

377

00:16:35,509 --> 00:16:33,240

hospital

378

00:16:37,490 --> 00:16:35,519

um in a physical therapy department for

379

00:16:40,550 --> 00:16:37,500

several years and then for some reason

380

00:16:42,710 --> 00:16:40,560

said uh I just I want to go do

381

00:16:46,189 --> 00:16:42,720

astrophysics okay

382

00:16:48,829 --> 00:16:46,199

um so she came to uh Johns Hopkins last

383

00:16:51,470 --> 00:16:48,839

year oh no actually she went to uh

384

00:16:53,930 --> 00:16:51,480

Wesleyan University in Connecticut and

385

00:16:56,949 --> 00:16:53,940

got her Master's Degree and then came to

386

00:17:00,290 --> 00:16:56,959

Johns Hopkins uh to do her PhD

387

00:17:02,210 --> 00:17:00,300

so she has a interesting background and

388

00:17:04,789 --> 00:17:02,220

I think she's gonna you know really hit

389

00:17:06,710 --> 00:17:04,799

hit it hard when she gets to it and I

390

00:17:08,630 --> 00:17:06,720

always ask my speakers for something fun

391

00:17:10,549 --> 00:17:08,640

about what them that they've done well

392

00:17:13,610 --> 00:17:10,559

inner travels up and down the East Coast

393

00:17:16,970 --> 00:17:13,620

she has actually walked about one half

394

00:17:18,890 --> 00:17:16,980

of the Appalachian Trail so she's done

395

00:17:21,350 --> 00:17:18,900

an awful awful lot of hiking out there

396

00:17:23,870 --> 00:17:21,360

all right so ladies and gentlemen

397

00:17:27,470 --> 00:17:23,880

Katie Bennett

398

00:17:33,169 --> 00:17:30,590

I am so excited to be here virtually

399

00:17:36,590 --> 00:17:33,179

with you all and talk about planets with

400

00:17:39,190 --> 00:17:36,600

you so yes I have quite an unusual

401
00:17:42,289 --> 00:17:39,200
background I have yet to meet another

402
00:17:45,289 --> 00:17:42,299
astronomy PhD student who has a degree

403
00:17:48,230 --> 00:17:45,299
in exercise science but I will just say

404
00:17:50,630 --> 00:17:48,240
that this has been a love of mine for my

405
00:17:52,850 --> 00:17:50,640
whole life and it took a long time you

406
00:17:55,789 --> 00:17:52,860
know past the gauge of senior year of

407
00:17:57,770 --> 00:17:55,799
college to quite figure out how to

408
00:17:59,990 --> 00:17:57,780
follow that passion but I was able to do

409
00:18:01,970 --> 00:18:00,000
it and I'm really grateful for that and

410
00:18:03,590 --> 00:18:01,980
I just you know want to say if you have

411
00:18:06,830 --> 00:18:03,600
something that you feel like you'd want

412
00:18:09,169 --> 00:18:06,840
to do I always recommend going for it I

413
00:18:10,970 --> 00:18:09,179

couldn't be happier being here now and

414

00:18:13,430 --> 00:18:10,980

getting to share the work that I have

415

00:18:15,710 --> 00:18:13,440

gotten to be a part of just a couple of

416

00:18:17,930 --> 00:18:15,720

years ago I was you know the one

417

00:18:19,310 --> 00:18:17,940

watching these videos and dreaming about

418

00:18:21,230 --> 00:18:19,320

this kind of stuff and now I'm actually

419

00:18:22,330 --> 00:18:21,240

getting to do it and it is quite

420

00:18:26,029 --> 00:18:22,340

remarkable

421

00:18:28,130 --> 00:18:26,039

but with that said tonight we are going

422

00:18:30,049 --> 00:18:28,140

to be talking about planets and if you

423

00:18:31,970 --> 00:18:30,059

don't love planets I really hope that by

424

00:18:33,770 --> 00:18:31,980

the end of this presentation I have

425

00:18:37,490 --> 00:18:33,780

changed your mind

426

00:18:40,130 --> 00:18:37,500

uh I think that we really are on quite a

427

00:18:42,169 --> 00:18:40,140

brink of Discovery with the James Webb

428

00:18:43,909 --> 00:18:42,179

Space Telescope and I think that over

429

00:18:46,010 --> 00:18:43,919

the course of the next decade and

430

00:18:47,810 --> 00:18:46,020

decades to come we're going to learn so

431

00:18:50,029 --> 00:18:47,820

much more than we ever thought possible

432

00:18:54,110 --> 00:18:50,039

even 10 years ago

433

00:18:57,169 --> 00:18:54,120

but before I dive into that I wanted to

434

00:18:59,210 --> 00:18:57,179

just pause and talk about you know why

435

00:19:02,750 --> 00:18:59,220

astronomy is so cool to be a part of

436

00:19:05,210 --> 00:19:02,760

these days and uh Frank pretty much I

437

00:19:06,110 --> 00:19:05,220

already summed it up for me I mean the

438

00:19:11,450 --> 00:19:06,120

the

439

00:19:14,029 --> 00:19:11,460

new web telescope is just wonderful and

440

00:19:17,330 --> 00:19:14,039

so I'm sure you guys have many of you

441

00:19:19,970 --> 00:19:17,340

have seen this image before this is a

442

00:19:23,690 --> 00:19:19,980

deep field of the James using the James

443

00:19:27,110 --> 00:19:23,700

Webb Telescope to look at at many many

444

00:19:30,370 --> 00:19:27,120

different galaxies that are uncross just

445

00:19:33,110 --> 00:19:30,380

a tiny tiny bit sliver of space

446

00:19:36,350 --> 00:19:33,120

we've gotten many many beautiful images

447

00:19:40,370 --> 00:19:36,360

from the new web telescope recently

448

00:19:44,150 --> 00:19:40,380

we see a nebula where baby stars are

449

00:19:46,130 --> 00:19:44,160

forming we see Galaxy mergers happening

450

00:19:47,510 --> 00:19:46,140

or two galaxies are coming and

451
00:19:50,450 --> 00:19:47,520
interacting

452
00:19:53,630 --> 00:19:50,460
but the web telescope isn't just looking

453
00:19:56,630 --> 00:19:53,640
at big stars and galaxies it's also

454
00:20:02,330 --> 00:19:56,640
looking at planets and

455
00:20:06,169 --> 00:20:02,340
while sometimes the images are not quite

456
00:20:08,630 --> 00:20:06,179
as spectacular as seeing you know

457
00:20:10,070 --> 00:20:08,640
galaxies upon galaxies I want to try to

458
00:20:12,950 --> 00:20:10,080
convince you guys tonight that the

459
00:20:14,150 --> 00:20:12,960
information that we get by looking at

460
00:20:18,169 --> 00:20:14,160
not

461
00:20:21,409 --> 00:20:18,179
photos or photometry but spectroscopy is

462
00:20:23,150 --> 00:20:21,419
just as intriguing as these images

463
00:20:24,890 --> 00:20:23,160

but

464

00:20:28,370 --> 00:20:24,900

Webb doesn't discriminate it looks

465

00:20:31,250 --> 00:20:28,380

across all uh all planets including

466

00:20:33,950 --> 00:20:31,260

those in the solar system

467

00:20:38,510 --> 00:20:33,960

so this is a beautiful image of Jupiter

468

00:20:40,250 --> 00:20:38,520

in the uh near infrared and it looks

469

00:20:42,169 --> 00:20:40,260

similar to the pictures that Frank just

470

00:20:43,850 --> 00:20:42,179

showed but the colors are kind of off

471

00:20:46,549 --> 00:20:43,860

right that's because this is a false

472

00:20:48,590 --> 00:20:46,559

color image again with different filters

473

00:20:51,470 --> 00:20:48,600

stacked on top of each other

474

00:20:53,750 --> 00:20:51,480

but I just love this because you can see

475

00:20:55,430 --> 00:20:53,760

the Great Red Spot which doesn't look

476
00:20:59,390 --> 00:20:55,440
red in this image because we haven't

477
00:21:02,390 --> 00:20:59,400
colored it so but you can see ionized

478
00:21:05,090 --> 00:21:02,400
gas at the poles which correlates to

479
00:21:08,029 --> 00:21:05,100
Jupiter's own Northern Lights

480
00:21:10,730 --> 00:21:08,039
uh and so you know this is just another

481
00:21:12,409 --> 00:21:10,740
spectacular image of a planet here and

482
00:21:15,350 --> 00:21:12,419
I'm going to be talking about some other

483
00:21:17,830 --> 00:21:15,360
gas giants like Jupiter but before I

484
00:21:20,990 --> 00:21:17,840
wanted before we kind of dive into that

485
00:21:23,870 --> 00:21:21,000
let's go ahead and Orient ourselves

486
00:21:28,190 --> 00:21:23,880
because the universe is a pretty big

487
00:21:30,289 --> 00:21:28,200
place right so here we are I love this

488
00:21:34,190 --> 00:21:30,299

image this is an

489

00:21:37,070 --> 00:21:34,200

image that is scaled by size correctly

490

00:21:39,830 --> 00:21:37,080

not distance so these distances are not

491

00:21:42,110 --> 00:21:39,840

accurate however the relative sizes are

492

00:21:43,010 --> 00:21:42,120

and what I mean by that is that you can

493

00:21:46,370 --> 00:21:43,020

see

494

00:21:48,950 --> 00:21:46,380

Earth as a tiny tiny little ball right

495

00:21:53,149 --> 00:21:48,960

here that is how small it really is

496

00:21:55,130 --> 00:21:53,159

relative to the sun on the far right and

497

00:21:58,130 --> 00:21:55,140

so here we are

498

00:21:59,810 --> 00:21:58,140

now here's the fun part I wish I could

499

00:22:01,430 --> 00:21:59,820

be here in person with you guys to see

500

00:22:03,950 --> 00:22:01,440

your reactions but we're gonna we can

501
00:22:06,289 --> 00:22:03,960
all do a little pop quiz together to see

502
00:22:08,810 --> 00:22:06,299
if we remember our elementary school

503
00:22:10,370 --> 00:22:08,820
ordering of the planets and our solar

504
00:22:12,350 --> 00:22:10,380
system so

505
00:22:14,810 --> 00:22:12,360
are we ready

506
00:22:16,250 --> 00:22:14,820
excellent we're going to start from the

507
00:22:18,049 --> 00:22:16,260
innermost planet

508
00:22:19,909 --> 00:22:18,059
right next to the Sun

509
00:22:21,289 --> 00:22:19,919
that one is

510
00:22:24,409 --> 00:22:21,299
Mercury

511
00:22:26,930 --> 00:22:24,419
then right next to us our nearest

512
00:22:28,730 --> 00:22:26,940
neighbor our twin planet that sometimes

513
00:22:31,070 --> 00:22:28,740

people say

514

00:22:32,930 --> 00:22:31,080

we have Venus

515

00:22:35,870 --> 00:22:32,940

then there's us Earth is the third

516

00:22:37,730 --> 00:22:35,880

planet then next to Earth the planet

517

00:22:40,549 --> 00:22:37,740

that probably gets the most amount of

518

00:22:44,450 --> 00:22:40,559

attention in the media and certainly the

519

00:22:47,390 --> 00:22:44,460

movies is Mars these are our four rocky

520

00:22:50,870 --> 00:22:47,400

planets that we have in our solar system

521

00:22:53,630 --> 00:22:50,880

after that of course we have Jupiter

522

00:22:55,130 --> 00:22:53,640

next to Jupiter we have big beautiful

523

00:22:58,130 --> 00:22:55,140

Saturn

524

00:23:01,370 --> 00:22:58,140

and then out in the outermost regions of

525

00:23:03,169 --> 00:23:01,380

the solar system we have Uranus and then

526

00:23:04,789 --> 00:23:03,179

you remember the last one

527

00:23:08,390 --> 00:23:04,799

Neptune

528

00:23:11,570 --> 00:23:08,400

now out on the very far left hand side

529

00:23:15,350 --> 00:23:11,580

we also see our dwarf planets and

530

00:23:17,630 --> 00:23:15,360

yes that is where Pluto is we categorize

531

00:23:19,430 --> 00:23:17,640

Pluto as a dwarf planet now it's still

532

00:23:21,830 --> 00:23:19,440

doing its thing and there are others

533

00:23:24,649 --> 00:23:21,840

like it so if you don't don't have to

534

00:23:26,390 --> 00:23:24,659

feel too badly for Pluto

535

00:23:28,970 --> 00:23:26,400

so here we are

536

00:23:31,130 --> 00:23:28,980

this is our solar system the Earth

537

00:23:33,770 --> 00:23:31,140

orbits around the Sun as do all of these

538

00:23:37,010 --> 00:23:33,780

other planets and I would wager a guess

539

00:23:38,870 --> 00:23:37,020

as most of us in school growing up when

540

00:23:42,049 --> 00:23:38,880

you heard the word planets you thought

541

00:23:44,930 --> 00:23:42,059

about these eight yes nine including

542

00:23:46,610 --> 00:23:44,940

Pluto uh these nine planets and that was

543

00:23:49,669 --> 00:23:46,620

all we knew

544

00:23:52,130 --> 00:23:49,679

but that is not all there is to it there

545

00:23:53,570 --> 00:23:52,140

are so many more planets orbiting other

546

00:23:56,930 --> 00:23:53,580

stars

547

00:23:58,909 --> 00:23:56,940

so we have Earth that orbits the Sun but

548

00:24:01,370 --> 00:23:58,919

the sun is just a very average Star

549

00:24:02,510 --> 00:24:01,380

right when the sun is in the Milky Way

550

00:24:05,029 --> 00:24:02,520

galaxy

551
00:24:08,510 --> 00:24:05,039
here's a little artist rendition of the

552
00:24:11,270 --> 00:24:08,520
Milky Way and we can pretend we do know

553
00:24:14,810 --> 00:24:11,280
that the sun is kind of just in the kind

554
00:24:17,149 --> 00:24:14,820
of an outermost neighborhood of the of

555
00:24:19,430 --> 00:24:17,159
the Milky Way and so there are billions

556
00:24:22,909 --> 00:24:19,440
of stars in our one Galaxy alone

557
00:24:26,330 --> 00:24:22,919
billions of suns in this galaxy

558
00:24:28,669 --> 00:24:26,340
but let's take a step back farther

559
00:24:30,890 --> 00:24:28,679
I showed you that beautiful Deep Field

560
00:24:32,330 --> 00:24:30,900
Web image that I'm sure many of you have

561
00:24:34,130 --> 00:24:32,340
seen before

562
00:24:38,330 --> 00:24:34,140
we'll look at it again

563
00:24:39,230 --> 00:24:38,340

all of these spots from the one right in

564

00:24:41,570 --> 00:24:39,240

the center with this beautiful

565

00:24:44,630 --> 00:24:41,580

diffraction pattern all the way out to

566

00:24:47,870 --> 00:24:44,640

just these small dots that you see every

567

00:24:51,470 --> 00:24:47,880

single one of them are also galaxies

568

00:24:53,930 --> 00:24:51,480

meaning all of these galaxies likely

569

00:24:56,870 --> 00:24:53,940

have billions of stars and maybe

570

00:25:00,110 --> 00:24:56,880

billions of planets we don't know about

571

00:25:03,470 --> 00:25:00,120

other planets in other galaxies yet

572

00:25:05,690 --> 00:25:03,480

but we can only imagine

573

00:25:08,210 --> 00:25:05,700

what there is

574

00:25:11,450 --> 00:25:08,220

we know about planets in our own Galaxy

575

00:25:15,110 --> 00:25:11,460

so that was a lot I know it's hard to

576

00:25:17,450 --> 00:25:15,120

think about the Sun and as a star and

577

00:25:19,669 --> 00:25:17,460

billions of stars in the Milky Way

578

00:25:21,110 --> 00:25:19,679

galaxy and billions of galaxies in the

579

00:25:22,669 --> 00:25:21,120

universe it's my I think it's

580

00:25:24,470 --> 00:25:22,679

mind-boggling and I get to think about

581

00:25:28,430 --> 00:25:24,480

this all the time

582

00:25:29,870 --> 00:25:28,440

but let's return home to the Milky Way

583

00:25:34,090 --> 00:25:29,880

and

584

00:25:36,769 --> 00:25:34,100

just focus on a tiny tiny little

585

00:25:38,210 --> 00:25:36,779

subsection of the Milky Way which is the

586

00:25:41,630 --> 00:25:38,220

region of

587

00:25:45,710 --> 00:25:41,640

of our galaxy that we have searched for

588

00:25:47,029 --> 00:25:45,720

uh other planets around other stars

589

00:25:50,930 --> 00:25:47,039

so again

590

00:25:53,690 --> 00:25:50,940

today we're going to focus on exoplanets

591

00:25:57,649 --> 00:25:53,700

and an exoplanet is simply a planet that

592

00:26:00,529 --> 00:25:57,659

orbits a star other than the Sun

593

00:26:03,289 --> 00:26:00,539

so we all by we I mean you know Earth

594

00:26:05,269 --> 00:26:03,299

and Mars and Saturn and Jupiter and all

595

00:26:08,630 --> 00:26:05,279

those planets that we know and love we

596

00:26:11,630 --> 00:26:08,640

all orbit the Sun but we said that the

597

00:26:12,830 --> 00:26:11,640

sun is only one of billions of stars in

598

00:26:15,529 --> 00:26:12,840

the galaxy

599

00:26:17,810 --> 00:26:15,539

which must mean that there are many

600

00:26:20,090 --> 00:26:17,820

other solar systems out there

601
00:26:23,810 --> 00:26:20,100
and indeed we we know that that's true

602
00:26:25,669 --> 00:26:23,820
now we know uh about thousands of

603
00:26:29,210 --> 00:26:25,679
planets now and we'll get to the exact

604
00:26:31,130 --> 00:26:29,220
number in a little while uh but I I

605
00:26:32,630 --> 00:26:31,140
really just want to pause for a minute

606
00:26:36,230 --> 00:26:32,640
and talk about

607
00:26:39,470 --> 00:26:36,240
uh how rapidly this has happened and how

608
00:26:41,330 --> 00:26:39,480
how quickly we're gaining knowledge so

609
00:26:43,549 --> 00:26:41,340
the you know people have been wondering

610
00:26:47,090 --> 00:26:43,559
if there were planets outside of our

611
00:26:49,610 --> 00:26:47,100
solar system for centuries but it really

612
00:26:51,590 --> 00:26:49,620
wasn't until the 9th of the 1900s that

613
00:26:54,190 --> 00:26:51,600

people started to really look into this

614

00:26:58,549 --> 00:26:54,200

and it wasn't until

615

00:27:02,269 --> 00:26:58,559

1995 that the first planet around a main

616

00:27:04,850 --> 00:27:02,279

sequence star around a sun-like star was

617

00:27:08,269 --> 00:27:04,860

actually detected so I'll tell you guys

618

00:27:10,850 --> 00:27:08,279

that I am a 1994 baby so I was one year

619

00:27:12,590 --> 00:27:10,860

old when this happened and that means

620

00:27:15,350 --> 00:27:12,600

that pretty much the whole field of

621

00:27:16,789 --> 00:27:15,360

exoplanets has started uh since I've

622

00:27:18,649 --> 00:27:16,799

been alive

623

00:27:20,029 --> 00:27:18,659

and now

624

00:27:30,250 --> 00:27:20,039

we

625

00:27:32,690 --> 00:27:30,260

and that's really this has just

626
00:27:35,029 --> 00:27:32,700
exponentially increased especially in

627
00:27:37,909 --> 00:27:35,039
the last decade or so with specific

628
00:27:39,890 --> 00:27:37,919
dedicated space space missions to try to

629
00:27:42,710 --> 00:27:39,900
find these planets

630
00:27:45,710 --> 00:27:42,720
and now we're at the point where we're

631
00:27:47,810 --> 00:27:45,720
not only finding them but we are also

632
00:27:50,870 --> 00:27:47,820
trying to characterize them and trying

633
00:27:52,850 --> 00:27:50,880
to understand what these atmosphere what

634
00:27:55,730 --> 00:27:52,860
what these planets are like do they have

635
00:27:58,549 --> 00:27:55,740
atmospheres what's in them are they big

636
00:28:03,970 --> 00:27:58,559
gas giants are they small and Rocky like

637
00:28:09,529 --> 00:28:07,190
and so we've basically started to

638
00:28:13,310 --> 00:28:09,539

discover that there is almost every

639

00:28:15,470 --> 00:28:13,320

possibility of Planet out there I love

640

00:28:17,870 --> 00:28:15,480

this image from Time Magazine this is

641

00:28:20,210 --> 00:28:17,880

obviously an artist rendition imagining

642

00:28:24,169 --> 00:28:20,220

all of the different types of planets

643

00:28:27,830 --> 00:28:24,179

that we've discovered so you see big gas

644

00:28:30,169 --> 00:28:27,840

Big Balls of gas like Jupiter you also

645

00:28:33,289 --> 00:28:30,179

see kind of these intermediate sized

646

00:28:34,549 --> 00:28:33,299

planets and then many smaller rocky

647

00:28:36,950 --> 00:28:34,559

planets too

648

00:28:38,450 --> 00:28:36,960

and so we we kind of have we have many

649

00:28:41,269 --> 00:28:38,460

questions right I mean we have every

650

00:28:44,390 --> 00:28:41,279

question you know for all of

651
00:28:46,610 --> 00:28:44,400
uh you know the history of science we've

652
00:28:47,990 --> 00:28:46,620
been focused on nine planets and now all

653
00:28:50,570 --> 00:28:48,000
of a sudden I'm telling you that we have

654
00:28:52,370 --> 00:28:50,580
thousands and they're super far away and

655
00:28:55,010 --> 00:28:52,380
we have to figure out how we can find

656
00:28:56,330 --> 00:28:55,020
figure out anything about them

657
00:28:58,310 --> 00:28:56,340
and so let's

658
00:29:01,789 --> 00:28:58,320
not get too overwhelmed we'll we'll keep

659
00:29:05,110 --> 00:29:01,799
it simple and we will just ask a few

660
00:29:09,110 --> 00:29:05,120
questions to start out with to try to

661
00:29:11,269 --> 00:29:09,120
basically Orient ourselves and and and

662
00:29:13,789 --> 00:29:11,279
and and figure out where where we can go

663
00:29:16,130 --> 00:29:13,799

and what we can find out so kind of the

664

00:29:19,310 --> 00:29:16,140

biggest questions that we are trying to

665

00:29:21,409 --> 00:29:19,320

answer about exoplanets are one how many

666

00:29:23,269 --> 00:29:21,419

planets are there

667

00:29:27,590 --> 00:29:23,279

what are they like

668

00:29:30,110 --> 00:29:27,600

and are any of them like Earth

669

00:29:32,090 --> 00:29:30,120

to start off with the first question how

670

00:29:35,409 --> 00:29:32,100

many planets are there I alluded to this

671

00:29:39,110 --> 00:29:35,419

earlier uh according to

672

00:29:42,950 --> 00:29:39,120

NASA's website as of last week

673

00:29:44,510 --> 00:29:42,960

there are over 5 000 exoplanets that

674

00:29:46,130 --> 00:29:44,520

we've discovered

675

00:29:49,010 --> 00:29:46,140

and of course

676
00:29:50,210 --> 00:29:49,020
this number goes up about about every

677
00:29:51,950 --> 00:29:50,220
week

678
00:29:54,289 --> 00:29:51,960
this mean this doesn't mean that there

679
00:29:56,570 --> 00:29:54,299
are only 5 000 planets these are only

680
00:29:59,149 --> 00:29:56,580
the ones that we've discovered in the

681
00:30:01,490 --> 00:29:59,159
last 30 years and again we're

682
00:30:04,250 --> 00:30:01,500
discovering them quicker and quicker

683
00:30:07,730 --> 00:30:04,260
every year as our technology and our

684
00:30:11,630 --> 00:30:07,740
techniques improve

685
00:30:14,330 --> 00:30:11,640
the mind-boggling thing to me is that we

686
00:30:16,909 --> 00:30:14,340
think that there are likely more stars

687
00:30:19,010 --> 00:30:16,919
than there are planets we know we've

688
00:30:22,250 --> 00:30:19,020

estimated that there is at least a

689

00:30:26,029 --> 00:30:22,260

planet per star on average

690

00:30:28,250 --> 00:30:26,039

uh but we are again uncovering

691

00:30:31,789 --> 00:30:28,260

more and more planets it just seems to

692

00:30:35,149 --> 00:30:31,799

be a planet filled you know Galaxy at

693

00:30:40,549 --> 00:30:38,269

now next question what do these planets

694

00:30:43,610 --> 00:30:40,559

like let's go back to our own solar

695

00:30:45,649 --> 00:30:43,620

system for a minute just to orient uh

696

00:30:47,630 --> 00:30:45,659

ourselves and remind ourselves what

697

00:30:48,470 --> 00:30:47,640

types of planets we see in our solar

698

00:30:50,810 --> 00:30:48,480

system

699

00:30:52,730 --> 00:30:50,820

so we have Earth along with its

700

00:30:53,870 --> 00:30:52,740

neighbors these make up the rocky

701
00:30:58,010 --> 00:30:53,880

planets

702
00:30:59,510 --> 00:30:58,020

and then you have the the four big gas

703
00:31:01,610 --> 00:30:59,520

and Ice drives these are the eight

704
00:31:03,289 --> 00:31:01,620

planets in our solar system

705
00:31:06,950 --> 00:31:03,299

now

706
00:31:08,990 --> 00:31:06,960

we see that exoplanets fall both in this

707
00:31:11,029 --> 00:31:09,000

category and not

708
00:31:13,669 --> 00:31:11,039

and not quite in this category there

709
00:31:16,970 --> 00:31:13,679

seems to be other types that we don't

710
00:31:18,289 --> 00:31:16,980

quite have analogous types of planets in

711
00:31:21,110 --> 00:31:18,299

our solar system

712
00:31:24,169 --> 00:31:21,120

so this is a great little graphic from

713
00:31:27,409 --> 00:31:24,179

NASA that I really like

714

00:31:31,190 --> 00:31:27,419

going over broadly the four types of

715

00:31:35,149 --> 00:31:31,200

planets that we can detect now and I

716

00:31:38,090 --> 00:31:35,159

want to make an point that we as humans

717

00:31:40,909 --> 00:31:38,100

really like to categorize things to

718

00:31:43,570 --> 00:31:40,919

understand them but it's very likely

719

00:31:47,769 --> 00:31:43,580

that there are no

720

00:31:50,470 --> 00:31:47,779

set categories especially say between

721

00:31:54,289 --> 00:31:50,480

gas giants and

722

00:31:56,450 --> 00:31:54,299

Neptune or Saturn's size planets but

723

00:31:59,330 --> 00:31:56,460

there is this Continuum and we're

724

00:32:01,370 --> 00:31:59,340

working to understand if there are sharp

725

00:32:04,850 --> 00:32:01,380

cutoffs between all of these types of

726

00:32:06,350 --> 00:32:04,860

planets or if they all have a common

727

00:32:08,870 --> 00:32:06,360

history

728

00:32:11,210 --> 00:32:08,880

so if you look on the left side you have

729

00:32:13,250 --> 00:32:11,220

your biggest gas giant planets these are

730

00:32:15,110 --> 00:32:13,260

our Jupiter these are Saturn and

731

00:32:19,250 --> 00:32:15,120

jupiter-like planets

732

00:32:20,870 --> 00:32:19,260

we often uh we we talk a lot and if

733

00:32:23,029 --> 00:32:20,880

you've ever been to one of these

734

00:32:25,190 --> 00:32:23,039

presentations before or if you've seen

735

00:32:28,130 --> 00:32:25,200

another presentation about exoplanets

736

00:32:31,250 --> 00:32:28,140

you've likely heard the word hot Jupiter

737

00:32:33,049 --> 00:32:31,260

we refer to many of the planets that

738

00:32:35,269 --> 00:32:33,059

we've discovered as hot Jupiters because

739

00:32:37,789 --> 00:32:35,279

the planets that we have discovered that

740

00:32:39,590 --> 00:32:37,799

are the size are also orbiting very

741

00:32:43,190 --> 00:32:39,600

close to their host star

742

00:32:44,810 --> 00:32:43,200

and I that's actually just a bias in our

743

00:32:47,330 --> 00:32:44,820

techniques and we can talk more about

744

00:32:50,389 --> 00:32:47,340

that later but they are closer to their

745

00:32:52,909 --> 00:32:50,399

Stars than Mercury is to the Sun

746

00:32:54,889 --> 00:32:52,919

and so they're they're very hot and so

747

00:32:57,289 --> 00:32:54,899

we call them hot Jupiters they're you

748

00:32:59,870 --> 00:32:57,299

know very creative here

749

00:33:02,870 --> 00:32:59,880

we also have neptune-like planets so

750

00:33:06,110 --> 00:33:02,880

these are smaller in size to our hot

751

00:33:08,649 --> 00:33:06,120

Jupiters but they are they likely still

752

00:33:12,049 --> 00:33:08,659

have a lot of gas so they're likely

753

00:33:14,690 --> 00:33:12,059

largely hydrogen and helium dominated

754

00:33:17,509 --> 00:33:14,700

they might have ice they might have some

755

00:33:19,909 --> 00:33:17,519

rock we're not quite sure what's going

756

00:33:22,669 --> 00:33:19,919

on with these planets yet

757

00:33:24,950 --> 00:33:22,679

and then you have your super Earths and

758

00:33:27,169 --> 00:33:24,960

your terrestrial planets and really the

759

00:33:30,289 --> 00:33:27,179

difference the only difference in

760

00:33:33,590 --> 00:33:30,299

category are and these are the size that

761

00:33:35,210 --> 00:33:33,600

we know of yet so we're not sure say if

762

00:33:38,090 --> 00:33:35,220

super Earths are more likely to have

763

00:33:40,909 --> 00:33:38,100

atmospheres and earth-sized planets are

764

00:33:42,529 --> 00:33:40,919

more likely to just be bare rock

765

00:33:43,909 --> 00:33:42,539

these are the types of questions that

766

00:33:46,190 --> 00:33:43,919

we're hoping to answer with the James

767

00:33:47,810 --> 00:33:46,200

Webb Telescope

768

00:33:51,710 --> 00:33:47,820

so

769

00:33:53,870 --> 00:33:51,720

these broadly are what we like to focus

770

00:33:55,610 --> 00:33:53,880

on for this talk I'm going to talk

771

00:33:57,470 --> 00:33:55,620

mostly about terrestrial and super

772

00:34:00,889 --> 00:33:57,480

earth-sized planets I think that this is

773

00:34:02,210 --> 00:34:00,899

what gets people the most excited but I

774

00:34:03,950 --> 00:34:02,220

want to make the point now and I'm going

775

00:34:05,990 --> 00:34:03,960

to make it again at the very end of the

776

00:34:08,810 --> 00:34:06,000

talk that all of these planets are

777

00:34:11,930 --> 00:34:08,820

important we don't just want to say okay

778

00:34:13,609 --> 00:34:11,940

oh we just want to care we we just care

779

00:34:15,169 --> 00:34:13,619

about you know searching for life

780

00:34:17,629 --> 00:34:15,179

outside of Earth so we're only going to

781

00:34:19,909 --> 00:34:17,639

look at terrestrial planets we need to

782

00:34:23,089 --> 00:34:19,919

understand the whole landscape of

783

00:34:24,770 --> 00:34:23,099

exoplanets in order to understand each

784

00:34:27,409 --> 00:34:24,780

individual one because if we see

785

00:34:29,869 --> 00:34:27,419

something on it on a terrestrial planet

786

00:34:32,930 --> 00:34:29,879

without say having a really good sense

787

00:34:36,169 --> 00:34:32,940

of it's a neighboring gas giant we can't

788

00:34:40,010 --> 00:34:36,179

it's hard to make any kind of

789

00:34:43,369 --> 00:34:40,020

a a deduction about what is going on

790

00:34:46,369 --> 00:34:43,379

so just like we still love and Jupiter

791

00:34:48,409 --> 00:34:46,379

in our own solar system we must and we

792

00:34:52,629 --> 00:34:48,419

still do care about the Neptunes and the

793

00:34:58,690 --> 00:34:55,970

and of course like I said the final

794

00:35:01,790 --> 00:34:58,700

question that so many of us want to know

795

00:35:05,210 --> 00:35:01,800

are any of them like Earth

796

00:35:06,589 --> 00:35:05,220

and I mean yeah I want to know and so do

797

00:35:07,849 --> 00:35:06,599

you that's probably why you're here

798

00:35:11,870 --> 00:35:07,859

tonight

799

00:35:15,349 --> 00:35:11,880

now I'm I have to tell you that we just

800

00:35:18,290 --> 00:35:15,359

don't know the answer yet we're hoping

801
00:35:21,109 --> 00:35:18,300
to take the first steps now with the web

802
00:35:25,069 --> 00:35:21,119
telescope and I'll talk to you about how

803
00:35:28,490 --> 00:35:25,079
exactly we are going about doing that

804
00:35:30,410 --> 00:35:28,500
now I just I just pulled this image up

805
00:35:31,910 --> 00:35:30,420
just because I love it and I think it's

806
00:35:33,530 --> 00:35:31,920
beautiful and I think that it really

807
00:35:35,510 --> 00:35:33,540
makes you realize how large this

808
00:35:37,310 --> 00:35:35,520
telescope is so you can see these folks

809
00:35:39,950 --> 00:35:37,320
down here for scale

810
00:35:43,609 --> 00:35:39,960
uh

811
00:35:44,930 --> 00:35:43,619
I just want to emphasize and and take a

812
00:35:46,430 --> 00:35:44,940
moment to thank and appreciate the

813
00:35:49,550 --> 00:35:46,440

people who have spent the last two

814

00:35:52,730 --> 00:35:49,560

decades working to make this telescope a

815

00:35:55,010 --> 00:35:52,740

reality I say this to many people but I

816

00:35:57,349 --> 00:35:55,020

feel like I came into this field at

817

00:36:00,109 --> 00:35:57,359

exactly the right time and I feel really

818

00:36:02,450 --> 00:36:00,119

grateful for the people who have put in

819

00:36:05,450 --> 00:36:02,460

the work for so long to get us where we

820

00:36:09,170 --> 00:36:05,460

are now because I'm looking at data now

821

00:36:11,450 --> 00:36:09,180

that people uh you know 10 years ago

822

00:36:14,270 --> 00:36:11,460

wouldn't have been able to imagine that

823

00:36:18,069 --> 00:36:14,280

our data would have ever been this good

824

00:36:20,270 --> 00:36:18,079

so this telescope is really uh

825

00:36:22,730 --> 00:36:20,280

revolutionizing the the field of

826
00:36:24,589 --> 00:36:22,740
exoplanet atmospheres and we are really

827
00:36:27,290 --> 00:36:24,599
on the precipice of a new frontier

828
00:36:29,750 --> 00:36:27,300
because this telescope is more powerful

829
00:36:32,870 --> 00:36:29,760
than any other instrument that we've

830
00:36:36,170 --> 00:36:32,880
ever put into space before and we are

831
00:36:38,569 --> 00:36:36,180
actually able to look at rocky planets

832
00:36:41,329 --> 00:36:38,579
and look at their atmospheres for the

833
00:36:43,190 --> 00:36:41,339
very first time rocky planets are small

834
00:36:45,170 --> 00:36:43,200
right they're smaller than the hot

835
00:36:47,810 --> 00:36:45,180
Jupiters which means that they're

836
00:36:51,230 --> 00:36:47,820
equally harder to see and understand

837
00:36:55,069 --> 00:36:51,240
what's going on but we're doing it

838
00:36:57,290 --> 00:36:55,079

and I know that you're wondering how

839

00:37:00,530 --> 00:36:57,300

is the time where we roll up our sleeves

840

00:37:03,290 --> 00:37:00,540

and we take our pencils out and start

841

00:37:04,670 --> 00:37:03,300

vigorously taking notes no I'm just

842

00:37:06,589 --> 00:37:04,680

kidding I'm just kidding we're not doing

843

00:37:08,270 --> 00:37:06,599

that but we aren't I do want to tell you

844

00:37:10,790 --> 00:37:08,280

guys about the technique that we use

845

00:37:13,810 --> 00:37:10,800

because I think that it's

846

00:37:17,089 --> 00:37:13,820

one I think that it's just really cool

847

00:37:19,370 --> 00:37:17,099

and two I think that it's very important

848

00:37:22,130 --> 00:37:19,380

to actually understand how

849

00:37:26,150 --> 00:37:22,140

uh you know wear these where the

850

00:37:29,270 --> 00:37:26,160

information is and how how we get it

851

00:37:32,150 --> 00:37:29,280

so the technique that I use and that

852

00:37:34,910 --> 00:37:32,160

many exoplanet astronomers use is

853

00:37:36,290 --> 00:37:34,920

something called the transit technique

854

00:37:45,589 --> 00:37:36,300

so

855

00:37:48,770 --> 00:37:45,599

see the full thing I was uh I was in

856

00:37:52,130 --> 00:37:48,780

Florida at that time and it was partial

857

00:37:54,410 --> 00:37:52,140

but it was still spectacular

858

00:37:57,290 --> 00:37:54,420

uh and it's also hard to imagine that

859

00:37:59,569 --> 00:37:57,300

2017 was what six years ago now

860

00:38:01,849 --> 00:37:59,579

but

861

00:38:04,190 --> 00:38:01,859

during the solar eclipse

862

00:38:06,770 --> 00:38:04,200

and during any solar eclipse you have

863

00:38:09,230 --> 00:38:06,780

the moon coming between us and the Sun

864

00:38:11,630 --> 00:38:09,240

and when that happens the Moon is

865

00:38:12,950 --> 00:38:11,640

blocking the Sun the Sun's light so the

866

00:38:15,710 --> 00:38:12,960

amount of light that we're getting from

867

00:38:19,250 --> 00:38:15,720

the Sun is it decreasing obviously as

868

00:38:20,690 --> 00:38:19,260

the moon goes in front of the Sun

869

00:38:23,390 --> 00:38:20,700

this is

870

00:38:26,870 --> 00:38:23,400

exactly the same technique that we use

871

00:38:28,250 --> 00:38:26,880

every day to look for and characterize

872

00:38:30,410 --> 00:38:28,260

planets

873

00:38:33,050 --> 00:38:30,420

so if you take a step back instead of

874

00:38:36,829 --> 00:38:33,060

thinking of the Sun and the Moon you

875

00:38:40,370 --> 00:38:36,839

think of a star and its Planet you can

876

00:38:43,430 --> 00:38:40,380

say all right so here we have a star

877

00:38:46,670 --> 00:38:43,440

in the middle and we have a planet

878

00:38:50,210 --> 00:38:46,680

orbiting it and if a planet is at just

879

00:38:53,930 --> 00:38:50,220

the right angle relative to its star and

880

00:38:57,290 --> 00:38:53,940

relative to us it will pass between

881

00:39:00,770 --> 00:38:57,300

this between us and the star and it will

882

00:39:03,710 --> 00:39:00,780

block some of the star's light

883

00:39:05,390 --> 00:39:03,720

and we can measure this and we can say

884

00:39:07,310 --> 00:39:05,400

that there's a planet there

885

00:39:10,849 --> 00:39:07,320

and so I just wanted to pause for a

886

00:39:13,310 --> 00:39:10,859

second and say too that uh you know we

887

00:39:17,390 --> 00:39:13,320

we measure this because when we use

888

00:39:19,609 --> 00:39:17,400

telescopes like the web or Hubble or any

889

00:39:22,730 --> 00:39:19,619

ground telescope for that matter too

890

00:39:24,170 --> 00:39:22,740

it's it's no longer like that I'm going

891

00:39:26,089 --> 00:39:24,180

up to a telescope and I'm looking

892

00:39:29,089 --> 00:39:26,099

through it like sometimes you do on a

893

00:39:30,589 --> 00:39:29,099

cool space night you know uh and I still

894

00:39:32,569 --> 00:39:30,599

love to do that don't get me wrong I

895

00:39:35,810 --> 00:39:32,579

love looking through telescopes directly

896

00:39:39,230 --> 00:39:35,820

but my eye is now a lot less powerful

897

00:39:41,690 --> 00:39:39,240

than the computers and detectors that we

898

00:39:45,650 --> 00:39:41,700

have used to gather our data

899

00:39:47,930 --> 00:39:45,660

so everything is done uh digitally these

900

00:39:50,329 --> 00:39:47,940

days there's there's nothing that my eye

901
00:39:52,490 --> 00:39:50,339
can really do anymore so what the web

902
00:39:54,710 --> 00:39:52,500
telescope does is collect information

903
00:39:56,329 --> 00:39:54,720
about the amount of brightness we

904
00:39:58,069 --> 00:39:56,339
receive from a star

905
00:40:00,290 --> 00:39:58,079
over time

906
00:40:01,730 --> 00:40:00,300
and so that's what we're measuring so

907
00:40:05,270 --> 00:40:01,740
when the plan is not in front of the

908
00:40:08,510 --> 00:40:05,280
star and important an important caveat

909
00:40:10,569 --> 00:40:08,520
is if the star is a quiet star you can

910
00:40:13,670 --> 00:40:10,579
have stars that are

911
00:40:16,310 --> 00:40:13,680
that are full of activity and change too

912
00:40:18,230 --> 00:40:16,320
but we can just assume for now that the

913
00:40:20,510 --> 00:40:18,240

star is just quiet

914

00:40:22,010 --> 00:40:20,520

we would assume that you know the amount

915

00:40:25,010 --> 00:40:22,020

of brightness that we get from the star

916

00:40:27,050 --> 00:40:25,020

is the same over time but then all of a

917

00:40:30,470 --> 00:40:27,060

sudden as the planet passes in front of

918

00:40:34,370 --> 00:40:30,480

the star a small amount of of Starlight

919

00:40:36,770 --> 00:40:34,380

gets blocked and we see that as a dip in

920

00:40:37,849 --> 00:40:36,780

the planet in the star's light curve we

921

00:40:40,310 --> 00:40:37,859

call this

922

00:40:42,410 --> 00:40:40,320

now this plot I will admit is a little

923

00:40:45,290 --> 00:40:42,420

deceiving because it makes it look like

924

00:40:49,609 --> 00:40:45,300

half of the star's brightness is is

925

00:40:52,490 --> 00:40:49,619

getting blocked in reality this dip is a

926
00:40:54,470 --> 00:40:52,500
very small amount on the order of a

927
00:40:58,130 --> 00:40:54,480
tenth to one percent

928
00:41:00,109 --> 00:40:58,140
so it's a very small dip in Starlight

929
00:41:03,230 --> 00:41:00,119
but we are able to measure it

930
00:41:04,609 --> 00:41:03,240
and we call this dip the transit depth

931
00:41:07,130 --> 00:41:04,619
so you're going to hear me use that word

932
00:41:09,109 --> 00:41:07,140
a lot the transit depth is basically

933
00:41:11,990 --> 00:41:09,119
like the quintessential measurement that

934
00:41:14,810 --> 00:41:12,000
we take and this tells us the size of

935
00:41:16,490 --> 00:41:14,820
the planet right because if you think

936
00:41:18,410 --> 00:41:16,500
about it

937
00:41:20,990 --> 00:41:18,420
a bigger planet

938
00:41:22,190 --> 00:41:21,000

is going to block more of the Stars

939

00:41:25,910 --> 00:41:22,200

light

940

00:41:28,430 --> 00:41:25,920

the very nature that it is it's larger

941

00:41:30,170 --> 00:41:28,440

so it's covering a higher fraction of

942

00:41:32,569 --> 00:41:30,180

the star's disk

943

00:41:36,349 --> 00:41:32,579

and so that's why it's easier to detect

944

00:41:39,109 --> 00:41:36,359

bigger planets using this technique

945

00:41:41,210 --> 00:41:39,119

we uh so for the longest time and in

946

00:41:44,089 --> 00:41:41,220

fact the planet that was discovered in

947

00:41:46,730 --> 00:41:44,099

1995 was a big gas giant and many

948

00:41:47,930 --> 00:41:46,740

planets were for for several years after

949

00:41:50,210 --> 00:41:47,940

that

950

00:41:53,870 --> 00:41:50,220

and so you can see the difference again

951
00:41:56,510 --> 00:41:53,880
this is highly uh dramaticized but you

952
00:41:59,329 --> 00:41:56,520
can see that a jupiter-sized planet the

953
00:42:02,089 --> 00:41:59,339
light curve the transit depth is going

954
00:42:04,010 --> 00:42:02,099
to be much bigger than say an

955
00:42:06,710 --> 00:42:04,020
earth-sized planet where it just dips

956
00:42:08,630 --> 00:42:06,720
down a little bit

957
00:42:10,550 --> 00:42:08,640
so I want you to just remember this

958
00:42:13,970 --> 00:42:10,560
because this is going to be very

959
00:42:19,490 --> 00:42:17,270
and again with jwst it's more powerful

960
00:42:22,550 --> 00:42:19,500
and we can actually start looking at

961
00:42:25,069 --> 00:42:22,560
these earth-sized planets

962
00:42:26,990 --> 00:42:25,079
okay but I have been kind of alluding to

963
00:42:28,190 --> 00:42:27,000

the fact that we don't just care about

964

00:42:34,670 --> 00:42:28,200

the planet

965

00:42:36,650 --> 00:42:34,680

atmosphere

966

00:42:38,530 --> 00:42:36,660

and I'm going to talk to you about how

967

00:42:41,690 --> 00:42:38,540

we do that

968

00:42:44,089 --> 00:42:41,700

so if you think about it

969

00:42:48,230 --> 00:42:44,099

as the planet is coming in front of the

970

00:42:50,030 --> 00:42:48,240

star the sunlight is or the Starlight is

971

00:42:52,310 --> 00:42:50,040

actually hitting the planet's atmosphere

972

00:42:55,010 --> 00:42:52,320

and filtering through the planet's

973

00:42:57,290 --> 00:42:55,020

atmosphere so in this graphic you can

974

00:43:00,470 --> 00:42:57,300

see you can pretend that this black

975

00:43:03,829 --> 00:43:00,480

circle is the planet and then the tiny

976
00:43:06,109 --> 00:43:03,839
blue Rim around that is the planet's

977
00:43:08,930 --> 00:43:06,119
atmosphere

978
00:43:11,510 --> 00:43:08,940
and this information this actually gives

979
00:43:13,490 --> 00:43:11,520
us information about what is inside the

980
00:43:15,829 --> 00:43:13,500
atmosphere because the atoms and the

981
00:43:19,130 --> 00:43:15,839
molecules that exist in the atmosphere

982
00:43:21,470 --> 00:43:19,140
actually imprint a signature on the

983
00:43:25,849 --> 00:43:21,480
light that we see

984
00:43:26,750 --> 00:43:25,859
so we are going to dive into how this

985
00:43:28,309 --> 00:43:26,760
works

986
00:43:30,410 --> 00:43:28,319
are you ready

987
00:43:31,430 --> 00:43:30,420
I think so I think so

988
00:43:34,970 --> 00:43:31,440

okay

989

00:43:39,109 --> 00:43:34,980

so the reason that this works uh is if

990

00:43:41,510 --> 00:43:39,119

you think back again to you know the

991

00:43:44,870 --> 00:43:41,520

last cool astronomy talk that you went

992

00:43:47,210 --> 00:43:44,880

to or think or dig farther back to some

993

00:43:51,290 --> 00:43:47,220

lab experiments that you did in school

994

00:43:54,829 --> 00:43:51,300

growing up we remember that if you split

995

00:43:58,730 --> 00:43:54,839

light if you if you put light through a

996

00:43:59,870 --> 00:43:58,740

prism it is split into its constituent

997

00:44:04,069 --> 00:43:59,880

colors

998

00:44:07,250 --> 00:44:04,079

of the rainbow

999

00:44:10,550 --> 00:44:07,260

and why is this well this is because

1000

00:44:13,130 --> 00:44:10,560

light is a wave

1001
00:44:15,050 --> 00:44:13,140
if we want I'm going to talk to you a

1002
00:44:17,050 --> 00:44:15,060
little bit about just some terminology

1003
00:44:20,630 --> 00:44:17,060
because again I'm going to use it a lot

1004
00:44:23,990 --> 00:44:20,640
and so light is a wave

1005
00:44:27,170 --> 00:44:24,000
with very specific wavelengths and so a

1006
00:44:29,690 --> 00:44:27,180
wavelength if you have a wave here is

1007
00:44:32,690 --> 00:44:29,700
literally just the different the the

1008
00:44:36,349 --> 00:44:32,700
distance between one Crest one peak of

1009
00:44:38,390 --> 00:44:36,359
the wave and the next so the calmer of

1010
00:44:41,470 --> 00:44:38,400
the wave if you think about the beach

1011
00:44:44,210 --> 00:44:41,480
and you just everything's very calm and

1012
00:44:45,829 --> 00:44:44,220
you know there's not big Windstorm or

1013
00:44:48,589 --> 00:44:45,839

something that would have long

1014

00:44:51,470 --> 00:44:48,599

wavelengths because the distance between

1015

00:44:53,809 --> 00:44:51,480

crests are big but if you had a big old

1016

00:44:56,390 --> 00:44:53,819

storm and things were really choppy and

1017

00:44:58,370 --> 00:44:56,400

and highly energetic that wavelength

1018

00:45:00,829 --> 00:44:58,380

would be shorter because the distance

1019

00:45:03,050 --> 00:45:00,839

between the peaks of the Waves would be

1020

00:45:05,690 --> 00:45:03,060

shorter

1021

00:45:07,550 --> 00:45:05,700

the same is true for light and that is

1022

00:45:09,710 --> 00:45:07,560

the difference say between red light and

1023

00:45:12,050 --> 00:45:09,720

blue light the red light has a longer

1024

00:45:14,990 --> 00:45:12,060

wavelength than blue light and that is

1025

00:45:17,569 --> 00:45:15,000

why light gets split up into its

1026
00:45:20,589 --> 00:45:17,579
different colors so we can see red light

1027
00:45:24,490 --> 00:45:20,599
down here is around

1028
00:45:28,250 --> 00:45:24,500
650 nanometers and M is just nanometers

1029
00:45:30,770 --> 00:45:28,260
versus blue or Violet is all the way

1030
00:45:33,170 --> 00:45:30,780
down to 400 that wavelength is all the

1031
00:45:36,770 --> 00:45:33,180
way down to 400 nanometers

1032
00:45:38,930 --> 00:45:36,780
and so this is very critical so light is

1033
00:45:40,550 --> 00:45:38,940
a wave and different colors represent

1034
00:45:45,050 --> 00:45:40,560
different wavelengths

1035
00:45:47,809 --> 00:45:45,060
we often now we often learn about this

1036
00:45:50,230 --> 00:45:47,819
in reference to visible light but this

1037
00:45:52,430 --> 00:45:50,240
is actually true across the entire

1038
00:45:55,490 --> 00:45:52,440

electromagnetic spectrum

1039

00:45:58,730 --> 00:45:55,500

so we have visible light up here but as

1040

00:46:02,089 --> 00:45:58,740

you may know visible light is just a

1041

00:46:04,730 --> 00:46:02,099

tiny tiny sliver right here of the

1042

00:46:07,730 --> 00:46:04,740

entire electromagnetic spectrum

1043

00:46:09,770 --> 00:46:07,740

so we have from highly energetic gamma

1044

00:46:12,470 --> 00:46:09,780

rays down to your x-rays just like you

1045

00:46:14,089 --> 00:46:12,480

get at the doctor's office into your

1046

00:46:16,910 --> 00:46:14,099

infrared like those cool night vision

1047

00:46:19,190 --> 00:46:16,920

goggles all the way into the radio and

1048

00:46:22,730 --> 00:46:19,200

yes that radio

1049

00:46:24,589 --> 00:46:22,740

and all of these different all of these

1050

00:46:28,730 --> 00:46:24,599

different regions of Light have

1051

00:46:32,750 --> 00:46:30,349

all right

1052

00:46:36,530 --> 00:46:32,760

are you with me still

1053

00:46:38,390 --> 00:46:36,540

now this is really important because the

1054

00:46:41,030 --> 00:46:38,400

way because of the way that light

1055

00:46:43,430 --> 00:46:41,040

interacts with matter basically if you

1056

00:46:46,010 --> 00:46:43,440

wanted to summarize astronomy in a

1057

00:46:48,650 --> 00:46:46,020

nutshell we just we try to figure out

1058

00:46:51,589 --> 00:46:48,660

how light interacts with atoms and

1059

00:46:53,690 --> 00:46:51,599

particles and then interpret that based

1060

00:46:57,530 --> 00:46:53,700

on what we are seeing

1061

00:47:01,069 --> 00:46:57,540

and so if we had say an atom

1062

00:47:02,630 --> 00:47:01,079

in a planet's atmosphere the light is

1063

00:47:05,089 --> 00:47:02,640

coming from the star

1064

00:47:07,430 --> 00:47:05,099

hitting that atom and interacting with

1065

00:47:09,530 --> 00:47:07,440

it but it's interacting with it in a

1066

00:47:12,770 --> 00:47:09,540

very particular way

1067

00:47:14,829 --> 00:47:12,780

and what's happening is that if you have

1068

00:47:17,750 --> 00:47:14,839

an atom

1069

00:47:19,550 --> 00:47:17,760

represented here by these uh by these

1070

00:47:22,490 --> 00:47:19,560

concentric circles

1071

00:47:24,349 --> 00:47:22,500

atoms and molecules will absorb some of

1072

00:47:26,690 --> 00:47:24,359

that weight some of that light coming in

1073

00:47:28,970 --> 00:47:26,700

from the Star again the light coming the

1074

00:47:32,450 --> 00:47:28,980

light is coming in from the Star at all

1075

00:47:35,210 --> 00:47:32,460

wavelengths however the atoms are only

1076

00:47:37,970 --> 00:47:35,220

absorbing light at very particular

1077

00:47:39,349 --> 00:47:37,980

wavelengths and this imparts a chemical

1078

00:47:42,890 --> 00:47:39,359

signature

1079

00:47:46,790 --> 00:47:42,900

and so if you had an observer say on

1080

00:47:49,849 --> 00:47:46,800

Earth looking back at these uh at this

1081

00:47:52,130 --> 00:47:49,859

planet's atmosphere you would see the

1082

00:47:54,109 --> 00:47:52,140

full electromagnetic spectrum but you

1083

00:47:58,069 --> 00:47:54,119

would see light being blocked at very

1084

00:48:00,589 --> 00:47:58,079

specific wavelengths correlating with uh

1085

00:48:03,410 --> 00:48:00,599

correlating with the wavelengths that

1086

00:48:04,790 --> 00:48:03,420

are being absorbed by the atom or

1087

00:48:08,390 --> 00:48:04,800

molecule

1088

00:48:09,650 --> 00:48:08,400

and so this gives us a spectrum and so

1089

00:48:11,089 --> 00:48:09,660

anytime I'm going to use the word

1090

00:48:12,589 --> 00:48:11,099

spectrum a lot for the rest of the talk

1091

00:48:14,870 --> 00:48:12,599

and anytime I say Spectrum I'm just

1092

00:48:17,210 --> 00:48:14,880

talking about uh you know the the

1093

00:48:20,690 --> 00:48:17,220

measurement of the amount of light or

1094

00:48:22,970 --> 00:48:20,700

the intensity on the y-axis across

1095

00:48:24,230 --> 00:48:22,980

different wavelengths on the x-axis so

1096

00:48:25,849 --> 00:48:24,240

we're going to look at several plots

1097

00:48:28,730 --> 00:48:25,859

like this and you might see different

1098

00:48:32,809 --> 00:48:28,740

words here you might see Transit depth

1099

00:48:34,609 --> 00:48:32,819

you might see flux but you can just

1100

00:48:37,790 --> 00:48:34,619

think of this as the amount of light

1101

00:48:41,569 --> 00:48:37,800

receipt and you can see that

1102

00:48:43,670 --> 00:48:41,579

uh this is just a particular example say

1103

00:48:46,250 --> 00:48:43,680

hydrogen if there was hydrogen in a

1104

00:48:50,030 --> 00:48:46,260

planet's atmosphere it would block light

1105

00:48:52,550 --> 00:48:50,040

at very specific wavelengths so you see

1106

00:48:54,910 --> 00:48:52,560

these dips here where hydrogen is

1107

00:48:58,150 --> 00:48:54,920

absorbing the light

1108

00:49:00,589 --> 00:48:58,160

okay so like let's go back to talk about

1109

00:49:02,990 --> 00:49:00,599

what this has to do with planets because

1110

00:49:05,030 --> 00:49:03,000

I know we did kind of a little bit of a

1111

00:49:07,490 --> 00:49:05,040

deep dive into physics here but let's

1112

00:49:10,490 --> 00:49:07,500

let's bring it back to planets so

1113

00:49:12,890 --> 00:49:10,500

remember that the quintessential

1114

00:49:15,290 --> 00:49:12,900

measurement that we're making is this

1115

00:49:18,410 --> 00:49:15,300

Transit depth understanding the amount

1116

00:49:19,910 --> 00:49:18,420

of dip in Starlight when a planet passes

1117

00:49:22,069 --> 00:49:19,920

in front of its star

1118

00:49:23,030 --> 00:49:22,079

but the key is that we don't just do

1119

00:49:26,930 --> 00:49:23,040

this

1120

00:49:29,650 --> 00:49:26,940

at one wavelength we do it at a bunch

1121

00:49:33,770 --> 00:49:29,660

and that will actually change

1122

00:49:36,349 --> 00:49:33,780

the change the size of the planet to

1123

00:49:38,990 --> 00:49:36,359

tell us uh to tell us what it's made of

1124

00:49:44,930 --> 00:49:39,000

and the way this works

1125

00:49:48,050 --> 00:49:44,940

is that we can we can have a planet so

1126

00:49:50,230 --> 00:49:48,060

here is a fancier drawing of a star with

1127

00:49:56,329 --> 00:49:50,240

a planet in front of it

1128

00:49:59,390 --> 00:49:56,339

and you can imagine that as a that the

1129

00:50:02,030 --> 00:49:59,400

molecules in the atmosphere are going to

1130

00:50:04,190 --> 00:50:02,040

block light at very specific wavelengths

1131

00:50:07,910 --> 00:50:04,200

and so let's say let's pretend for a

1132

00:50:10,790 --> 00:50:07,920

moment that this green Rim around here

1133

00:50:12,770 --> 00:50:10,800

is hydrogen again all of this is just

1134

00:50:14,630 --> 00:50:12,780

hypothetical not necessarily saying but

1135

00:50:18,050 --> 00:50:14,640

that is where hydrogen is that's not

1136

00:50:22,210 --> 00:50:18,060

true but let's pretend that this this

1137

00:50:26,809 --> 00:50:22,220

green Rim is hydrogen now

1138

00:50:30,109 --> 00:50:26,819

uh at 2.1 microns hydrogen all of a

1139

00:50:34,250 --> 00:50:30,119

sudden is going to absorb the light the

1140

00:50:36,710 --> 00:50:34,260

light at 2.1 microns coming from they

1141

00:50:39,770 --> 00:50:36,720

coming from the Star and that makes the

1142

00:50:41,950 --> 00:50:39,780

planet actually appear bigger or let's

1143

00:50:45,290 --> 00:50:41,960

say at 1.8 microns

1144

00:50:47,450 --> 00:50:45,300

the we'll call this carbon actually

1145

00:50:50,270 --> 00:50:47,460

makes the planet appear even bigger than

1146

00:50:52,730 --> 00:50:50,280

that and so this actually changes the

1147

00:50:55,430 --> 00:50:52,740

transit depth at different wavelengths

1148

00:50:58,849 --> 00:50:55,440

again remember because the transit depth

1149

00:51:03,230 --> 00:50:58,859

is dependent on the size of the planet

1150

00:51:06,410 --> 00:51:03,240

so the key takeaway here is that the

1151
00:51:09,410 --> 00:51:06,420
molecules in a planet's atmosphere are

1152
00:51:12,470 --> 00:51:09,420
going to induce a wavelength dependent

1153
00:51:14,150 --> 00:51:12,480
change in transit depth

1154
00:51:15,530 --> 00:51:14,160
and we're going to do this together so

1155
00:51:17,930 --> 00:51:15,540
you can actually really see what it

1156
00:51:21,410 --> 00:51:19,549
here we have

1157
00:51:24,470 --> 00:51:21,420
our make-believe planet with our

1158
00:51:26,990 --> 00:51:24,480
make-believe uh colors in the atmosphere

1159
00:51:28,549 --> 00:51:27,000
and here are the associated Transit

1160
00:51:31,250 --> 00:51:28,559
depths so you can see that the orange

1161
00:51:34,609 --> 00:51:31,260
one is the biggest and so

1162
00:51:36,890 --> 00:51:34,619
the transit depth is the deepest and so

1163
00:51:40,549 --> 00:51:36,900

what we'll do is we'll measure these

1164

00:51:42,290 --> 00:51:40,559

three so we'll measure the side we'll

1165

00:51:46,130 --> 00:51:42,300

measure the transit depth

1166

00:51:49,549 --> 00:51:46,140

at Green at 2.1 we'll measure it at 1.8

1167

00:51:51,410 --> 00:51:49,559

and we'll measure it at 2.3

1168

00:51:53,870 --> 00:51:51,420

and I'm going to give you just some

1169

00:51:57,589 --> 00:51:53,880

arbitrary numbers here and we can just

1170

00:51:59,750 --> 00:51:57,599

pretend that these are we can just say

1171

00:52:01,069 --> 00:51:59,760

that you know let's call this one let's

1172

00:52:06,170 --> 00:52:01,079

call this

1173

00:52:08,650 --> 00:52:06,180

and what we're going to do now instead

1174

00:52:12,170 --> 00:52:08,660

of making a plot that's brightness

1175

00:52:14,089 --> 00:52:12,180

versus time we're actually just going to

1176
00:52:16,069 --> 00:52:14,099
plot these two things against each other

1177
00:52:19,790 --> 00:52:16,079
so we're going to plot wavelength and

1178
00:52:24,230 --> 00:52:21,349
and so

1179
00:52:27,349 --> 00:52:24,240
what we'll do is we'll put Transit depth

1180
00:52:30,049 --> 00:52:27,359
on the y-axis and we'll put wavelength

1181
00:52:32,329 --> 00:52:30,059
on the x-axis and so let's we'll do it

1182
00:52:35,150 --> 00:52:32,339
together okay so if we have wavelength

1183
00:52:38,930 --> 00:52:35,160
at 1.8 which corresponds to a Transit

1184
00:52:42,230 --> 00:52:38,940
depth of two so here's 1.8 and there's

1185
00:52:44,930 --> 00:52:42,240
two so there's our purple fuchsia

1186
00:52:49,190 --> 00:52:44,940
magenta Dot we can do the same thing

1187
00:52:51,890 --> 00:52:49,200
with green green is at 2.1 microns and a

1188
00:52:54,290 --> 00:52:51,900

Transit depth at one so we'll plot that

1189

00:52:58,609 --> 00:52:54,300

green point right there and then finally

1190

00:53:01,549 --> 00:52:58,619

that orange point is 2.3 microns

1191

00:53:05,150 --> 00:53:01,559

four so we'll put that right there

1192

00:53:08,569 --> 00:53:05,160

and this is our transmission Spectrum

1193

00:53:09,890 --> 00:53:08,579

this is what I spend my days trying to

1194

00:53:12,230 --> 00:53:09,900

make

1195

00:53:14,690 --> 00:53:12,240

now the really really important point

1196

00:53:17,329 --> 00:53:14,700

that I want you to take away from this

1197

00:53:20,329 --> 00:53:17,339

plot is that the fact that these points

1198

00:53:22,910 --> 00:53:20,339

are not at the same depth at every

1199

00:53:25,910 --> 00:53:22,920

wavelength suggest that the planet has

1200

00:53:28,370 --> 00:53:25,920

an atmosphere because it suggests that

1201
00:53:30,770 --> 00:53:28,380
there are molecules in the atmosphere

1202
00:53:33,710 --> 00:53:30,780
that are absorbing at very specific

1203
00:53:36,230 --> 00:53:33,720
wavelengths causing the planet to change

1204
00:53:39,109 --> 00:53:36,240
its apparent size in a wavelength

1205
00:53:43,069 --> 00:53:39,119
dependent manner

1206
00:53:45,109 --> 00:53:43,079
so you might ask me okay what happens if

1207
00:53:47,089 --> 00:53:45,119
we just see this

1208
00:53:49,790 --> 00:53:47,099
what happens if we don't see any

1209
00:53:52,309 --> 00:53:49,800
difference in the transit depth across

1210
00:53:55,910 --> 00:53:52,319
all of the different wavelengths

1211
00:53:58,010 --> 00:53:55,920
that would suggest that the planet has

1212
00:53:59,809 --> 00:53:58,020
no atmosphere in other words that the

1213
00:54:01,370 --> 00:53:59,819

spectrum is flat

1214

00:54:04,010 --> 00:54:01,380

because

1215

00:54:06,849 --> 00:54:04,020

this is basically telling us that

1216

00:54:09,829 --> 00:54:06,859

there's nothing about the planet that's

1217

00:54:12,349 --> 00:54:09,839

changing across wavelengths meaning

1218

00:54:14,450 --> 00:54:12,359

there are no atoms or molecules that are

1219

00:54:17,569 --> 00:54:14,460

absorbing at specific wavelengths

1220

00:54:19,549 --> 00:54:17,579

causing specific changes everything is

1221

00:54:24,710 --> 00:54:19,559

the same

1222

00:54:27,950 --> 00:54:24,720

uh so if a spectrum is a flat line we we

1223

00:54:30,470 --> 00:54:27,960

think that it likely does not have an

1224

00:54:32,450 --> 00:54:30,480

atmosphere or at least not a detectable

1225

00:54:34,730 --> 00:54:32,460

atmosphere we'll get more into this

1226

00:54:36,470 --> 00:54:34,740

later

1227

00:54:39,950 --> 00:54:36,480

okay

1228

00:54:42,530 --> 00:54:39,960

so again just to kind of summarize and

1229

00:54:45,290 --> 00:54:42,540

make sure we're all on the same page we

1230

00:54:47,230 --> 00:54:45,300

can look at these Transit depths at

1231

00:54:49,849 --> 00:54:47,240

different wavelengths and that tells us

1232

00:54:52,609 --> 00:54:49,859

what is in the atmosphere

1233

00:54:53,990 --> 00:54:52,619

and we use the molecules that are in the

1234

00:54:55,670 --> 00:54:54,000

atmosphere to then tell us about

1235

00:54:57,109 --> 00:54:55,680

something that's in the planet but to

1236

00:55:00,170 --> 00:54:57,119

tell us something about the planet right

1237

00:55:02,569 --> 00:55:00,180

so if a planet say

1238

00:55:05,990 --> 00:55:02,579

uh like Earth if we were to look at

1239

00:55:08,030 --> 00:55:06,000

Earth we would expect to see ozone in

1240

00:55:09,890 --> 00:55:08,040

Earth's transmission spectrum because we

1241

00:55:13,069 --> 00:55:09,900

know there's ozone in Earth's atmosphere

1242

00:55:16,390 --> 00:55:13,079

that tells us things like you know we we

1243

00:55:19,130 --> 00:55:16,400

think that ozone might be a

1244

00:55:22,250 --> 00:55:19,140

biosignature if you couple it with other

1245

00:55:25,309 --> 00:55:22,260

molecules under certain situations

1246

00:55:27,650 --> 00:55:25,319

uh you can also say oh all right I want

1247

00:55:31,430 --> 00:55:27,660

I see I only see water on this world

1248

00:55:33,589 --> 00:55:31,440

maybe this world is an ocean world

1249

00:55:36,049 --> 00:55:33,599

again we're really in the early stages

1250

00:55:39,950 --> 00:55:36,059

of trying to

1251
00:55:41,510 --> 00:55:39,960
um go from this uh leftmost point to the

1252
00:55:43,190 --> 00:55:41,520
rightmost point we're trying to under

1253
00:55:44,870 --> 00:55:43,200
we're trying to see what molecules are

1254
00:55:46,970 --> 00:55:44,880
in the atmosphere and then interpret

1255
00:55:50,270 --> 00:55:46,980
them based on what we know about the

1256
00:55:52,069 --> 00:55:50,280
planet's radius and mass and kind of

1257
00:55:53,690 --> 00:55:52,079
create a picture of the planet because

1258
00:55:55,730 --> 00:55:53,700
with all of this we're never actually

1259
00:55:57,710 --> 00:55:55,740
like taking an image of the planet right

1260
00:56:01,790 --> 00:55:57,720
all we're getting is the Starlight from

1261
00:56:05,569 --> 00:56:01,800
the planet which means that we right now

1262
00:56:08,270 --> 00:56:05,579
you know only have validation from these

1263
00:56:10,430 --> 00:56:08,280

Spectrum from from the Spectra we don't

1264

00:56:15,410 --> 00:56:10,440

can't actually take a snapshot of it

1265

00:56:21,170 --> 00:56:17,990

's doing a great job I think that we're

1266

00:56:23,329 --> 00:56:21,180

ready to look at some real data now I'm

1267

00:56:25,430 --> 00:56:23,339

excited to show you this because it's it

1268

00:56:28,809 --> 00:56:25,440

is beautiful I think it's beautiful and

1269

00:56:33,710 --> 00:56:28,819

I hope you will too so this says data

1270

00:56:36,049 --> 00:56:33,720

that my friend and colleague Zafar uh

1271

00:56:37,910 --> 00:56:36,059

worked on very hard last year and it was

1272

00:56:40,730 --> 00:56:37,920

actually presented to Congress a few

1273

00:56:43,609 --> 00:56:40,740

months ago so I just always have to uh

1274

00:56:45,770 --> 00:56:43,619

brag about that presented in a good way

1275

00:56:47,450 --> 00:56:45,780

to say you know look at what the James

1276

00:56:49,670 --> 00:56:47,460

Webb Telescope has been able to

1277

00:56:55,549 --> 00:56:49,680

accomplish so what you're looking at

1278

00:56:58,250 --> 00:56:55,559

here are the are various light curves at

1279

00:57:01,250 --> 00:56:58,260

different wavelengths so this is

1280

00:57:05,210 --> 00:57:01,260

my crons are micrometers this is again

1281

00:57:07,309 --> 00:57:05,220

just a different uh unit of distance and

1282

00:57:10,130 --> 00:57:07,319

this offset that you use is just

1283

00:57:11,569 --> 00:57:10,140

arbitrary it's uh we're seeing them

1284

00:57:13,549 --> 00:57:11,579

stacked on top of each other just to

1285

00:57:17,510 --> 00:57:13,559

make a really pretty picture

1286

00:57:20,809 --> 00:57:17,520

but you can see this transition from the

1287

00:57:23,870 --> 00:57:20,819

redder wavelengths all the way down to

1288

00:57:26,990 --> 00:57:23,880

Bluer wavelengths

1289

00:57:29,150 --> 00:57:27,000

and so then what Safar did was measure

1290

00:57:31,250 --> 00:57:29,160

that Transit depth in all of these

1291

00:57:35,089 --> 00:57:31,260

different wavelength bins we call them

1292

00:57:36,109 --> 00:57:35,099

just like we did before and he made this

1293

00:57:39,349 --> 00:57:36,119

graph

1294

00:57:42,410 --> 00:57:39,359

he might have seen it before this is a

1295

00:57:44,690 --> 00:57:42,420

transmission spectrum of the hot Jupiter

1296

00:57:47,809 --> 00:57:44,700

wasp 39b

1297

00:57:50,030 --> 00:57:47,819

and look at this so we have again you

1298

00:57:51,410 --> 00:57:50,040

can think of here just the amount of

1299

00:57:54,710 --> 00:57:51,420

that you can think of this is the

1300

00:57:57,589 --> 00:57:54,720

transit depth on the y-axis compared to

1301
00:57:59,450 --> 00:57:57,599
wavelength on the x-axis and we can see

1302
00:58:02,089 --> 00:57:59,460
Peaks here where there's a sodium

1303
00:58:04,910 --> 00:58:02,099
feature here where there is a big carbon

1304
00:58:06,890 --> 00:58:04,920
dioxide feature and then even bigger one

1305
00:58:10,250 --> 00:58:06,900
over here

1306
00:58:13,370 --> 00:58:10,260
right around 4.3 micrometers

1307
00:58:16,549 --> 00:58:13,380
we can also see a small bump here that

1308
00:58:18,049 --> 00:58:16,559
we determined was sulfur dioxide and

1309
00:58:21,410 --> 00:58:18,059
that was the first time this molecule

1310
00:58:23,930 --> 00:58:21,420
was ever detected in an exoplanet

1311
00:58:28,849 --> 00:58:23,940
and so this is

1312
00:58:31,010 --> 00:58:28,859
a big deal because one it's the bin the

1313
00:58:34,329 --> 00:58:31,020

widest wavelength coverage that we have

1314

00:58:36,650 --> 00:58:34,339

ever been able to do with any kind of

1315

00:58:41,150 --> 00:58:36,660

spectroscopy before

1316

00:58:44,049 --> 00:58:41,160

Hubble looks at a smaller subset of this

1317

00:58:47,030 --> 00:58:44,059

region but never before have we had an

1318

00:58:51,049 --> 00:58:47,040

near-infrared detector that measures

1319

00:58:53,870 --> 00:58:51,059

more than one micron at such high at a

1320

00:58:57,530 --> 00:58:53,880

high resolution in space

1321

00:58:59,270 --> 00:58:57,540

and so we are able to see these

1322

00:59:00,650 --> 00:58:59,280

molecules for the very first time even

1323

00:59:02,089 --> 00:59:00,660

though we thought they would be there so

1324

00:59:05,270 --> 00:59:02,099

you know we thought there was likely

1325

00:59:07,910 --> 00:59:05,280

carbon dioxide in this gas giant but

1326

00:59:11,150 --> 00:59:07,920

nobody had ever measured it before and

1327

00:59:13,190 --> 00:59:11,160

so with gas giants in particular now

1328

00:59:15,049 --> 00:59:13,200

we're going to be able to take these

1329

00:59:17,390 --> 00:59:15,059

beautiful Spectra and really understand

1330

00:59:19,670 --> 00:59:17,400

the physics and chemistry of what's

1331

00:59:23,450 --> 00:59:19,680

going on and try to help answer

1332

00:59:26,750 --> 00:59:23,460

questions like do all are do all

1333

00:59:29,990 --> 00:59:26,760

Jupiters form in the same way do they

1334

00:59:32,329 --> 00:59:30,000

form far away from the Star and then

1335

00:59:34,069 --> 00:59:32,339

migrate do they all form where they are

1336

00:59:36,370 --> 00:59:34,079

we're going to really work to understand

1337

00:59:39,349 --> 00:59:36,380

to use these planets to understand

1338

00:59:43,309 --> 00:59:39,359

Planet formation in context and to

1339

00:59:46,250 --> 00:59:43,319

understand you know if all solar systems

1340

00:59:47,510 --> 00:59:46,260

form the same way or if there are a wide

1341

00:59:50,329 --> 00:59:47,520

variety

1342

00:59:57,109 --> 00:59:53,630

types but for now uh we're gonna keep

1343

00:59:59,150 --> 00:59:57,119

going and we are going to talk again

1344

01:00:01,370 --> 00:59:59,160

about rocky planets because I know

1345

01:00:03,829 --> 01:00:01,380

that's why many of you are here and I

1346

01:00:06,349 --> 01:00:03,839

admit that I get very excited about

1347

01:00:08,750 --> 01:00:06,359

rocky planets too

1348

01:00:10,609 --> 01:00:08,760

uh and before we dive into the rocky

1349

01:00:13,190 --> 01:00:10,619

planets I just wanted to give you one

1350

01:00:15,650 --> 01:00:13,200

more caveat that it's not just the size

1351

01:00:17,809 --> 01:00:15,660

of the planet that matters in changing

1352

01:00:20,990 --> 01:00:17,819

the transit depth but it's also the size

1353

01:00:23,030 --> 01:00:21,000

of the star because remember the transit

1354

01:00:26,030 --> 01:00:23,040

depth is dependent on the amount of

1355

01:00:28,549 --> 01:00:26,040

Starlight that blocked which is of

1356

01:00:31,250 --> 01:00:28,559

course dependent on both the size of the

1357

01:00:33,890 --> 01:00:31,260

planet and the size of the star so if

1358

01:00:37,130 --> 01:00:33,900

you have a smaller star a

1359

01:00:38,569 --> 01:00:37,140

correspondingly larger fraction of

1360

01:00:42,289 --> 01:00:38,579

Starlight

1361

01:00:45,530 --> 01:00:42,299

is blocked and so the ideal scenario is

1362

01:00:48,890 --> 01:00:45,540

to have as big a star a bigger planet

1363

01:00:49,970 --> 01:00:48,900

you can around as small a star as

1364

01:00:52,309 --> 01:00:49,980

possible

1365

01:00:55,370 --> 01:00:52,319

and so what this is really brought

1366

01:00:58,490 --> 01:00:55,380

astronomers to is something that we call

1367

01:01:00,170 --> 01:00:58,500

the M dwarf opportunity and to explain

1368

01:01:01,849 --> 01:01:00,180

what that means we're going to take a

1369

01:01:04,309 --> 01:01:01,859

small pause and I'm just going to tell

1370

01:01:07,250 --> 01:01:04,319

you that there are many different types

1371

01:01:10,670 --> 01:01:07,260

of stars we tend to think of

1372

01:01:13,069 --> 01:01:10,680

them all the same when you look up at at

1373

01:01:15,049 --> 01:01:13,079

the stars at night but in fact even with

1374

01:01:17,270 --> 01:01:15,059

your naked eye you can see that some

1375

01:01:19,309 --> 01:01:17,280

stars appear to be bluish while some

1376

01:01:22,670 --> 01:01:19,319

stars appear to be a little bit more red

1377

01:01:24,770 --> 01:01:22,680

there are different types of stars which

1378

01:01:26,870 --> 01:01:24,780

correspond to their size and their

1379

01:01:28,670 --> 01:01:26,880

temperature this is related to that HR

1380

01:01:32,150 --> 01:01:28,680

diagram that Frank was talking about

1381

01:01:34,910 --> 01:01:32,160

earlier before the talk started

1382

01:01:37,370 --> 01:01:34,920

so the sun is a g-type star right here

1383

01:01:40,490 --> 01:01:37,380

and so it's it's pretty average as far

1384

01:01:43,370 --> 01:01:40,500

as size goes I I know the O and B stars

1385

01:01:45,410 --> 01:01:43,380

are huge but we as exoplanets we don't

1386

01:01:50,150 --> 01:01:45,420

we don't really focus on these Stars too

1387

01:01:53,690 --> 01:01:50,160

much yet we really focus on uh the mkg

1388

01:01:55,849 --> 01:01:53,700

and F Stars over here on the left and so

1389

01:01:59,270 --> 01:01:55,859

the sun is pretty average but look how

1390

01:02:01,670 --> 01:01:59,280

small these M dwarf stars are so M stars

1391

01:02:03,410 --> 01:02:01,680

are the smallest star possible which

1392

01:02:06,170 --> 01:02:03,420

means that the data that we collect

1393

01:02:08,930 --> 01:02:06,180

about their planets are going to be the

1394

01:02:10,789 --> 01:02:08,940

the highest quality and so

1395

01:02:13,010 --> 01:02:10,799

for rocky planets we've really called

1396

01:02:16,549 --> 01:02:13,020

this the M dwarf opportunity because

1397

01:02:19,490 --> 01:02:16,559

rocky planets are really hard to detect

1398

01:02:22,670 --> 01:02:19,500

and characterize and so the smaller the

1399

01:02:24,890 --> 01:02:22,680

star the easier it is so we're really

1400

01:02:27,049 --> 01:02:24,900

focused here

1401

01:02:29,150 --> 01:02:27,059

the other caveat to that is that M

1402

01:02:32,930 --> 01:02:29,160

dwarfs are

1403

01:02:36,289 --> 01:02:32,940

are cooler so the smaller the star is

1404

01:02:38,750 --> 01:02:36,299

the cooler it is and that means that the

1405

01:02:40,370 --> 01:02:38,760

habitable zones of these Stars the

1406

01:02:43,250 --> 01:02:40,380

region around these stars that could

1407

01:02:45,349 --> 01:02:43,260

likely host liquid water is a lot closer

1408

01:02:47,630 --> 01:02:45,359

into the star

1409

01:02:49,370 --> 01:02:47,640

and that is important because almost all

1410

01:02:53,450 --> 01:02:49,380

of the planets we see are very very

1411

01:02:56,329 --> 01:02:53,460

close into the star and and that is

1412

01:02:58,309 --> 01:02:56,339

simply an observational bias because we

1413

01:03:00,470 --> 01:02:58,319

need to see the planet going around the

1414

01:03:03,109 --> 01:03:00,480

star multiple times in order for it to

1415

01:03:05,270 --> 01:03:03,119

be around a planet so if we had a planet

1416

01:03:09,349 --> 01:03:05,280

like Earth that means that it would

1417

01:03:11,089 --> 01:03:09,359

Transit every 365 days right but the

1418

01:03:14,569 --> 01:03:11,099

planets that we are looking at are

1419

01:03:17,990 --> 01:03:14,579

largely trans are largely transiting on

1420

01:03:20,210 --> 01:03:18,000

the order of every 2 to 20 days so

1421

01:03:23,030 --> 01:03:20,220

they're much much closer in to their

1422

01:03:25,730 --> 01:03:23,040

host stars but this also means again for

1423

01:03:27,589 --> 01:03:25,740

M dwarfs that the habitable zone is that

1424

01:03:31,250 --> 01:03:27,599

much closer in so you might have a

1425

01:03:34,609 --> 01:03:31,260

planet that is still transits its star

1426

01:03:38,510 --> 01:03:34,619

every say 15 days meaning its whole year

1427

01:03:41,450 --> 01:03:38,520

is only 15 days yet it's still

1428

01:03:43,730 --> 01:03:41,460

in a region where we might expect liquid

1429

01:03:45,170 --> 01:03:43,740

water to be

1430

01:03:47,690 --> 01:03:45,180

so

1431

01:03:49,130 --> 01:03:47,700

there's one uh mdorf system that's

1432

01:03:54,470 --> 01:03:49,140

pretty popular and you might have heard

1433

01:03:59,990 --> 01:03:58,490

again we I I just want to bring this up

1434

01:04:01,670 --> 01:04:00,000

as an example because I know it's the

1435

01:04:04,430 --> 01:04:01,680

one that people love and get excited

1436

01:04:08,089 --> 01:04:04,440

about so you can see that if you compare

1437

01:04:11,210 --> 01:04:08,099

the inner solar system here uh here's

1438

01:04:14,930 --> 01:04:11,220

Mercury's orbit and here is this little

1439

01:04:17,270 --> 01:04:14,940

drawing of where the Trappist planets

1440

01:04:21,109 --> 01:04:17,280

would be if you placed them around the

1441

01:04:23,150 --> 01:04:21,119

Sun so this outermost ring corresponds

1442

01:04:25,069 --> 01:04:23,160

to this planet H that's all the way

1443

01:04:27,289 --> 01:04:25,079

around here so all these planets are

1444

01:04:29,270 --> 01:04:27,299

really really close to their host star

1445

01:04:32,450 --> 01:04:29,280

if you haven't heard of the Travis 1

1446

01:04:35,930 --> 01:04:32,460

System it is a it is a system of seven

1447

01:04:38,930 --> 01:04:35,940

uh presumably rocky planets

1448

01:04:41,990 --> 01:04:38,940

um that that is pretty close by to Earth

1449

01:04:44,809 --> 01:04:42,000

that people have been really excited to

1450

01:04:46,370 --> 01:04:44,819

look at for the possibility of seeing an

1451

01:04:50,990 --> 01:04:46,380

atmosphere

1452

01:04:53,630 --> 01:04:51,000

are so small we've actually never

1453

01:04:55,970 --> 01:04:53,640

successfully measured a molecule around

1454

01:04:57,349 --> 01:04:55,980

a rocky planet before and that is what

1455

01:04:58,849 --> 01:04:57,359

we're trying to do

1456

01:05:01,730 --> 01:04:58,859

right now

1457

01:05:03,530 --> 01:05:01,740

and the reason that that is the first

1458

01:05:05,870 --> 01:05:03,540

question that we're trying to answer is

1459

01:05:07,309 --> 01:05:05,880

that this is you know now I would argue

1460

01:05:08,630 --> 01:05:07,319

with the launch of the James Webb

1461

01:05:11,030 --> 01:05:08,640

Telescope we're on the road to

1462

01:05:13,430 --> 01:05:11,040

understanding habitability and so again

1463

01:05:15,890 --> 01:05:13,440

we're the very first question we have to

1464

01:05:18,650 --> 01:05:15,900

ask is do these planets have atmospheres

1465

01:05:21,589 --> 01:05:18,660

do we see signs of molecules absorbing

1466

01:05:23,930 --> 01:05:21,599

light in their atmospheres

1467

01:05:26,630 --> 01:05:23,940

from there we can ask you know could

1468

01:05:29,030 --> 01:05:26,640

this planet host liquid water on its

1469

01:05:31,309 --> 01:05:29,040

surface and be habitable

1470

01:05:33,950 --> 01:05:31,319

and then after we answer that question

1471

01:05:36,049 --> 01:05:33,960

then we can ask does this planet have

1472

01:05:37,549 --> 01:05:36,059

Signs of Life in its atmosphere

1473

01:05:40,309 --> 01:05:37,559

atmosphere and I I really want to

1474

01:05:43,010 --> 01:05:40,319

emphasize that we are only at this first

1475

01:05:46,309 --> 01:05:43,020

question we are just starting to answer

1476

01:05:48,770 --> 01:05:46,319

this first question for rocky planets

1477

01:05:52,789 --> 01:05:48,780

and by just I mean like literally in the

1478

01:05:54,470 --> 01:05:52,799

last six months so I have some uh you

1479

01:05:57,170 --> 01:05:54,480

know I I don't have an answer for you

1480

01:05:59,750 --> 01:05:57,180

yet we are actively trying to figure

1481

01:06:01,069 --> 01:05:59,760

this out but I really encourage you to

1482

01:06:04,789 --> 01:06:01,079

stay tuned

1483

01:06:06,770 --> 01:06:04,799

over the course of the next year two

1484

01:06:08,510 --> 01:06:06,780

years five years a decade because I

1485

01:06:11,210 --> 01:06:08,520

really do feel like soon we'll be able

1486

01:06:13,910 --> 01:06:11,220

to understand the landscape of rocky

1487

01:06:15,890 --> 01:06:13,920

planets a lot more to see you know do

1488

01:06:18,349 --> 01:06:15,900

these have atmosphere do many of them

1489

01:06:20,329 --> 01:06:18,359

have atmospheres or do many of them not

1490

01:06:22,250 --> 01:06:20,339

but we're gonna look at an example don't

1491

01:06:25,430 --> 01:06:22,260

worry I don't have no I don't have I

1492

01:06:28,370 --> 01:06:25,440

have some information for you and what

1493

01:06:30,230 --> 01:06:28,380

we typically do is we we want to

1494

01:06:32,210 --> 01:06:30,240

understand these planets in the context

1495

01:06:34,670 --> 01:06:32,220

of our own solar system so that we have

1496

01:06:37,549 --> 01:06:34,680

something to compare them to so usually

1497

01:06:39,829 --> 01:06:37,559

we look at a rocky exoplanet and we say

1498

01:06:42,470 --> 01:06:39,839

okay can I compare this to a rocky

1499

01:06:44,230 --> 01:06:42,480

planet in our own solar system so what I

1500

01:06:47,510 --> 01:06:44,240

mean by that is that you have say

1501

01:06:48,950 --> 01:06:47,520

Mercury which has basically no

1502

01:06:50,569 --> 01:06:48,960

atmosphere

1503

01:06:52,609 --> 01:06:50,579

could it be like Mercury

1504

01:06:55,010 --> 01:06:52,619

could it be like Venus and have a really

1505

01:06:57,770 --> 01:06:55,020

really thick atmosphere that's made

1506

01:07:00,109 --> 01:06:57,780

mostly of carbon dioxide it's very toxic

1507

01:07:02,089 --> 01:07:00,119

and hot and dense

1508

01:07:05,089 --> 01:07:02,099

could it be like Earth could it be

1509

01:07:08,270 --> 01:07:05,099

thinner possibly hospitable

1510

01:07:10,069 --> 01:07:08,280

or could it be like Mars very tenuous

1511

01:07:14,089 --> 01:07:10,079

and thin

1512

01:07:17,270 --> 01:07:14,099

these are the usual comparisons that we

1513

01:07:19,069 --> 01:07:17,280

make when we when we look at Rocky

1514

01:07:21,470 --> 01:07:19,079

exoplanets

1515

01:07:24,470 --> 01:07:21,480

and again just like it's easier to

1516

01:07:27,950 --> 01:07:24,480

detect bigger planets it's also easier

1517

01:07:30,049 --> 01:07:27,960

to detect thicker atmospheres because by

1518

01:07:32,329 --> 01:07:30,059

Nature they're they're just bigger and

1519

01:07:34,789 --> 01:07:32,339

so that means the signal is that much

1520

01:07:36,950 --> 01:07:34,799

stronger

1521

01:07:39,890 --> 01:07:36,960

what this means is that what I told you

1522

01:07:42,289 --> 01:07:39,900

before about a flat line meaning that

1523

01:07:46,130 --> 01:07:42,299

the planet has no atmosphere was uh was

1524

01:07:49,010 --> 01:07:46,140

kind of a lie because it might not be

1525

01:07:52,490 --> 01:07:49,020

that simple the planet might have an

1526

01:07:56,329 --> 01:07:52,500

atmosphere but it might just not be

1527

01:07:58,670 --> 01:07:56,339

detectable you because of our data

1528

01:08:02,809 --> 01:07:58,680

quality because the atmosphere is too

1529

01:08:06,170 --> 01:08:02,819

thin or or too full of clouds that block

1530

01:08:09,049 --> 01:08:06,180

signal to actually be able to detect

1531

01:08:10,910 --> 01:08:09,059

anything in our transmission Spectrum

1532

01:08:13,970 --> 01:08:10,920

so I'm going to show you an example of

1533

01:08:16,729 --> 01:08:13,980

that this is a project that I worked on

1534

01:08:20,269 --> 01:08:16,739

in the fall this pup this paper was

1535

01:08:23,510 --> 01:08:20,279

published a couple of months ago and I'm

1536

01:08:26,709 --> 01:08:23,520

going to show you what I mean by this so

1537

01:08:30,590 --> 01:08:26,719

this is a planet called LHS

1538

01:08:32,689 --> 01:08:30,600

475b yes I know we are very good at

1539

01:08:34,910 --> 01:08:32,699

naming things in astronomy

1540

01:08:38,570 --> 01:08:34,920

I can't take credit

1541

01:08:40,070 --> 01:08:38,580

and we can see the transmission Spectrum

1542

01:08:42,530 --> 01:08:40,080

here

1543

01:08:45,709 --> 01:08:42,540

all of these black points this is our

1544

01:08:47,930 --> 01:08:45,719

data so anytime you know in astronomy we

1545

01:08:49,910 --> 01:08:47,940

have data and basically all science you

1546

01:08:52,849 --> 01:08:49,920

have data that you then have to compare

1547

01:08:55,970 --> 01:08:52,859

to a model in order to interpret it

1548

01:08:57,769 --> 01:08:55,980

and so here are all of our points and

1549

01:09:00,110 --> 01:08:57,779

you can see that like if you just kind

1550

01:09:04,070 --> 01:09:00,120

of take a look step back and look at it

1551

01:09:06,110 --> 01:09:04,080

that looks pretty flat by eye right and

1552

01:09:07,970 --> 01:09:06,120

especially when you plop a couple of

1553

01:09:10,189 --> 01:09:07,980

these models on here that would predict

1554

01:09:13,430 --> 01:09:10,199

huge features and you say okay I don't

1555

01:09:16,729 --> 01:09:13,440

see anything there that is clearly flat

1556

01:09:20,209 --> 01:09:16,739

there's no atmosphere on this planet

1557

01:09:23,689 --> 01:09:20,219

but what if it's not as simple what if

1558

01:09:26,209 --> 01:09:23,699

we zoom in on this region in Gray here

1559

01:09:28,970 --> 01:09:26,219

and we plot some more models on it

1560

01:09:32,510 --> 01:09:28,980

and okay so now we're zoomed in and we

1561

01:09:36,470 --> 01:09:32,520

have some more models here and we can

1562

01:09:38,630 --> 01:09:36,480

see okay what if there's water or carbon

1563

01:09:41,689 --> 01:09:38,640

dioxide like there are these lines

1564

01:09:44,030 --> 01:09:41,699

basically run through the data but we

1565

01:09:46,309 --> 01:09:44,040

can't distinguish which of these lines

1566

01:09:49,309 --> 01:09:46,319

is accurate and we also have again just

1567

01:09:52,010 --> 01:09:49,319

this very flat line that seems to fit

1568

01:09:55,310 --> 01:09:52,020

the data just as well

1569

01:09:57,350 --> 01:09:55,320

and so in this scenario we can say that

1570

01:10:00,110 --> 01:09:57,360

all right while we can rule out an

1571

01:10:02,030 --> 01:10:00,120

Earth-like atmosphere we're actually not

1572

01:10:03,530 --> 01:10:02,040

sure which of these other scenarios it

1573

01:10:06,530 --> 01:10:03,540

is it could be that there's no

1574

01:10:09,290 --> 01:10:06,540

atmosphere but it could also be that

1575

01:10:11,810 --> 01:10:09,300

there are too many clouds that block our

1576

01:10:14,390 --> 01:10:11,820

signal or it could be that the

1577

01:10:16,130 --> 01:10:14,400

atmosphere is just too thin to detect so

1578

01:10:18,229 --> 01:10:16,140

we need better data quality to

1579

01:10:21,310 --> 01:10:18,239

distinguish between these scenarios for

1580

01:10:23,810 --> 01:10:21,320

now that means we need either different

1581

01:10:27,050 --> 01:10:23,820

different techniques that we can use

1582

01:10:29,570 --> 01:10:27,060

with the James Webb Telescope or more

1583

01:10:31,390 --> 01:10:29,580

transits with the telescope to improve

1584

01:10:33,410 --> 01:10:31,400

our data quality

1585

01:10:37,189 --> 01:10:33,420

and so that's

1586

01:10:39,050 --> 01:10:37,199

that is where we are at right now

1587

01:10:42,410 --> 01:10:39,060

where are we going

1588

01:10:45,350 --> 01:10:42,420

I will say right now we have not no

1589

01:10:48,950 --> 01:10:45,360

astronomer has published a paper showing

1590

01:10:52,790 --> 01:10:48,960

an uh an atmosphere around a rocky

1591

01:10:55,189 --> 01:10:52,800

exoplanet uh and by and specifically

1592

01:10:57,410 --> 01:10:55,199

showing a an atmosphere made of things

1593

01:11:00,169 --> 01:10:57,420

other than just hydrogen we've never

1594

01:11:02,090 --> 01:11:00,179

detected carbon dioxide or of water or

1595

01:11:04,550 --> 01:11:02,100

methane or any of those things around a

1596

01:11:06,110 --> 01:11:04,560

rocky exoplanet I'm really excited at

1597

01:11:08,030 --> 01:11:06,120

the possibility that the James live

1598

01:11:10,430 --> 01:11:08,040

telescope will be able to do that for us

1599

01:11:13,250 --> 01:11:10,440

but I do need to add another caveat

1600

01:11:16,790 --> 01:11:13,260

about the M dwarf opportunity which is

1601
01:11:19,189 --> 01:11:16,800
that yes while these stars are ideal to

1602
01:11:22,370 --> 01:11:19,199
look at there is a caveat that they are

1603
01:11:25,189 --> 01:11:22,380
really really active and what I mean by

1604
01:11:26,990 --> 01:11:25,199
that is that they are spewing out large

1605
01:11:29,870 --> 01:11:27,000
amounts of

1606
01:11:32,149 --> 01:11:29,880
of high energy radiation that could

1607
01:11:34,010 --> 01:11:32,159
actually just be stripping away all of

1608
01:11:35,570 --> 01:11:34,020
these atmospheres and we don't know

1609
01:11:37,430 --> 01:11:35,580
whether this is happening or not yet

1610
01:11:39,770 --> 01:11:37,440
this is what we're trying to find out

1611
01:11:41,689 --> 01:11:39,780
right now so with that first planet that

1612
01:11:43,669 --> 01:11:41,699
I showed you we didn't see an atmosphere

1613
01:11:45,649 --> 01:11:43,679

but again you can't draw a conclusion

1614

01:11:48,110 --> 01:11:45,659

just based on one planet we need to

1615

01:11:50,930 --> 01:11:48,120

build up a statistical sample in order

1616

01:11:53,030 --> 01:11:50,940

to say okay on average rocky planets

1617

01:11:56,209 --> 01:11:53,040

around M dwarfs do or don't have

1618

01:11:58,790 --> 01:11:56,219

atmospheres or somewhere in between

1619

01:12:01,370 --> 01:11:58,800

so we're really trying to Define what

1620

01:12:04,070 --> 01:12:01,380

has been become known as The Cosmic

1621

01:12:06,530 --> 01:12:04,080

Shoreline so this is trying to

1622

01:12:09,890 --> 01:12:06,540

understand if there is a dividing line

1623

01:12:11,630 --> 01:12:09,900

between planets with atmospheres and

1624

01:12:13,390 --> 01:12:11,640

those without

1625

01:12:16,610 --> 01:12:13,400

and so

1626

01:12:18,590 --> 01:12:16,620

uh you know we want to know does a

1627

01:12:20,510 --> 01:12:18,600

planet have to be a particular size does

1628

01:12:22,790 --> 01:12:20,520

it have to be a particular distance away

1629

01:12:25,250 --> 01:12:22,800

from its star in order to hold on to

1630

01:12:27,350 --> 01:12:25,260

that and that is kind of I think the big

1631

01:12:29,870 --> 01:12:27,360

question that we'll be able to answer in

1632

01:12:32,209 --> 01:12:29,880

the next five years or so or start to

1633

01:12:35,450 --> 01:12:32,219

answer I guess I should say

1634

01:12:37,430 --> 01:12:35,460

and then of course you know we we all

1635

01:12:39,530 --> 01:12:37,440

are I mean I think most people are

1636

01:12:42,649 --> 01:12:39,540

excited at the idea of

1637

01:12:44,990 --> 01:12:42,659

of this burgeoning field of astrobiology

1638

01:12:46,970 --> 01:12:45,000

and and trying to understand if there is

1639

01:12:49,010 --> 01:12:46,980

life in the universe and I I believe

1640

01:12:51,410 --> 01:12:49,020

that we will get there but I encourage

1641

01:12:53,630 --> 01:12:51,420

all of you to just be patient and to be

1642

01:12:56,750 --> 01:12:53,640

skeptical about news that you see

1643

01:12:58,189 --> 01:12:56,760

because people are are and will be

1644

01:13:01,310 --> 01:12:58,199

trying to

1645

01:13:05,090 --> 01:13:01,320

uh claim detections that we just don't

1646

01:13:06,770 --> 01:13:05,100

quite understand yet if they are true or

1647

01:13:09,050 --> 01:13:06,780

or not true we're still in the really

1648

01:13:11,330 --> 01:13:09,060

early stages and one day we will answer

1649

01:13:15,290 --> 01:13:11,340

this but I don't believe that we will

1650

01:13:17,810 --> 01:13:15,300

answer it yet but we are actively

1651

01:13:19,850 --> 01:13:17,820

working on it and we would not be we are

1652

01:13:21,830 --> 01:13:19,860

getting closer with the James Webb Space

1653

01:13:23,870 --> 01:13:21,840

Telescope

1654

01:13:25,490 --> 01:13:23,880

and again the last thing I just want to

1655

01:13:27,950 --> 01:13:25,500

end with is

1656

01:13:30,110 --> 01:13:27,960

to reiterate what I mentioned earlier

1657

01:13:31,970 --> 01:13:30,120

with the fact that there are so many

1658

01:13:34,070 --> 01:13:31,980

different types of exoplanets out there

1659

01:13:36,530 --> 01:13:34,080

and we don't want to neglect our gas

1660

01:13:39,050 --> 01:13:36,540

giants for our rocky planets because in

1661

01:13:41,090 --> 01:13:39,060

order to understand the full story we

1662

01:13:43,790 --> 01:13:41,100

can't just look at a tree we need to

1663

01:13:46,790 --> 01:13:43,800

understand the entire Forest to

1664

01:13:49,910 --> 01:13:46,800

understand the whole landscape

1665

01:13:51,709 --> 01:13:49,920

and and for that we need to care about

1666

01:13:53,450 --> 01:13:51,719

our Jupiters we need to care about our

1667

01:13:55,610 --> 01:13:53,460

Neptunes and we need to care about our

1668

01:13:57,649 --> 01:13:55,620

Earths

1669

01:14:00,590 --> 01:13:57,659

but this is a remarkable time that we're

1670

01:14:02,870 --> 01:14:00,600

living in we are able to look at

1671

01:14:04,430 --> 01:14:02,880

atmospheres of Rocky exoplanets that we

1672

01:14:07,729 --> 01:14:04,440

didn't know existed

1673

01:14:09,950 --> 01:14:07,739

20 years ago and I think that you know

1674

01:14:11,450 --> 01:14:09,960

if if we do this talk again in five

1675

01:14:13,130 --> 01:14:11,460

years I hope it'll be a totally

1676

01:14:16,189 --> 01:14:13,140

different talk and that we know so much

1677

01:14:20,390 --> 01:14:16,199

more but this is this is really uh this

1678

01:14:23,209 --> 01:14:20,400

is the start of of a new of a new

1679

01:14:25,130 --> 01:14:23,219

frontier and so I'm I'm really grateful

1680

01:14:27,110 --> 01:14:25,140

to be here I'd just like to thank the

1681

01:14:28,790 --> 01:14:27,120

Space Telescope for giving me the

1682

01:14:31,310 --> 01:14:28,800

opportunity to come and speak with you

1683

01:14:34,430 --> 01:14:31,320

guys and I'm really excited to take your

1684

01:14:37,010 --> 01:14:34,440

questions thank you very much

1685

01:14:39,229 --> 01:14:37,020

all right well thank you Katie for

1686

01:14:40,610 --> 01:14:39,239

coming and uh giving your talk here

1687

01:14:42,950 --> 01:14:40,620

today

1688

01:14:44,390 --> 01:14:42,960

um very pleasant to have very wonderful

1689

01:14:46,550 --> 01:14:44,400

to have you

1690

01:14:50,030 --> 01:14:46,560

um and you know what I liked so much

1691

01:14:52,070 --> 01:14:50,040

about it is that um you know

1692

01:14:54,830 --> 01:14:52,080

first of all you're of the exoplanet

1693

01:14:56,990 --> 01:14:54,840

generation yeah I mean the fact that you

1694

01:14:58,910 --> 01:14:57,000

were born just as the first exoplanets

1695

01:15:01,550 --> 01:14:58,920

were being discovered you're you've

1696

01:15:02,990 --> 01:15:01,560

never been alive when there were when

1697

01:15:05,630 --> 01:15:03,000

there weren't eggplants around other

1698

01:15:07,189 --> 01:15:05,640

stars okay some of us remember a little

1699

01:15:09,050 --> 01:15:07,199

bit of time in our lives before that

1700

01:15:12,950 --> 01:15:09,060

happened right

1701

01:15:15,709 --> 01:15:12,960

um and so you know you represent this

1702

01:15:17,870 --> 01:15:15,719

whole thing and furthermore you know for

1703

01:15:20,209 --> 01:15:17,880

so many years it was always discussing

1704

01:15:22,550 --> 01:15:20,219

these hot Jupiters or maybe some maybe

1705

01:15:24,169 --> 01:15:22,560

the a Saturn size but we're only talking

1706

01:15:25,430 --> 01:15:24,179

about the largest planets because that's

1707

01:15:28,850 --> 01:15:25,440

all we could really do with the radio

1708

01:15:31,430 --> 01:15:28,860

velocity technique of the 1990s and the

1709

01:15:34,189 --> 01:15:31,440

dream of pushing down to rocky planet

1710

01:15:37,430 --> 01:15:34,199

size objects you know was still just a

1711

01:15:39,229 --> 01:15:37,440

dream back then right and so it's not

1712

01:15:41,149 --> 01:15:39,239

only are you the exponent generation but

1713

01:15:44,630 --> 01:15:41,159

you're moving on to the the second

1714

01:15:47,330 --> 01:15:44,640

generation sort of of uh of searching

1715

01:15:50,090 --> 01:15:47,340

for exoplanets so that's uh

1716

01:15:55,729 --> 01:15:50,100

it it's quite PR as a symbol of progress

1717

01:15:59,330 --> 01:15:57,470

I granted

1718

01:16:00,890 --> 01:15:59,340

the fat can study right Rock sub planets

1719

01:16:03,110 --> 01:16:00,900

because I know people have dreamed about

1720

01:16:05,689 --> 01:16:03,120

this for a long time

1721

01:16:08,390 --> 01:16:05,699

I mean um I was at the American Museum

1722

01:16:10,250 --> 01:16:08,400

of Natural History and um Neil Tyson

1723

01:16:13,189 --> 01:16:10,260

Steve Soder and I did the exhibits there

1724

01:16:14,689 --> 01:16:13,199

and at one point we looked at each other

1725

01:16:17,689 --> 01:16:14,699

and said wait a minute

1726

01:16:20,149 --> 01:16:17,699

we now know of more planets outside our

1727

01:16:22,209 --> 01:16:20,159

solar system than we do inside our solar

1728

01:16:24,950 --> 01:16:22,219

system and that was a cool

1729

01:16:25,990 --> 01:16:24,960

that's awesome it's a cool marking point

1730

01:16:28,010 --> 01:16:26,000

right

1731

01:16:29,990 --> 01:16:28,020

we're trying to figure out oh there's a

1732

01:16:31,250 --> 01:16:30,000

way there wasn't a way to put it into

1733

01:16:32,990 --> 01:16:31,260

the exhibits or anything but it was just

1734

01:16:35,330 --> 01:16:33,000

an interesting moment in time to go from

1735

01:16:37,250 --> 01:16:35,340

that yes so um

1736

01:16:39,470 --> 01:16:37,260

I have some questions for you from

1737

01:16:41,930 --> 01:16:39,480

myself and and we've got some questions

1738

01:16:44,870 --> 01:16:41,940

from the uh the Youtube chat here sure

1739

01:16:48,229 --> 01:16:44,880

uh first one I want to ask about is um

1740

01:16:50,810 --> 01:16:48,239

mini Neptunes versus super Earth so

1741

01:16:52,910 --> 01:16:50,820

those planets that are in the you know

1742

01:16:56,270 --> 01:16:52,920

five to eight

1743

01:16:58,310 --> 01:16:56,280

um Earth mass type range right yeah

1744

01:16:59,930 --> 01:16:58,320

um I Heidi Hamel is sometimes described

1745

01:17:02,149 --> 01:16:59,940

them as many raccoons and a lot of

1746

01:17:03,590 --> 01:17:02,159

people describe them as super Earth and

1747

01:17:05,209 --> 01:17:03,600

to me in my head that says all right

1748

01:17:07,070 --> 01:17:05,219

well that just depends upon their

1749

01:17:08,990 --> 01:17:07,080

density doesn't it

1750

01:17:10,490 --> 01:17:09,000

um if they're low density that would be

1751

01:17:12,350 --> 01:17:10,500

a mini Neptune if they're a high density

1752

01:17:14,450 --> 01:17:12,360

that would be a super Earth what do we

1753

01:17:18,229 --> 01:17:14,460

know about that class of class of

1754

01:17:20,270 --> 01:17:18,239

planets and yes yes so the reason that

1755

01:17:22,130 --> 01:17:20,280

there is a question I would argue a

1756

01:17:24,550 --> 01:17:22,140

bigger question mark around those types

1757

01:17:27,229 --> 01:17:24,560

of planets is that there is actually

1758

01:17:29,570 --> 01:17:27,239

degeneracy in the density that we

1759

01:17:32,810 --> 01:17:29,580

measure what we

1760

01:17:35,810 --> 01:17:32,820

we do we measure a bulk density but

1761

01:17:39,530 --> 01:17:35,820

there is kind of a region of size where

1762

01:17:43,209 --> 01:17:39,540

that density based on where that density

1763

01:17:48,470 --> 01:17:43,219

Falls and the planet size it could be

1764

01:17:50,810 --> 01:17:48,480

a small rocky planet surrounded by a big

1765

01:17:55,970 --> 01:17:50,820

heaping Wallop of gas

1766

01:17:58,070 --> 01:17:55,980

or it could be uh it could be say more

1767

01:18:01,850 --> 01:17:58,080

of a large ice giant with a little bit

1768

01:18:03,950 --> 01:18:01,860

of gas so it's that in this it's in this

1769

01:18:06,229 --> 01:18:03,960

kind of intermediate State we can't

1770

01:18:09,050 --> 01:18:06,239

really tell it could be one or it could

1771

01:18:11,209 --> 01:18:09,060

be another but we can't just decide

1772

01:18:12,709 --> 01:18:11,219

based on mass and radius you're right

1773

01:18:15,410 --> 01:18:12,719

that you can absolutely do that with

1774

01:18:17,990 --> 01:18:15,420

like the big hot Jupiters you can

1775

01:18:20,090 --> 01:18:18,000

measure mass measure radius and say okay

1776

01:18:22,610 --> 01:18:20,100

I basically know this is a Jupiter you

1777

01:18:25,189 --> 01:18:22,620

can do it with a really tiny planets the

1778

01:18:26,990 --> 01:18:25,199

earth-sized planets and smaller you can

1779

01:18:29,930 --> 01:18:27,000

say okay I measure a mass I measure

1780

01:18:32,930 --> 01:18:29,940

radius all right this is Rocky but there

1781

01:18:34,490 --> 01:18:32,940

is uh there's just this hazy region in

1782

01:18:36,470 --> 01:18:34,500

the Middle where we can't quite lump

1783

01:18:39,370 --> 01:18:36,480

them in one category or another which is

1784

01:18:42,649 --> 01:18:39,380

why we need to use transmission

1785

01:18:44,270 --> 01:18:42,659

spectroscopy to see if we can see signs

1786

01:18:46,610 --> 01:18:44,280

and molecules in the atmosphere to break

1787

01:18:49,070 --> 01:18:46,620

that degeneracy and tell us is it a mini

1788

01:18:51,709 --> 01:18:49,080

Neptune or is it a super Earth okay okay

1789

01:18:53,689 --> 01:18:51,719

okay so the error bars on the density in

1790

01:18:56,570 --> 01:18:53,699

this mid-range are are large enough that

1791

01:19:00,350 --> 01:18:56,580

you can't really differentiate okay that

1792

01:19:01,729 --> 01:19:00,360

sounds cool all right great so I've been

1793

01:19:03,649 --> 01:19:01,739

watching some of the chat and I know

1794

01:19:05,930 --> 01:19:03,659

Grand justice has been watching it even

1795

01:19:08,870 --> 01:19:05,940

closer than I have so Grant why don't

1796

01:19:10,430 --> 01:19:08,880

you turn on your video and uh tell us

1797

01:19:11,930 --> 01:19:10,440

some of the favorite questions you found

1798

01:19:14,090 --> 01:19:11,940

in the chat tonight

1799

01:19:16,370 --> 01:19:14,100

absolutely

1800

01:19:20,570 --> 01:19:16,380

so um yeah we've had a good chat tonight

1801
01:19:22,310 --> 01:19:20,580
uh I'm Gonna Get Us started with

1802
01:19:23,570 --> 01:19:22,320
this one

1803
01:19:27,050 --> 01:19:23,580
um so we did a lot of talk about

1804
01:19:29,030 --> 01:19:27,060
exoplanets and Discovery Futures thereof

1805
01:19:31,610 --> 01:19:29,040
and I would encourage this speaker I

1806
01:19:34,970 --> 01:19:31,620
mean this commenter to check out our

1807
01:19:38,209 --> 01:19:34,980
video on specifically EXO moons but are

1808
01:19:40,669 --> 01:19:38,219
a lot of the same principles applied to

1809
01:19:43,370 --> 01:19:40,679
finding exoplanets as it as they are to

1810
01:19:46,130 --> 01:19:43,380
EXO moons what's different in how you

1811
01:19:57,530 --> 01:19:46,140
search or how you

1812
01:20:05,209 --> 01:20:01,070
technique meaning you know we still use

1813
01:20:07,729 --> 01:20:05,219

the transit technique uh to look for an

1814

01:20:10,370 --> 01:20:07,739

EXO moon but what you can do is if you

1815

01:20:13,070 --> 01:20:10,380

if you think about that light curve you

1816

01:20:15,110 --> 01:20:13,080

basically want to look at the light

1817

01:20:18,169 --> 01:20:15,120

curve and then see if there's another

1818

01:20:20,810 --> 01:20:18,179

dip in the light curve caused by a moon

1819

01:20:24,290 --> 01:20:20,820

that's moving around and blocking or

1820

01:20:27,709 --> 01:20:24,300

blocking an extra portion of the light

1821

01:20:29,209 --> 01:20:27,719

uh I would say that we are

1822

01:20:32,450 --> 01:20:29,219

um

1823

01:20:35,750 --> 01:20:32,460

it's it's hazy you're trying to you know

1824

01:20:38,450 --> 01:20:35,760

trying to uncover an exomoon because the

1825

01:20:43,250 --> 01:20:38,460

signals from the planets themselves are

1826
01:20:43,910 --> 01:20:43,260
so noisy that it would be hard to then

1827
01:20:46,370 --> 01:20:43,920
um

1828
01:20:49,490 --> 01:20:46,380
it would be hard to then go down even

1829
01:20:51,590 --> 01:20:49,500
smaller to try to find the moon people

1830
01:20:53,810 --> 01:20:51,600
are looking for sure and we do have some

1831
01:20:56,870 --> 01:20:53,820
EXO Moon candidates we don't have any

1832
01:20:59,390 --> 01:20:56,880
that have been verified yet and that's

1833
01:21:01,970 --> 01:20:59,400
mostly because the data is is noisy so

1834
01:21:03,830 --> 01:21:01,980
it's hard to validate that but yes it's

1835
01:21:07,189 --> 01:21:03,840
the same technique it's basically you

1836
01:21:08,990 --> 01:21:07,199
lit you look for uh blips in the data

1837
01:21:12,709 --> 01:21:09,000
where you wouldn't expect there to be

1838
01:21:14,750 --> 01:21:12,719

let's go okay and and so for most of the

1839

01:21:16,490 --> 01:21:14,760

moons like in the solar system yeah

1840

01:21:19,130 --> 01:21:16,500

they're much much smaller than their

1841

01:21:23,270 --> 01:21:19,140

planet right right I mean actually Earth

1842

01:21:25,490 --> 01:21:23,280

and our moon is as as as an anomaly that

1843

01:21:28,010 --> 01:21:25,500

uh our moon is a significant size

1844

01:21:29,990 --> 01:21:28,020

compared to compared to Earth so if it's

1845

01:21:32,689 --> 01:21:30,000

like you know one one-tenth the size

1846

01:21:35,810 --> 01:21:32,699

that's only one 100th the the blocking

1847

01:21:38,510 --> 01:21:35,820

area right and then the the planet that

1848

01:21:41,750 --> 01:21:38,520

decrement is only like two percent maybe

1849

01:21:44,149 --> 01:21:41,760

of the the light and so that would be

1850

01:21:46,130 --> 01:21:44,159

for a huge Planet you know even Jupiter

1851
01:21:49,070 --> 01:21:46,140
a jupiter-sized planet would only block

1852
01:21:52,490 --> 01:21:49,080
one percent of the Sun and then so you'd

1853
01:21:55,070 --> 01:21:52,500
be talking 0.01 right for the moon all

1854
01:21:57,110 --> 01:21:55,080
right so yeah that the I mean generously

1855
01:21:59,270 --> 01:21:57,120
I I absolutely love the diagram you

1856
01:22:02,390 --> 01:21:59,280
showed and just all that beautiful data

1857
01:22:04,250 --> 01:22:02,400
lining up so nicely yes getting one

1858
01:22:06,410 --> 01:22:04,260
percent and finding a one percent

1859
01:22:08,090 --> 01:22:06,420
Diplomat that's got to be in the error

1860
01:22:09,890 --> 01:22:08,100
of ours right which which is why it

1861
01:22:11,950 --> 01:22:09,900
would be hard to do there are some folks

1862
01:22:14,510 --> 01:22:11,960
who are look looking into kind of into

1863
01:22:16,550 --> 01:22:14,520

atmospheric signatures from the moons

1864

01:22:18,169 --> 01:22:16,560

themselves but it becomes very

1865

01:22:20,090 --> 01:22:18,179

complicated when you're trying to

1866

01:22:22,250 --> 01:22:20,100

disentangle you know you have

1867

01:22:23,750 --> 01:22:22,260

information coming from the star that

1868

01:22:25,910 --> 01:22:23,760

you have to in disentangle from the

1869

01:22:27,410 --> 01:22:25,920

planet and that's hard to start with you

1870

01:22:29,090 --> 01:22:27,420

need to make sure that the signal you're

1871

01:22:30,590 --> 01:22:29,100

seeing is from the planet and not the

1872

01:22:33,110 --> 01:22:30,600

star and then that would be a whole

1873

01:22:34,970 --> 01:22:33,120

other added layer on top of that if if

1874

01:22:36,770 --> 01:22:34,980

you say okay yes we do think that

1875

01:22:40,070 --> 01:22:36,780

there's a moon so what signal is coming

1876

01:22:42,470 --> 01:22:40,080

from the moon but I think I I think we

1877

01:22:45,709 --> 01:22:42,480

will get there but I it yeah it's

1878

01:22:47,630 --> 01:22:45,719

I I suspect right now many of the

1879

01:22:49,729 --> 01:22:47,640

signals of moons are just buried in the

1880

01:22:52,130 --> 01:22:49,739

noise

1881

01:22:53,630 --> 01:22:52,140

it's also a very new telescope so I

1882

01:22:56,810 --> 01:22:53,640

would imagine right just like Hubble

1883

01:22:59,090 --> 01:22:56,820

over time we'll refine those

1884

01:23:01,250 --> 01:22:59,100

exactly yes

1885

01:23:03,050 --> 01:23:01,260

okay uh this is interesting I hadn't

1886

01:23:06,830 --> 01:23:03,060

really thought about this one

1887

01:23:08,570 --> 01:23:06,840

um how do you know at what angle or like

1888

01:23:11,930 --> 01:23:08,580

at what

1889

01:23:14,450 --> 01:23:11,940

view you are observing the galaxies the

1890

01:23:15,890 --> 01:23:14,460

planets the systems yeah us oh that's a

1891

01:23:17,810 --> 01:23:15,900

good question I think I'm going to share

1892

01:23:18,950 --> 01:23:17,820

my screen again for that is that okay go

1893

01:23:21,530 --> 01:23:18,960

for it yeah

1894

01:23:24,830 --> 01:23:21,540

okay yes let's let's see okay okay can

1895

01:23:30,350 --> 01:23:26,390

get hold on one second let me actually

1896

01:23:36,110 --> 01:23:30,360

I'll just go back to the slide

1897

01:23:41,450 --> 01:23:36,120

first uh so basically we can measure

1898

01:23:41,460 --> 01:23:44,510

thank you

1899

01:23:49,310 --> 01:23:46,250

Okay so

1900

01:23:53,149 --> 01:23:49,320

basically we when we measure this light

1901

01:23:54,830 --> 01:23:53,159

curve we can measure the angle based on

1902

01:23:59,090 --> 01:23:54,840

the shape of the light curve everything

1903

01:24:02,209 --> 01:23:59,100

I showed you here was very symmetrical

1904

01:24:05,209 --> 01:24:02,219

um right you know what I this is a very

1905

01:24:08,570 --> 01:24:05,219

like Smooth coming down and very flat

1906

01:24:12,350 --> 01:24:08,580

coming over and smooth coming back but

1907

01:24:14,270 --> 01:24:12,360

basically we can measure something that

1908

01:24:16,370 --> 01:24:14,280

we call an impact parameter which is

1909

01:24:19,550 --> 01:24:16,380

basically just telling us like if we

1910

01:24:20,810 --> 01:24:19,560

imagine this planet is like coming right

1911

01:24:23,030 --> 01:24:20,820

in the middle

1912

01:24:26,930 --> 01:24:23,040

we measure the distance from the middle

1913

01:24:29,810 --> 01:24:26,940

to the top so the the top being

1914

01:24:31,490 --> 01:24:29,820

one so you can say or if an impact if

1915

01:24:32,930 --> 01:24:31,500

it's an impact parameter of zero is

1916

01:24:35,450 --> 01:24:32,940

coming right through the middle if it's

1917

01:24:38,090 --> 01:24:35,460

an impact parameter one it's right right

1918

01:24:41,209 --> 01:24:38,100

at the top and we actually get that from

1919

01:24:44,510 --> 01:24:41,219

the the very shape of the light curve so

1920

01:24:46,790 --> 01:24:44,520

the more kind of even it is the more the

1921

01:24:51,290 --> 01:24:46,800

closer to the center it is

1922

01:24:54,050 --> 01:24:51,300

but the important thing here is that uh

1923

01:24:58,850 --> 01:24:54,060

we we can we can so we can get that

1924

01:25:01,490 --> 01:24:58,860

angle and then if you couple this with a

1925

01:25:03,530 --> 01:25:01,500

radial velocity measurements

1926

01:25:05,810 --> 01:25:03,540

uh which is you know measuring the

1927

01:25:08,209 --> 01:25:05,820

actual motion of the star moving back

1928

01:25:10,910 --> 01:25:08,219

and forth you can also get the

1929

01:25:13,189 --> 01:25:10,920

eccentricity of the curve of the planet

1930

01:25:15,470 --> 01:25:13,199

so you know planets orbits are not

1931

01:25:17,570 --> 01:25:15,480

always totally circular right the planet

1932

01:25:20,990 --> 01:25:17,580

sometimes kind of Loops in more of an

1933

01:25:23,209 --> 01:25:21,000

oval shape around a star and based on

1934

01:25:25,610 --> 01:25:23,219

the shapes that we see in the light

1935

01:25:27,350 --> 01:25:25,620

curve and coupled to the radio velocity

1936

01:25:28,910 --> 01:25:27,360

we can get that information so there are

1937

01:25:30,890 --> 01:25:28,920

a bunch of different orbital parameters

1938

01:25:32,090 --> 01:25:30,900

we know a lot about planet's orbits I

1939

01:25:33,470 --> 01:25:32,100

would argue we probably know more about

1940

01:25:35,770 --> 01:25:33,480

planets orbits than we do about the

1941

01:25:38,750 --> 01:25:35,780

planets themselves

1942

01:25:41,810 --> 01:25:38,760

all right but Katie this also brings up

1943

01:25:43,850 --> 01:25:41,820

a special point that you know if that

1944

01:25:46,370 --> 01:25:43,860

planet were orbiting in the plane of the

1945

01:25:49,430 --> 01:25:46,380

sky up and down on a property we

1946

01:25:51,709 --> 01:25:49,440

wouldn't see a Transit right yes so what

1947

01:25:54,770 --> 01:25:51,719

percentage of orbits

1948

01:25:56,330 --> 01:25:54,780

would produce a Transit right yes in

1949

01:25:58,189 --> 01:25:56,340

order to cross in front of the face of

1950

01:26:00,770 --> 01:25:58,199

that that star from from our perspective

1951

01:26:02,149 --> 01:26:00,780

uh is it one out of ten one out of a

1952

01:26:03,890 --> 01:26:02,159

hundred what do you what's what's the

1953

01:26:05,209 --> 01:26:03,900

estimate there yeah that's so that's a

1954

01:26:06,770 --> 01:26:05,219

really great Point Frank and thank you

1955

01:26:09,229 --> 01:26:06,780

for bringing that up right we are we

1956

01:26:11,330 --> 01:26:09,239

only see planets that happen to be in

1957

01:26:13,370 --> 01:26:11,340

this orientation I'm sure there are many

1958

01:26:15,229 --> 01:26:13,380

planets that we have not discovered yet

1959

01:26:17,149 --> 01:26:15,239

because they're orbiting

1960

01:26:19,669 --> 01:26:17,159

um in our plane in other words they

1961

01:26:23,689 --> 01:26:19,679

don't Transit and the answer to your

1962

01:26:26,149 --> 01:26:23,699

question is that uh the percentage the

1963

01:26:29,090 --> 01:26:26,159

probability actually depends on how

1964

01:26:32,510 --> 01:26:29,100

close this the planet is to the star so

1965

01:26:34,129 --> 01:26:32,520

the closer a planet is to the star uh I

1966

01:26:36,350 --> 01:26:34,139

wonder if I can kind of do this with my

1967

01:26:37,430 --> 01:26:36,360

hand here if you think of like my I'm

1968

01:26:38,990 --> 01:26:37,440

not sure if this is going to work we're

1969

01:26:40,850 --> 01:26:39,000

going to try it um why don't you stop

1970

01:26:42,470 --> 01:26:40,860

your screenshots

1971

01:26:44,270 --> 01:26:42,480

thank you stop the screen share then we

1972

01:26:46,669 --> 01:26:44,280

can see your handy better yeah another

1973

01:26:48,649 --> 01:26:46,679

reminder better okay all right so you

1974

01:26:50,090 --> 01:26:48,659

know if if I have a if I have a planet

1975

01:26:51,590 --> 01:26:50,100

that's right here

1976

01:26:52,610 --> 01:26:51,600

basically it's face it's basically kind

1977

01:26:57,169 --> 01:26:52,620

of

1978

01:27:00,530 --> 01:26:57,179

the angle but if it's all the way say

1979

01:27:03,350 --> 01:27:00,540

out here a small angle means that it's

1980

01:27:06,709 --> 01:27:03,360

not in front of my hand anymore

1981

01:27:08,930 --> 01:27:06,719

right and so planets that are much so so

1982

01:27:12,770 --> 01:27:08,940

I think that

1983

01:27:14,689 --> 01:27:12,780

like something like the Earth already

1984

01:27:17,510 --> 01:27:14,699

like by the time you get out to the

1985

01:27:19,910 --> 01:27:17,520

Earth is a very very small likelihood of

1986

01:27:21,530 --> 01:27:19,920

transiting I mean I think I don't want

1987

01:27:23,750 --> 01:27:21,540

to quote an exact number percent because

1988

01:27:25,490 --> 01:27:23,760

I I don't remember off the top of my

1989

01:27:27,590 --> 01:27:25,500

head but I I mean it's something like on

1990

01:27:29,990 --> 01:27:27,600

the order of one or a few percent versus

1991

01:27:33,590 --> 01:27:30,000

planets that are much closer in are

1992

01:27:36,110 --> 01:27:33,600

closer to 50 transiting right so that's

1993

01:27:37,669 --> 01:27:36,120

why it's hard to look for Earth-like

1994

01:27:39,590 --> 01:27:37,679

twins because they're farther away and

1995

01:27:41,510 --> 01:27:39,600

they're less likely to Transit

1996

01:27:43,430 --> 01:27:41,520

great great I just want to make sure

1997

01:27:46,669 --> 01:27:43,440

that the public understands that you

1998

01:27:49,550 --> 01:27:46,679

know that that the likelihood of having

1999

01:27:51,830 --> 01:27:49,560

it pass by in that exact plane

2000

01:27:53,510 --> 01:27:51,840

um is kind of small and now you've

2001
01:27:55,370 --> 01:27:53,520
emphasized of course that and it's even

2002
01:27:57,590 --> 01:27:55,380
smaller the further you get out get away

2003
01:28:00,290 --> 01:27:57,600
from it right exactly and that's why

2004
01:28:01,910 --> 01:28:00,300
we're so biased to looking at really

2005
01:28:04,010 --> 01:28:01,920
close in planets because they are more

2006
01:28:06,470 --> 01:28:04,020
likely to Transit and so we see them

2007
01:28:10,010 --> 01:28:06,480
more frequently and hence an emphasis on

2008
01:28:13,010 --> 01:28:10,020
the mdorf opportunity right exactly

2009
01:28:16,250 --> 01:28:13,020
it definitely makes you call back just

2010
01:28:17,990 --> 01:28:16,260
how vast the distances are it's hard to

2011
01:28:20,330 --> 01:28:18,000
to imagine but when you take into

2012
01:28:22,910 --> 01:28:20,340
context light years of distance and then

2013
01:28:26,689 --> 01:28:22,920

like planets and transiting yeah right I

2014

01:28:28,250 --> 01:28:26,699

can't even imagine I know all right so

2015

01:28:31,310 --> 01:28:28,260

we've had two really technical questions

2016

01:28:33,649 --> 01:28:31,320

so let's have a little little easier one

2017

01:28:36,000 --> 01:28:33,659

um what's your favorite exoplanet and

2018

01:28:39,910 --> 01:28:36,010

why oh oh

2019

01:28:43,850 --> 01:28:39,920

[Laughter]

2020

01:28:48,470 --> 01:28:43,860

that's a really great question okay so I

2021

01:28:50,090 --> 01:28:48,480

I think that my favorite exoplanet I

2022

01:28:51,530 --> 01:28:50,100

feel like somebody is gonna say this is

2023

01:28:53,629 --> 01:28:51,540

a cop-out I'm gonna say one of the

2024

01:28:55,310 --> 01:28:53,639

Trappist planets which I feel like is

2025

01:28:57,590 --> 01:28:55,320

like saying Taylor Swift is your

2026

01:28:59,629 --> 01:28:57,600

favorite musician but whatever totally

2027

01:29:02,030 --> 01:28:59,639

true

2028

01:29:05,149 --> 01:29:02,040

um she is by the way

2029

01:29:09,050 --> 01:29:05,159

um but uh so I I'm gonna pick Trappist

2030

01:29:09,950 --> 01:29:09,060

one H which is the farthest out Trappist

2031

01:29:17,870 --> 01:29:09,960

planet

2032

01:29:20,149 --> 01:29:17,880

likely to be in the habitable zone and I

2033

01:29:23,270 --> 01:29:20,159

think I would suspect that if we were

2034

01:29:27,110 --> 01:29:23,280

gonna like find a planet that was

2035

01:29:30,890 --> 01:29:27,120

analogous to one of the icy moons of

2036

01:29:33,229 --> 01:29:30,900

that of the of Saturn or Jupiter it

2037

01:29:36,169 --> 01:29:33,239

would be that planet like it's in a

2038

01:29:38,270 --> 01:29:36,179

regime where there might be methane

2039

01:29:40,729 --> 01:29:38,280

there it could happen you know we have

2040

01:29:42,950 --> 01:29:40,739

no idea we haven't looked at it but I I

2041

01:29:44,629 --> 01:29:42,960

think that that is the most intriguing

2042

01:29:47,030 --> 01:29:44,639

planet to me

2043

01:29:48,709 --> 01:29:47,040

cool cool and of course the follow-up

2044

01:29:50,450 --> 01:29:48,719

question would be did you get tickets

2045

01:29:53,780 --> 01:29:50,460

for Taylor Swift's concert series this

2046

01:29:56,510 --> 01:29:53,790

fall yes I did

2047

01:29:59,030 --> 01:29:56,520

[Laughter]

2048

01:30:02,390 --> 01:29:59,040

you you lucked out on that my daughter

2049

01:30:04,370 --> 01:30:02,400

my daughter also lucked out so I got a

2050

01:30:06,410 --> 01:30:04,380

shout out to my friend guangway he was

2051

01:30:09,350 --> 01:30:06,420

the one who got his tickets so thanks

2052

01:30:13,850 --> 01:30:11,510

all right um we're getting on in time

2053

01:30:15,050 --> 01:30:13,860

here Grant so I think I'm gonna yeah one

2054

01:30:18,709 --> 01:30:15,060

more question

2055

01:30:21,229 --> 01:30:18,719

okay uh let me pick

2056

01:30:24,229 --> 01:30:21,239

uh oh I have to can I do two all right

2057

01:30:26,510 --> 01:30:24,239

let's do two okay Katie's been really

2058

01:30:29,030 --> 01:30:26,520

good I I yeah well I don't really want

2059

01:30:30,290 --> 01:30:29,040

to limit her but I feel like I should

2060

01:30:33,530 --> 01:30:30,300

that's fair

2061

01:30:36,530 --> 01:30:33,540

um okay so question uh do you think that

2062

01:30:39,110 --> 01:30:36,540

exoplanets can retain atmospheres close

2063

01:30:40,669 --> 01:30:39,120

to m-type main sequence Stars such as

2064

01:30:45,709 --> 01:30:40,679

red dwarf

2065

01:30:50,570 --> 01:30:45,719

oh yes I I spend uh most of my time

2066

01:30:55,910 --> 01:30:52,070

uh

2067

01:30:57,830 --> 01:30:55,920

I suspect and this is just a guess

2068

01:31:00,110 --> 01:30:57,840

because again we've only looked at a

2069

01:31:01,910 --> 01:31:00,120

handful of them I was about to give the

2070

01:31:05,209 --> 01:31:01,920

caveat you may not have the data yet

2071

01:31:08,450 --> 01:31:05,219

right we do not have the data yet

2072

01:31:12,169 --> 01:31:08,460

my hunch is that most of them are

2073

01:31:14,390 --> 01:31:12,179

stripped and don't have spheres so my

2074

01:31:18,470 --> 01:31:14,400

hunch is that many of them are like

2075

01:31:22,669 --> 01:31:18,480

Mercury bear Rock no planet and that we

2076

01:31:25,250 --> 01:31:22,679

will see many Flatline Spectra in the

2077

01:31:28,610 --> 01:31:25,260

next year or so and that's okay right

2078

01:31:31,430 --> 01:31:28,620

because that is also you know really

2079

01:31:33,110 --> 01:31:31,440

cool to understand and that actually I

2080

01:31:34,790 --> 01:31:33,120

mean if if we were to see that if we

2081

01:31:38,090 --> 01:31:34,800

were to just find out that this whole

2082

01:31:40,970 --> 01:31:38,100

slew of planets didn't have atmospheres

2083

01:31:42,830 --> 01:31:40,980

that we thought could one that tells us

2084

01:31:45,590 --> 01:31:42,840

a lot about

2085

01:31:47,870 --> 01:31:45,600

the Stellar astrophysics of what's going

2086

01:31:50,750 --> 01:31:47,880

on with these host stars and how strong

2087

01:31:51,709 --> 01:31:50,760

the high energy radiation is coming from

2088

01:31:52,850 --> 01:31:51,719

these

2089

01:31:56,330 --> 01:31:52,860

and

2090

01:31:59,990 --> 01:31:56,340

also important because most stars are M

2091

01:32:02,689 --> 01:32:00,000

Stars right like we if and if we were to

2092

01:32:05,330 --> 01:32:02,699

figure out that close in planets to M

2093

01:32:07,790 --> 01:32:05,340

Stars don't have atmospheres that would

2094

01:32:10,310 --> 01:32:07,800

basically like eliminate a whole

2095

01:32:12,530 --> 01:32:10,320

category a huge section of planets that

2096

01:32:15,590 --> 01:32:12,540

we thought could possibly be habitable

2097

01:32:17,570 --> 01:32:15,600

that aren't so it's it's a big one and

2098

01:32:20,930 --> 01:32:17,580

if they do have atmospheres then I mean

2099

01:32:24,350 --> 01:32:20,940

hooray that would be awesome to to start

2100

01:32:26,030 --> 01:32:24,360

to uncover them but uh my my and I and I

2101
01:32:28,189 --> 01:32:26,040
really say this because I've looked at

2102
01:32:31,250 --> 01:32:28,199
the graphs of the relative amounts of

2103
01:32:34,490 --> 01:32:31,260
high energy flux coming from M dwarfs

2104
01:32:36,830 --> 01:32:34,500
compared to stars like our sun and it's

2105
01:32:38,990 --> 01:32:36,840
orders of magnitude higher from these M

2106
01:32:41,510 --> 01:32:39,000
dwarfs so it would be like going and

2107
01:32:43,550 --> 01:32:41,520
getting blasted with XU like would you

2108
01:32:45,890 --> 01:32:43,560
or I like to be blasted with XUV

2109
01:32:48,709 --> 01:32:45,900
radiation all the time no we we don't

2110
01:32:50,330 --> 01:32:48,719
like our high energy radiation and I

2111
01:32:53,810 --> 01:32:50,340
suspect that a lot of these atmospheres

2112
01:32:56,149 --> 01:32:53,820
don't either right and the have ability

2113
01:32:58,430 --> 01:32:56,159

of the planets you know around you know

2114

01:32:59,810 --> 01:32:58,440

if you're getting high energy radiation

2115

01:33:02,209 --> 01:32:59,820

I mean we think about just the

2116

01:33:04,189 --> 01:33:02,219

ultraviolet radiation that we we worry

2117

01:33:05,629 --> 01:33:04,199

about in terms of skin cancer and such

2118

01:33:09,770 --> 01:33:05,639

right

2119

01:33:11,990 --> 01:33:09,780

um the M dwarf stars you know they

2120

01:33:13,550 --> 01:33:12,000

are very eruptive in in some in some of

2121

01:33:16,790 --> 01:33:13,560

their cases such

2122

01:33:18,590 --> 01:33:16,800

but I I will say you know in in the lure

2123

01:33:20,510 --> 01:33:18,600

of uh bad jokes

2124

01:33:22,669 --> 01:33:20,520

um you mentioned that these flatliners

2125

01:33:24,410 --> 01:33:22,679

would have no atmosphere and if they're

2126

01:33:25,850 --> 01:33:24,420

flatliners that make some dead planets

2127

01:33:27,530 --> 01:33:25,860

right

2128

01:33:29,930 --> 01:33:27,540

so they don't have anything to worry

2129

01:33:36,470 --> 01:33:32,090

the flat planet or a superhero origin

2130

01:33:41,689 --> 01:33:40,550

okay last question one more yes

2131

01:33:44,870 --> 01:33:41,699

um okay

2132

01:33:48,649 --> 01:33:44,880

uh is it possible to look for a planet

2133

01:33:50,149 --> 01:33:48,659

with an active molten core

2134

01:33:51,590 --> 01:33:50,159

um would it protect the planet with a

2135

01:33:54,649 --> 01:33:51,600

magnetic field is that something that

2136

01:33:58,450 --> 01:33:54,659

you were able to discern

2137

01:34:03,950 --> 01:34:01,610

okay uh yes so could we detect a planet

2138

01:34:06,050 --> 01:34:03,960

with a molten core that would have a

2139

01:34:07,970 --> 01:34:06,060

magnetic field

2140

01:34:11,750 --> 01:34:07,980

um so

2141

01:34:15,590 --> 01:34:11,760

I think one day yes I think today not

2142

01:34:19,250 --> 01:34:15,600

yet we could we we are actually closer

2143

01:34:22,610 --> 01:34:19,260

to being able to detect a molten surface

2144

01:34:25,310 --> 01:34:22,620

so we think that some planets that are

2145

01:34:27,590 --> 01:34:25,320

really close to their stars are so hot

2146

01:34:30,590 --> 01:34:27,600

that their surface is actually just like

2147

01:34:33,950 --> 01:34:30,600

pure magma and if they don't have an

2148

01:34:36,229 --> 01:34:33,960

atmosphere we can actually use a similar

2149

01:34:39,649 --> 01:34:36,239

technique to look at the composition of

2150

01:34:42,709 --> 01:34:39,659

the surface itself and say oh wow yes

2151
01:34:45,350 --> 01:34:42,719
this is a molten lava Planet we've

2152
01:34:47,810 --> 01:34:45,360
started to call them so we might be able

2153
01:34:51,169 --> 01:34:47,820
to do that actually I think we will be

2154
01:34:54,169 --> 01:34:51,179
able to do that soon with web as far as

2155
01:34:56,810 --> 01:34:54,179
a multi so we care about molten

2156
01:34:59,030 --> 01:34:56,820
Interiors because if a planet has a

2157
01:35:01,310 --> 01:34:59,040
molten interior that's what drives a

2158
01:35:03,290 --> 01:35:01,320
magnetic field

2159
01:35:05,750 --> 01:35:03,300
um and there are there are people

2160
01:35:08,990 --> 01:35:05,760
working on how to detect magnetic fields

2161
01:35:11,990 --> 01:35:09,000
in exoplanets but right now uh just like

2162
01:35:14,689 --> 01:35:12,000
the start basically gas giants are about

2163
01:35:17,209 --> 01:35:14,699

a decade ahead of where we are with

2164

01:35:19,370 --> 01:35:17,219

rocky planets maybe even a decade to two

2165

01:35:20,930 --> 01:35:19,380

decades ahead of where we are with rocky

2166

01:35:22,910 --> 01:35:20,940

planet so just like at first when we

2167

01:35:24,890 --> 01:35:22,920

started only to being able to detect

2168

01:35:26,750 --> 01:35:24,900

large gas giants and it wasn't until

2169

01:35:28,729 --> 01:35:26,760

much later that we could detect rocky

2170

01:35:30,169 --> 01:35:28,739

planets you know right now we are

2171

01:35:32,149 --> 01:35:30,179

starting to ask this question in

2172

01:35:34,729 --> 01:35:32,159

relation to gas giants because it would

2173

01:35:36,770 --> 01:35:34,739

be much easier to answer it there

2174

01:35:38,810 --> 01:35:36,780

because the signals will be larger and

2175

01:35:40,970 --> 01:35:38,820

then once we get a handle on can we

2176
01:35:45,050 --> 01:35:40,980
measure magnetic fields and gas giants

2177
01:35:47,330 --> 01:35:45,060
then we can start to push down into the

2178
01:35:48,890 --> 01:35:47,340
rocky planet regime so I I suspect that

2179
01:35:50,810 --> 01:35:48,900
one day we will have an answer to this

2180
01:35:54,470 --> 01:35:50,820
question but I don't think that we will

2181
01:35:55,970 --> 01:35:54,480
be able to do it in the next door so but

2182
01:35:58,370 --> 01:35:55,980
we will be able to determine if planet

2183
01:36:01,129 --> 01:35:58,380
has molten lava on its surface which is

2184
01:36:02,870 --> 01:36:01,139
also very cool that's a that's a that's

2185
01:36:05,689 --> 01:36:02,880
a really cool substitute for any of them

2186
01:36:07,850 --> 01:36:05,699
yeah I I think one of the caveats we

2187
01:36:10,430 --> 01:36:07,860
always have to remind people is that um

2188
01:36:12,709 --> 01:36:10,440

like I showed the HR diagram in my intro

2189

01:36:14,450 --> 01:36:12,719

talk right and that's a diagram of all

2190

01:36:17,270 --> 01:36:14,460

the different types of stars right if

2191

01:36:18,890 --> 01:36:17,280

you did a similar diagram for planets a

2192

01:36:20,930 --> 01:36:18,900

lot of it would be blank because we just

2193

01:36:24,430 --> 01:36:20,940

don't see it we don't have the

2194

01:36:29,510 --> 01:36:24,440

capability to see it you know um I uh

2195

01:36:31,129 --> 01:36:29,520

Saturn has a 30-year orbit okay so it's

2196

01:36:33,470 --> 01:36:31,139

only been 30 years since we started

2197

01:36:36,290 --> 01:36:33,480

discovering exoplas if we're trying to

2198

01:36:38,330 --> 01:36:36,300

use if we need a couple orbits uh in

2199

01:36:40,550 --> 01:36:38,340

order to see a Saturn it needs to be 60

2200

01:36:42,709 --> 01:36:40,560

to 90 years of observation before we

2201

01:36:44,270 --> 01:36:42,719

really see a Saturn in a Saturn sized

2202

01:36:47,990 --> 01:36:44,280

orbit even though we can detect a Saturn

2203

01:36:51,169 --> 01:36:48,000

sized Planet so there's a whole lot of

2204

01:36:53,510 --> 01:36:51,179

of planets that are out there that we

2205

01:36:55,129 --> 01:36:53,520

just can't detect yet and so that's is

2206

01:36:57,770 --> 01:36:55,139

why you are in such a growing field

2207

01:37:00,110 --> 01:36:57,780

right and if I were in graduate school

2208

01:37:02,390 --> 01:37:00,120

again this is where I'd be an

2209

01:37:04,669 --> 01:37:02,400

exoplanets too so you know thumbs up for

2210

01:37:05,950 --> 01:37:04,679

your choice that's very validating thank

2211

01:37:08,810 --> 01:37:05,960

you

2212

01:37:12,169 --> 01:37:08,820

I do cosmology because it was the 90s

2213

01:37:13,870 --> 01:37:12,179

and it was yes so cosmology is great too

2214

01:37:17,649 --> 01:37:13,880

okay

2215

01:37:19,990 --> 01:37:17,659

leading into you know uh the

2216

01:37:23,450 --> 01:37:20,000

cosmological constant and everything

2217

01:37:26,390 --> 01:37:23,460

some cool times to do

2218

01:37:29,209 --> 01:37:26,400

all right well thank you Katie

2219

01:37:31,610 --> 01:37:29,219

um really a great look into you know

2220

01:37:33,709 --> 01:37:31,620

what we know and what we're gonna know

2221

01:37:34,669 --> 01:37:33,719

and the this tease of where we're

2222

01:37:37,129 --> 01:37:34,679

getting through

2223

01:37:41,870 --> 01:37:37,139

um I gotta say that again that that that

2224

01:37:44,149 --> 01:37:41,880

wasp 39b stuff was amazing data

2225

01:37:46,610 --> 01:37:44,159

um and so we look forward to many more

2226

01:37:48,950 --> 01:37:46,620

of those things and um hopefully in your

2227

01:37:51,590 --> 01:37:48,960

PhD thesis some absolutely amazing

2228

01:37:53,330 --> 01:37:51,600

discoveries okay yeah thank you so much

2229

01:37:56,209 --> 01:37:53,340

for having me it was a pleasure to be

2230

01:38:00,410 --> 01:37:56,219

here all right well to our audience

2231

01:38:02,390 --> 01:38:00,420

thank you for watching uh May 2nd uh

2232

01:38:05,450 --> 01:38:02,400

Amanda pagul will be talking about

2233

01:38:08,090 --> 01:38:05,460

Galaxy clusters and the frontier fields