PUBLIC LECTURE SERIES

How to Hunt for Distant Worlds

Featuring Guest Speaker:
Emily Rickman

1
00:00:05,990 --> 00:00:04,630
welcome to the space telescope public

2
00:00:07,590 --> 00:00:06,000
lecture series

3
00:00:10,470 --> 00:00:07,600
our topic tonight

4
00:00:12,789 --> 00:00:10,480
how to hunt for distant worlds with

5
00:00:15,430 --> 00:00:12,799
emily rickman of the european space

6
00:00:17,510 --> 00:00:15,440
agency and the space telescope science

7
00:00:20,150 --> 00:00:17,520
institute

8
00:00:23,590 --> 00:00:20,160
i'm your host dr frank summers of the

9
00:00:26,070 --> 00:00:23,600
office of public outreach and i always

10
00:00:28,710 --> 00:00:26,080
always make sure to thank our amazing

11
00:00:31,669 --> 00:00:28,720
tech team thomas marufu and grant

12
00:00:33,350 --> 00:00:31,679
justice who take this recording and get

13
00:00:36,069 --> 00:00:33,360

it out to you

14
00:00:38,950 --> 00:00:36,079
i will also note as i do it every month

15
00:00:41,190 --> 00:00:38,960
for the last i guess about a year now uh

16
00:00:44,389 --> 00:00:41,200
that the space telescope public lecture

17
00:00:47,029 --> 00:00:44,399
series will be online only until further

18
00:00:53,270 --> 00:00:50,790
our upcoming talks include in july

19
00:00:55,510 --> 00:00:53,280
gwen hart if you were here last august

20
00:00:58,549 --> 00:00:55,520
she gave the first volume of her

21
00:01:00,630 --> 00:00:58,559
armchair astrophysics and this july she

22
00:01:03,990 --> 00:01:00,640
will be coming back to give you a second

23
00:01:06,310 --> 00:01:04,000
helping of armchair astrophysics the way

24
00:01:08,550 --> 00:01:06,320
to explore the universe

25
00:01:10,710 --> 00:01:08,560
basically from the comfort

26
00:01:13,670 --> 00:01:10,720
of that barca lounger

27
00:01:15,350 --> 00:01:13,680
in august we have our infamous tba which

28
00:01:17,190 --> 00:01:15,360
means that i have not succeeded in

29
00:01:19,830 --> 00:01:17,200
finding somebody to commit to august but

30
00:01:22,149 --> 00:01:19,840
don't worry i always do and we will have

31
00:01:25,190 --> 00:01:22,159
a wonderful speaker in august

32
00:01:26,870 --> 00:01:25,200
in september we will have recipes for

33
00:01:29,510 --> 00:01:26,880
planet formation

34
00:01:32,069 --> 00:01:29,520
nikal aru lanatham

35
00:01:33,670 --> 00:01:32,079
god i gotta practice that name i will be

36
00:01:35,749 --> 00:01:33,680
our speaker

37
00:01:38,310 --> 00:01:35,759
on september 7th

38
00:01:40,630 --> 00:01:38,320

if you want uh details of these and

39
00:01:43,030 --> 00:01:40,640
other talks upcoming you can go to our

40
00:01:47,109 --> 00:01:43,040
website for the public lecture series

41
00:01:52,789 --> 00:01:50,149
public hyphen lectures

42
00:01:55,270 --> 00:01:52,799
and on that page you can see on the left

43
00:01:58,389 --> 00:01:55,280
that you can get the webcast

44
00:02:00,389 --> 00:01:58,399
both the youtube playlist as well as the

45
00:02:02,870 --> 00:02:00,399
webcast archive at the space telescope

46
00:02:05,030 --> 00:02:02,880
science institute and you can also on

47
00:02:07,590 --> 00:02:05,040
the right see that you can subscribe to

48
00:02:09,669 --> 00:02:07,600
our email list

49
00:02:11,910 --> 00:02:09,679
also on our website are the list of the

50
00:02:13,910 --> 00:02:11,920
upcoming lectures and if you click on on

51
00:02:16,550 --> 00:02:13,920
those lectures you will get the full

52
00:02:18,470 --> 00:02:16,560
details including the full description

53
00:02:21,430 --> 00:02:18,480
also after it has been recorded we have

54
00:02:24,949 --> 00:02:21,440
the links to the sdsci webcast as well

55
00:02:27,589 --> 00:02:24,959
as the youtube version of the webcast

56
00:02:29,670 --> 00:02:27,599
as i said for the email it's easiest

57
00:02:31,670 --> 00:02:29,680
just to sign up at the at the website

58
00:02:34,830 --> 00:02:31,680
but i would also suggest that you want

59
00:02:37,509 --> 00:02:34,840
to subscribe to our youtube channel

60
00:02:38,630 --> 00:02:37,519
youtube.com hubble space telescope all

61
00:02:41,509 --> 00:02:38,640
one word

62
00:02:43,910 --> 00:02:41,519
uh you will get not only um you will get

63
00:02:46,710 --> 00:02:43,920

the the new video vote notices of our

64
00:02:48,550 --> 00:02:46,720
new videos as well as reminders of these

65
00:02:50,229 --> 00:02:48,560
live events

66
00:02:51,990 --> 00:02:50,239
and if you have comments or questions

67
00:02:58,390 --> 00:02:52,000
that you want to ask you can send them

68
00:03:02,229 --> 00:02:59,910
for those of you who want us follow us

69
00:03:04,790 --> 00:03:02,239
on social media we have social media for

70
00:03:06,309 --> 00:03:04,800
the hubble space telescope for the james

71
00:03:07,750 --> 00:03:06,319
webb space telescope that we'll be

72
00:03:10,309 --> 00:03:07,760
launching this fall

73
00:03:12,149 --> 00:03:10,319
and just for the space telescope science

74
00:03:15,030 --> 00:03:12,159
institute in general

75
00:03:17,589 --> 00:03:15,040
you can find us on facebook twitter

76
00:03:18,949 --> 00:03:17,599
youtube and instagram at the handles

77
00:03:21,190 --> 00:03:18,959
listed there

78
00:03:22,710 --> 00:03:21,200
i myself do a tiny little bit of social

79
00:03:25,190 --> 00:03:22,720
media and if you want to hear what i

80
00:03:29,589 --> 00:03:25,200
have to say you can find me on facebook

81
00:03:34,789 --> 00:03:31,990
and now our news from the universe for

82
00:03:36,869 --> 00:03:34,799
june 2021

83
00:03:40,949 --> 00:03:36,879
our first story

84
00:03:42,710 --> 00:03:40,959
droning on about mars

85
00:03:43,830 --> 00:03:42,720
actually this is much more exciting than

86
00:03:44,630 --> 00:03:43,840
it sounds

87
00:03:47,470 --> 00:03:44,640
so

88
00:03:51,990 --> 00:03:47,480

it was 1965

89
00:03:53,509 --> 00:03:52,000
56 years ago when we got our first image

90
00:03:56,070 --> 00:03:53,519
from mars

91
00:03:58,149 --> 00:03:56,080
on the right you can see the image that

92
00:04:01,030 --> 00:03:58,159
is they put a television camera on

93
00:04:02,550 --> 00:04:01,040
mariner 4 and this was the first image

94
00:04:05,589 --> 00:04:02,560
that came back

95
00:04:07,990 --> 00:04:05,599
now that image on the left is actually a

96
00:04:10,229 --> 00:04:08,000
hand drawing of this image

97
00:04:12,149 --> 00:04:10,239
what happened was the engineers and

98
00:04:14,789 --> 00:04:12,159
scientists were so excited about the

99
00:04:17,430 --> 00:04:14,799
first image ever from mars

100
00:04:19,990 --> 00:04:17,440
that they took a computer print out of

101
00:04:22,550 --> 00:04:20,000
the values of the image and then went

102
00:04:24,550 --> 00:04:22,560
down to the art store and hand colored

103
00:04:26,150 --> 00:04:24,560
them in in order to get the detail of

104
00:04:27,670 --> 00:04:26,160
what they were seeing on mars and they

105
00:04:28,710 --> 00:04:27,680
actually did a pretty pretty pretty good

106
00:04:31,270 --> 00:04:28,720
job

107
00:04:34,870 --> 00:04:31,280
so we have been going back to mars over

108
00:04:37,350 --> 00:04:34,880
and over and years and in the uh

109
00:04:41,430 --> 00:04:37,360
years since 1960

110
00:04:45,430 --> 00:04:41,440
there have been 48 missions to mars

111
00:04:49,749 --> 00:04:45,440
from the ussr from the u.s russia japan

112
00:04:52,710 --> 00:04:49,759
isa china india and even the uae united

113
00:04:54,469 --> 00:04:52,720

arab immigrants so there have been so

114
00:04:57,030 --> 00:04:54,479
many missions to mars

115
00:04:58,950 --> 00:04:57,040
and one of the reasons is that

116
00:05:01,749 --> 00:04:58,960
some of them have not really gone as

117
00:05:04,390 --> 00:05:01,759
expected mars is uh

118
00:05:06,629 --> 00:05:04,400
been an unlucky place to send spacecraft

119
00:05:09,430 --> 00:05:06,639
there have been 24 successful missions

120
00:05:11,830 --> 00:05:09,440
of these 48 that i got on this list but

121
00:05:13,830 --> 00:05:11,840
20 of them were complete failures and

122
00:05:16,390 --> 00:05:13,840
four of them were part successes and

123
00:05:18,310 --> 00:05:16,400
part failures so we've been going back

124
00:05:20,629 --> 00:05:18,320
to mars for you know

125
00:05:21,590 --> 00:05:20,639
almost 60 years

126
00:05:23,830 --> 00:05:21,600
and

127
00:05:26,950 --> 00:05:23,840
we're still going because there's still

128
00:05:29,430 --> 00:05:26,960
a ton of cool stuff to learn about mars

129
00:05:32,310 --> 00:05:29,440
the latest mission to mars was mars

130
00:05:34,870 --> 00:05:32,320
perseverance that arrived at mars on

131
00:05:36,310 --> 00:05:34,880
february 18 2021

132
00:05:39,189 --> 00:05:36,320
and if you're a regular viewer of the

133
00:05:41,749 --> 00:05:39,199
series i showed you this montage of six

134
00:05:44,550 --> 00:05:41,759
images back in march to say hey we're

135
00:05:46,469 --> 00:05:44,560
successfully landed on mars

136
00:05:49,029 --> 00:05:46,479
and also to

137
00:05:51,430 --> 00:05:49,039
do my normal little joke of hey it still

138
00:05:54,950 --> 00:05:51,440

contains rocks yeah

139
00:05:57,830 --> 00:05:54,960
well mars does still contain rocks

140
00:05:58,950 --> 00:05:57,840
and here is a selfie of the perseverance

141
00:06:00,629 --> 00:05:58,960
rover

142
00:06:03,270 --> 00:06:00,639
out there showing you some of the

143
00:06:05,990 --> 00:06:03,280
interesting rocks uh where it landed

144
00:06:07,749 --> 00:06:06,000
it also shows you something new

145
00:06:09,909 --> 00:06:07,759
something that has never been done

146
00:06:11,270 --> 00:06:09,919
before in all of the previous missions

147
00:06:13,189 --> 00:06:11,280
to mars

148
00:06:15,270 --> 00:06:13,199
that object in the background isn't a

149
00:06:18,550 --> 00:06:15,280
tripod for itselfy

150
00:06:21,350 --> 00:06:18,560
that is the ingenuity helicopter

151
00:06:22,710 --> 00:06:21,360
and so as a special test case to see we

152
00:06:24,309 --> 00:06:22,720
could fly

153
00:06:26,629 --> 00:06:24,319
on another planet

154
00:06:28,469 --> 00:06:26,639
the ingenuity helicopter went along on

155
00:06:30,469 --> 00:06:28,479
the perseverance mission

156
00:06:32,150 --> 00:06:30,479
and this

157
00:06:34,550 --> 00:06:32,160
is the video

158
00:06:38,469 --> 00:06:34,560
of that first flight of the ingenuity

159
00:06:40,390 --> 00:06:38,479
helicopter april 19 2021

160
00:06:41,749 --> 00:06:40,400
and i've edited it to sort of zoom in

161
00:06:43,430 --> 00:06:41,759
and now you can see the rotor is

162
00:06:44,469 --> 00:06:43,440
starting up

163
00:06:46,390 --> 00:06:44,479

and

164
00:06:49,350 --> 00:06:46,400
getting up to speed

165
00:06:50,870 --> 00:06:49,360
and it takes off now this isn't this is

166
00:06:52,710 --> 00:06:50,880
the first flight right so they're not

167
00:06:54,150 --> 00:06:52,720
trying to do too much with it okay

168
00:06:56,309 --> 00:06:54,160
they're basically going up and then

169
00:06:58,150 --> 00:06:56,319
they're spinning at 90 degrees

170
00:07:00,150 --> 00:06:58,160
and hovering in the air showing that

171
00:07:02,309 --> 00:07:00,160
that in this very you know the

172
00:07:04,390 --> 00:07:02,319
atmosphere of mars is 1 100th the

173
00:07:05,350 --> 00:07:04,400
density of earth's atmosphere so you

174
00:07:07,350 --> 00:07:05,360
know they

175
00:07:09,589 --> 00:07:07,360
really weren't able to really test this

176
00:07:10,870 --> 00:07:09,599
properly you know in the atmosphere and

177
00:07:13,350 --> 00:07:10,880
in the gravity

178
00:07:16,390 --> 00:07:13,360
and then it just goes back down

179
00:07:17,589 --> 00:07:16,400
right now that's not a terribly crazy

180
00:07:19,350 --> 00:07:17,599
flight but

181
00:07:21,990 --> 00:07:19,360
you got to think about this

182
00:07:25,189 --> 00:07:22,000
this is the wright brothers moment

183
00:07:27,189 --> 00:07:25,199
for flying on another planet

184
00:07:29,350 --> 00:07:27,199
this is really cool

185
00:07:31,029 --> 00:07:29,360
the ingenuity helicopter just rose up

186
00:07:33,589 --> 00:07:31,039
and came down now it's done

187
00:07:36,150 --> 00:07:33,599
several more uh flights after that but

188
00:07:38,710 --> 00:07:36,160

this is the most the significant one

189
00:07:40,230 --> 00:07:38,720
and i guess they call it a helicopter

190
00:07:43,350 --> 00:07:40,240
but when you look at it it really looks

191
00:07:45,670 --> 00:07:43,360
like it's just a drone right so if hey

192
00:07:48,070 --> 00:07:45,680
kids if you want to get your parents to

193
00:07:50,550 --> 00:07:48,080
pay for that really expensive drone you

194
00:07:52,790 --> 00:07:50,560
want just tell them you're in training

195
00:07:54,230 --> 00:07:52,800
for nasa that you want to fly drones on

196
00:07:57,189 --> 00:07:54,240
other planets

197
00:08:03,270 --> 00:08:00,390
our second story today is a luminous

198
00:08:05,589 --> 00:08:03,280
blue anniversary and this happens every

199
00:08:07,350 --> 00:08:05,599
year when we talk about the anniversary

200
00:08:09,749 --> 00:08:07,360
of the launch of the hubble space

201
00:08:12,869 --> 00:08:09,759
telescope that happened uh the launch

202
00:08:14,710 --> 00:08:12,879
was in april 24 1990

203
00:08:18,230 --> 00:08:14,720
and then the next day

204
00:08:20,550 --> 00:08:18,240
hubble was put into orbit

205
00:08:23,589 --> 00:08:20,560
by the space shuttle discovery

206
00:08:25,029 --> 00:08:23,599
this moment by the way has recently been

207
00:08:26,390 --> 00:08:25,039
commemorated

208
00:08:29,510 --> 00:08:26,400
with a

209
00:08:31,550 --> 00:08:29,520
master builder lego set

210
00:08:34,070 --> 00:08:31,560
this lego set is 2

211
00:08:35,990 --> 00:08:34,080
354 pieces

212
00:08:38,790 --> 00:08:36,000
and it shows the space shuttle discovery

213
00:08:41,589 --> 00:08:38,800

during sts 31 which was the launch of

214
00:08:44,550 --> 00:08:41,599
the hubble space telescope plus it has

215
00:08:47,910 --> 00:08:44,560
the hubble space telescope as well

216
00:08:50,150 --> 00:08:47,920
i know it has 2354 pieces because

217
00:08:52,550 --> 00:08:50,160
my wife and kids and i put one together

218
00:08:55,910 --> 00:08:52,560
and it's now sitting up on my dining

219
00:08:57,910 --> 00:08:55,920
room table it's a an expensive set uh

220
00:08:59,509 --> 00:08:57,920
quite a long build but

221
00:09:02,310 --> 00:08:59,519
well for those of us who are science

222
00:09:05,110 --> 00:09:02,320
geeks it's definitely worth it

223
00:09:05,990 --> 00:09:05,120
but what the story is really about is

224
00:09:07,590 --> 00:09:06,000
about

225
00:09:09,750 --> 00:09:07,600
all the amazing hubble images that

226
00:09:12,630 --> 00:09:09,760
hubble has released over the years

227
00:09:14,790 --> 00:09:12,640
and for the hubble anniversary they

228
00:09:16,470 --> 00:09:14,800
always ask us well

229
00:09:18,310 --> 00:09:16,480
give us something special

230
00:09:19,350 --> 00:09:18,320
and we always go oh my god what are we

231
00:09:22,470 --> 00:09:19,360
going to do

232
00:09:24,310 --> 00:09:22,480
somehow

233
00:09:26,389 --> 00:09:24,320
our image processors and our image

234
00:09:28,949 --> 00:09:26,399
selection team manages to come up with

235
00:09:33,350 --> 00:09:28,959
something really cool and this year for

236
00:09:34,790 --> 00:09:33,360
hubble's 31st anniversary the image is

237
00:09:38,070 --> 00:09:34,800
ag car

238
00:09:40,230 --> 00:09:38,080

a luminous blue variable star

239
00:09:43,990 --> 00:09:40,240
now this is one of the most massive

240
00:09:46,870 --> 00:09:44,000
stars in our entire milky way galaxy

241
00:09:48,630 --> 00:09:46,880
it's one of the you know 50 to 100 most

242
00:09:52,150 --> 00:09:48,640
bright the brightest and most massive

243
00:09:54,630 --> 00:09:52,160
stars that we know about in our galaxy

244
00:09:56,790 --> 00:09:54,640
and these stars are so

245
00:09:58,310 --> 00:09:56,800
so massive and they're sort of at the

246
00:10:00,070 --> 00:09:58,320
end of their life and they're in this

247
00:10:02,790 --> 00:10:00,080
variable phase where they actually blow

248
00:10:04,389 --> 00:10:02,800
off material okay they get bigger and

249
00:10:06,870 --> 00:10:04,399
smaller and then they actually blow off

250
00:10:09,190 --> 00:10:06,880
material and changes their brightness i

251
00:10:12,389 --> 00:10:09,200
mean what you see in this nebula around

252
00:10:15,990 --> 00:10:12,399
it is the material that came mostly from

253
00:10:18,870 --> 00:10:16,000
an eruption about 10 000 years ago

254
00:10:20,150 --> 00:10:18,880
so this luminous blue variable star is

255
00:10:21,910 --> 00:10:20,160
how we're celebrating hubble's

256
00:10:24,230 --> 00:10:21,920
anniversary

257
00:10:25,430 --> 00:10:24,240
the next thing they always do is say

258
00:10:28,069 --> 00:10:25,440
well

259
00:10:30,630 --> 00:10:28,079
can you put this into 3d for us

260
00:10:33,269 --> 00:10:30,640
and my team and i we work together we go

261
00:10:36,550 --> 00:10:33,279
hem and we haul we research and find it

262
00:10:39,829 --> 00:10:36,560
eventually we do it okay um and so this

263
00:10:42,310 --> 00:10:39,839

video um is composed of a lot of work uh

264
00:10:51,330 --> 00:10:42,320
to take this this beautiful image and

265
00:11:34,470 --> 00:11:22,430
[Music]

266
00:12:00,389 --> 00:11:34,480
do

267
00:12:04,310 --> 00:12:02,790
so that's our visualization a flight to

268
00:12:07,350 --> 00:12:04,320
a g current a

269
00:12:08,389 --> 00:12:07,360
we also produced a two blog post that

270
00:12:11,269 --> 00:12:08,399
explained

271
00:12:13,509 --> 00:12:11,279
how the image was produced as well as a

272
00:12:15,110 --> 00:12:13,519
lot of the details a lot a lot of the

273
00:12:17,430 --> 00:12:15,120
much more detail than we've ever done

274
00:12:19,990 --> 00:12:17,440
before of the details how we turn that

275
00:12:22,550 --> 00:12:20,000
image into the 3d visualization and you

276
00:12:28,470 --> 00:12:22,560
can find those at our blog illuminated

277
00:12:31,829 --> 00:12:29,509
and now

278
00:12:33,350 --> 00:12:31,839
our featured speaker

279
00:12:35,670 --> 00:12:33,360
emily rickman

280
00:12:37,910 --> 00:12:35,680
is an astronomer at the space telescope

281
00:12:40,870 --> 00:12:37,920
science institute she comes to us from

282
00:12:42,629 --> 00:12:40,880
the european space agency and she is an

283
00:12:44,790 --> 00:12:42,639
esa research fellow

284
00:12:47,269 --> 00:12:44,800
having previously been at sheffield

285
00:12:49,350 --> 00:12:47,279
university uh the australian national

286
00:12:51,910 --> 00:12:49,360
university in kambara

287
00:12:54,870 --> 00:12:51,920
and at the university of geneva so she's

288
00:12:56,389 --> 00:12:54,880

a well-traveled astronomer as we often

289
00:12:57,910 --> 00:12:56,399
get at the space telescope science

290
00:13:00,550 --> 00:12:57,920
institute

291
00:13:02,949 --> 00:13:00,560
she tells me that she is an avid hiker

292
00:13:05,990 --> 00:13:02,959
and has enjoyed hiking here in the u.s

293
00:13:09,910 --> 00:13:06,000
but that one of the highlights that she

294
00:13:13,590 --> 00:13:09,920
has had is that she skydived over the

295
00:13:15,829 --> 00:13:13,600
north face of the iger in the swiss alps

296
00:13:18,949 --> 00:13:15,839
so not just an astronomer but also a

297
00:13:21,269 --> 00:13:18,959
daredevil ladies and gentlemen emily

298
00:13:23,110 --> 00:13:21,279
rickman

299
00:13:30,310 --> 00:13:23,120
thank you so much let me just share my

300
00:13:30,320 --> 00:13:35,430
am i on the right screen

301
00:13:38,710 --> 00:13:37,750
yes you're good emily okay great thank

302
00:13:41,910 --> 00:13:38,720
you

303
00:13:45,030 --> 00:13:41,920
introduction and for having me here

304
00:13:47,590 --> 00:13:45,040
today um i'm really really excited to be

305
00:13:49,350 --> 00:13:47,600
talking to you all about how to hunt for

306
00:13:51,430 --> 00:13:49,360
distant worlds

307
00:13:53,750 --> 00:13:51,440
um as frank said my name is emily

308
00:13:55,269 --> 00:13:53,760
rickman i'm an esa research fellow based

309
00:13:57,670 --> 00:13:55,279
uh here in baltimore at the space

310
00:13:58,550 --> 00:13:57,680
telescope science institute

311
00:14:00,790 --> 00:13:58,560
um

312
00:14:03,910 --> 00:14:00,800
so really to understand the context for

313
00:14:05,670 --> 00:14:03,920

hunting for um so-called exoplanets or

314
00:14:08,150 --> 00:14:05,680
planets around other stars who really

315
00:14:10,710 --> 00:14:08,160
have to understand the kind of history

316
00:14:14,550 --> 00:14:10,720
and everything leading up to this this

317
00:14:16,790 --> 00:14:14,560
definitely isn't a new concept so um

318
00:14:18,069 --> 00:14:16,800
excuse me there we go so

319
00:14:21,430 --> 00:14:18,079
back in

320
00:14:24,310 --> 00:14:21,440
300 or 400 bc aristotle uh once said

321
00:14:25,910 --> 00:14:24,320
there cannot be uh more worlds than one

322
00:14:28,310 --> 00:14:25,920
and so this was already a thought that

323
00:14:30,949 --> 00:14:28,320
was going going on way way back in the

324
00:14:33,590 --> 00:14:30,959
um greek philosopher's time

325
00:14:36,069 --> 00:14:33,600
um but no one had really thought about

326
00:14:38,230 --> 00:14:36,079
this too hard or for too long in a very

327
00:14:41,269 --> 00:14:38,240
very long period of time until we get

328
00:14:43,350 --> 00:14:41,279
towards uh the 1500s or so where we

329
00:14:45,110 --> 00:14:43,360
start to think about um

330
00:14:47,269 --> 00:14:45,120
like what planets could be like or what

331
00:14:48,710 --> 00:14:47,279
other other planets or other systems

332
00:14:50,310 --> 00:14:48,720
could be like so

333
00:14:52,150 --> 00:14:50,320
up to this point there was a very

334
00:14:54,949 --> 00:14:52,160
geocentric view

335
00:14:57,910 --> 00:14:54,959
of the universe and many people believed

336
00:14:59,350 --> 00:14:57,920
that everything um orbited around the

337
00:15:01,350 --> 00:14:59,360
earth and that the earth was the center

338
00:15:04,470 --> 00:15:01,360

of the universe and didn't really have

339
00:15:05,670 --> 00:15:04,480
any other reason um to believe otherwise

340
00:15:07,350 --> 00:15:05,680
and it was

341
00:15:10,470 --> 00:15:07,360
copernicus that came up with the theory

342
00:15:12,550 --> 00:15:10,480
that actually we orbit around the sun

343
00:15:14,629 --> 00:15:12,560
which we now know to be true

344
00:15:17,189 --> 00:15:14,639
and but this was a revolutionary theory

345
00:15:19,750 --> 00:15:17,199
at the time this was in the 1500s and

346
00:15:21,030 --> 00:15:19,760
actually caused a lot of controversy um

347
00:15:22,310 --> 00:15:21,040
in the world but

348
00:15:24,310 --> 00:15:22,320
the whole thing was that we were

349
00:15:26,629 --> 00:15:24,320
starting to have this view

350
00:15:28,629 --> 00:15:26,639
of the universe that potentially that

351
00:15:30,949 --> 00:15:28,639
we're not at the center and that maybe

352
00:15:34,790 --> 00:15:30,959
we orbit around other things and if we

353
00:15:36,470 --> 00:15:34,800
orbit around our star our sun then may

354
00:15:38,389 --> 00:15:36,480
the other planets orbit around other

355
00:15:41,990 --> 00:15:38,399
stars in the universe

356
00:15:44,310 --> 00:15:42,000
this became even more exciting with the

357
00:15:46,389 --> 00:15:44,320
invention of the telescope and i put

358
00:15:49,110 --> 00:15:46,399
this in quotes here because really it

359
00:15:51,110 --> 00:15:49,120
was the retooling of a dutch invented

360
00:15:54,949 --> 00:15:51,120
spyglass um

361
00:15:56,870 --> 00:15:54,959
in the 1600s and 1609 by galileo

362
00:15:58,790 --> 00:15:56,880
who is a very renowned figure in

363
00:16:00,310 --> 00:15:58,800

astronomy i'm sure many of you have

364
00:16:02,069 --> 00:16:00,320
heard of before

365
00:16:04,470 --> 00:16:02,079
and that it was the invention of the

366
00:16:07,110 --> 00:16:04,480
telescope and turning the telescope to

367
00:16:08,550 --> 00:16:07,120
the skies that enabled us to actually

368
00:16:09,670 --> 00:16:08,560
figure out what we're looking at and

369
00:16:12,069 --> 00:16:09,680
whether this

370
00:16:13,990 --> 00:16:12,079
copernicus theory is true

371
00:16:16,710 --> 00:16:14,000
and so galileo

372
00:16:21,110 --> 00:16:16,720
was responsible for the invention or the

373
00:16:23,269 --> 00:16:21,120
the re-tooling of the use of a telescope

374
00:16:24,790 --> 00:16:23,279
and this enabled him to discover the

375
00:16:27,430 --> 00:16:24,800
phases of venus

376
00:16:30,550 --> 00:16:27,440
which is in line with the copernicus um

377
00:16:32,790 --> 00:16:30,560
heliocentric theory of planets

378
00:16:35,030 --> 00:16:32,800
but this also could be uh described by

379
00:16:37,509 --> 00:16:35,040
the geocentric theory from the years

380
00:16:39,189 --> 00:16:37,519
prior to that so this wasn't really

381
00:16:41,430 --> 00:16:39,199
proof that we are actually in a

382
00:16:43,670 --> 00:16:41,440
heliocentric system

383
00:16:46,470 --> 00:16:43,680
but when galileo discovered that there

384
00:16:48,949 --> 00:16:46,480
were moons orbiting around jupiter the

385
00:16:51,910 --> 00:16:48,959
so-called galilean moons this was

386
00:16:54,230 --> 00:16:51,920
confirmation that not everything orbits

387
00:16:56,230 --> 00:16:54,240
around the earth as once as once was

388
00:16:57,590 --> 00:16:56,240

thought and so this was really the

389
00:17:00,710 --> 00:16:57,600
beginning of a revolution of

390
00:17:03,189 --> 00:17:00,720
understanding that there may just be

391
00:17:05,829 --> 00:17:03,199
planets in other systems

392
00:17:09,350 --> 00:17:05,839
so then we fast forward a little bit to

393
00:17:11,189 --> 00:17:09,360
the later into the 1600s and 1698

394
00:17:15,189 --> 00:17:11,199
and this is the first

395
00:17:17,750 --> 00:17:15,199
documented um piece of of a scientist

396
00:17:19,669 --> 00:17:17,760
saying that there may be other planets

397
00:17:21,909 --> 00:17:19,679
that they're of actually considering

398
00:17:23,510 --> 00:17:21,919
what these planets might be like and and

399
00:17:25,350 --> 00:17:23,520
what they what they may look like and

400
00:17:28,789 --> 00:17:25,360
whether they will have life on them and

401
00:17:31,029 --> 00:17:28,799
so hugons uh published in 1698 that his

402
00:17:32,950 --> 00:17:31,039
cosmopheros of the speculations of the

403
00:17:35,270 --> 00:17:32,960
construction of the universe

404
00:17:37,350 --> 00:17:35,280
and the potential habitability of other

405
00:17:40,070 --> 00:17:37,360
planets and so when we talk about

406
00:17:42,789 --> 00:17:40,080
exoplanets it's a very new and exciting

407
00:17:45,270 --> 00:17:42,799
field but actually this goes way way way

408
00:17:47,110 --> 00:17:45,280
back to these times where we can really

409
00:17:49,270 --> 00:17:47,120
start to think about how how these

410
00:17:51,350 --> 00:17:49,280
things came about

411
00:17:54,630 --> 00:17:51,360
okay so then we fast forward

412
00:17:56,789 --> 00:17:54,640
a lot to 1992

413
00:17:58,710 --> 00:17:56,799

and this is when the first exoplanet was

414
00:18:00,870 --> 00:17:58,720
actually discovered

415
00:18:02,950 --> 00:18:00,880
so this exoplanet is very interesting

416
00:18:04,070 --> 00:18:02,960
because it orbits around what we call a

417
00:18:09,270 --> 00:18:04,080
pulsar

418
00:18:12,070 --> 00:18:09,280
that's left over after a supernova so

419
00:18:14,310 --> 00:18:12,080
after a star depletes all of its energy

420
00:18:16,070 --> 00:18:14,320
all of its fuel it explodes in what's

421
00:18:18,789 --> 00:18:16,080
called a supernovae

422
00:18:20,310 --> 00:18:18,799
and after this you're left um for some

423
00:18:22,230 --> 00:18:20,320
situations you're left with what's

424
00:18:26,310 --> 00:18:22,240
called a neutron star and they emit

425
00:18:29,350 --> 00:18:26,320
these pulses very regular periodic um

426
00:18:32,230 --> 00:18:29,360
timing that can be measured so accurate

427
00:18:33,430 --> 00:18:32,240
in fact more accurately than an atomic

428
00:18:35,990 --> 00:18:33,440
clock

429
00:18:37,830 --> 00:18:36,000
and so if there are any perturbations to

430
00:18:40,150 --> 00:18:37,840
this measuring of the pulses that we

431
00:18:43,669 --> 00:18:40,160
receive from pulsars then this could be

432
00:18:46,150 --> 00:18:43,679
due to a companion so ie a planet or

433
00:18:48,630 --> 00:18:46,160
something orbiting around it so that as

434
00:18:50,470 --> 00:18:48,640
they orbit around their center of mass

435
00:18:52,630 --> 00:18:50,480
and this causes this would cause the

436
00:18:54,390 --> 00:18:52,640
pulsar the neutron star to to move

437
00:18:56,630 --> 00:18:54,400
towards and away from us and then that

438
00:18:58,549 --> 00:18:56,640

would cause perturbations in the um

439
00:19:00,630 --> 00:18:58,559
pulses that we're

440
00:19:02,549 --> 00:19:00,640
observing and so that's exactly what

441
00:19:06,310 --> 00:19:02,559
happened in 1992 that the first

442
00:19:08,150 --> 00:19:06,320
exoplanet was discovered around a pulsar

443
00:19:09,350 --> 00:19:08,160
and so then it was only a few years

444
00:19:11,270 --> 00:19:09,360
later

445
00:19:12,870 --> 00:19:11,280
in 1995

446
00:19:14,789 --> 00:19:12,880
which is kind of the

447
00:19:16,549 --> 00:19:14,799
sort of famous one that many people

448
00:19:19,990 --> 00:19:16,559
probably know about was the first

449
00:19:21,909 --> 00:19:20,000
exoplanet that was discovered around a

450
00:19:24,310 --> 00:19:21,919
solar type star

451
00:19:26,070 --> 00:19:24,320
and so this was discovered by michelle

452
00:19:27,750 --> 00:19:26,080
mia and diriacolo

453
00:19:28,950 --> 00:19:27,760
um who were at the university of geneva

454
00:19:32,549 --> 00:19:28,960
at the time

455
00:19:35,430 --> 00:19:32,559
and this was extremely exciting so

456
00:19:37,350 --> 00:19:35,440
i mean the the discovery in 92 was of

457
00:19:39,830 --> 00:19:37,360
course very exciting

458
00:19:41,669 --> 00:19:39,840
but you would never expect to find life

459
00:19:43,510 --> 00:19:41,679
around such an object and pole cells

460
00:19:45,510 --> 00:19:43,520
emit such high

461
00:19:49,190 --> 00:19:45,520
radiation that life just would not be

462
00:19:50,710 --> 00:19:49,200
able to perform around such such an uh

463
00:19:52,870 --> 00:19:50,720

such a host

464
00:19:55,110 --> 00:19:52,880
whereas in this case they were targeting

465
00:19:57,669 --> 00:19:55,120
stars that are very much like our sun so

466
00:20:00,310 --> 00:19:57,679
similar in size similar in temperature

467
00:20:03,190 --> 00:20:00,320
and very much as we as we expect our own

468
00:20:03,990 --> 00:20:03,200
sun um but this was still

469
00:20:06,549 --> 00:20:04,000
um

470
00:20:09,190 --> 00:20:06,559
very interesting very obscure

471
00:20:12,070 --> 00:20:09,200
um discovery which i'm gonna talk a lot

472
00:20:13,909 --> 00:20:12,080
a bit a little bit later on um because

473
00:20:15,510 --> 00:20:13,919
what they discovered was something that

474
00:20:18,549 --> 00:20:15,520
wasn't really in line at the time with

475
00:20:20,310 --> 00:20:18,559
how we expected um other stellar systems

476
00:20:21,909 --> 00:20:20,320
to look like and did not look like our

477
00:20:24,070 --> 00:20:21,919
own solar system

478
00:20:26,390 --> 00:20:24,080
but this is extremely exciting and it

479
00:20:28,549 --> 00:20:26,400
was just in 2019

480
00:20:32,310 --> 00:20:28,559
that michelle and didier were awarded

481
00:20:35,830 --> 00:20:32,320
the physics um nobel prize and as a

482
00:20:38,470 --> 00:20:35,840
university of geneva and alum i was very

483
00:20:40,870 --> 00:20:38,480
happy and very excited to have been

484
00:20:43,110 --> 00:20:40,880
there when when this was awarded

485
00:20:45,669 --> 00:20:43,120
and but the photo the image on the right

486
00:20:48,470 --> 00:20:45,679
there i absolutely adore dallas michelle

487
00:20:50,390 --> 00:20:48,480
when he um just found out that he had

488
00:20:51,909 --> 00:20:50,400

been awarded the nobel prize i believe

489
00:20:52,950 --> 00:20:51,919
he's at madrid airport when that

490
00:20:55,029 --> 00:20:52,960
happened

491
00:20:57,510 --> 00:20:55,039
and so i think the look on his face says

492
00:20:58,870 --> 00:20:57,520
it all but it was very well deserved and

493
00:21:02,070 --> 00:20:58,880
and this was

494
00:21:05,190 --> 00:21:02,080
the the very start of the field of

495
00:21:07,510 --> 00:21:05,200
exoplanets as it is today and this was

496
00:21:10,789 --> 00:21:07,520
you know this is a very recent thing

497
00:21:13,190 --> 00:21:10,799
1995 is not very long ago and so it has

498
00:21:14,830 --> 00:21:13,200
been a very very rapidly

499
00:21:17,909 --> 00:21:14,840
expanding field and extremely

500
00:21:20,310 --> 00:21:17,919
interesting so when i tell people

501
00:21:21,590 --> 00:21:20,320
oh yeah i find um planets for a living

502
00:21:22,950 --> 00:21:21,600
that's what i do

503
00:21:25,270 --> 00:21:22,960
this is kind of

504
00:21:27,110 --> 00:21:25,280
what people expect that i look at every

505
00:21:28,630 --> 00:21:27,120
day and not what i see and you see all

506
00:21:30,390 --> 00:21:28,640
these wonderful

507
00:21:32,870 --> 00:21:30,400
artists impression

508
00:21:35,029 --> 00:21:32,880
of what exoplanets look like and i think

509
00:21:37,270 --> 00:21:35,039
they're absolutely wonderful i love them

510
00:21:39,990 --> 00:21:37,280
so much and but this is what's portrayed

511
00:21:40,789 --> 00:21:40,000
in the media and often we will work with

512
00:21:42,630 --> 00:21:40,799
um

513
00:21:44,070 --> 00:21:42,640

artists to ensure that we try and get an

514
00:21:46,710 --> 00:21:44,080
accurate depiction of what we might

515
00:21:48,950 --> 00:21:46,720
expect the planet to to look like but we

516
00:21:51,029 --> 00:21:48,960
don't know that it looks like this

517
00:21:52,470 --> 00:21:51,039
um and we certainly are not receiving

518
00:21:54,870 --> 00:21:52,480
data that looks like this i can

519
00:21:56,470 --> 00:21:54,880
absolutely assure you um and i've

520
00:21:59,029 --> 00:21:56,480
already been guilty

521
00:22:00,630 --> 00:21:59,039
um in my time already of showing you a

522
00:22:02,549 --> 00:22:00,640
handful of

523
00:22:05,750 --> 00:22:02,559
artists impressions that are not

524
00:22:07,830 --> 00:22:05,760
representative of what we look at

525
00:22:11,110 --> 00:22:07,840
well what we really find

526
00:22:14,390 --> 00:22:11,120
in general and this is one example

527
00:22:16,230 --> 00:22:14,400
is something like this so this is an

528
00:22:17,909 --> 00:22:16,240
image and from the european southern

529
00:22:18,870 --> 00:22:17,919
observatory or eso

530
00:22:21,990 --> 00:22:18,880
um

531
00:22:23,909 --> 00:22:22,000
from 2005 and this is actually an image

532
00:22:26,710 --> 00:22:23,919
of the first confirmation of the first

533
00:22:28,870 --> 00:22:26,720
ever directly imaged planet

534
00:22:31,990 --> 00:22:28,880
and so the the sort of big blob on the

535
00:22:33,830 --> 00:22:32,000
right there in blue that's the host um

536
00:22:36,789 --> 00:22:33,840
and that's the uh

537
00:22:38,070 --> 00:22:36,799
it was actually orbiting around a a

538
00:22:40,549 --> 00:22:38,080

brown dwarf

539
00:22:42,070 --> 00:22:40,559
um and so again this is a very

540
00:22:44,710 --> 00:22:42,080
interesting system because it's not

541
00:22:47,270 --> 00:22:44,720
orbiting around a solar type star like

542
00:22:49,750 --> 00:22:47,280
our own our own star this is a very

543
00:22:53,350 --> 00:22:49,760
interesting widely separated

544
00:22:55,990 --> 00:22:53,360
so 55 au as it's written there one au is

545
00:22:58,789 --> 00:22:56,000
the distance between earth and the sun

546
00:23:01,430 --> 00:22:58,799
so multiply that by 55 times and that's

547
00:23:02,549 --> 00:23:01,440
how far away this planet is from its

548
00:23:04,470 --> 00:23:02,559
host

549
00:23:07,029 --> 00:23:04,480
and so again this is by no means a

550
00:23:08,630 --> 00:23:07,039
representation of um a potentially

551
00:23:11,110 --> 00:23:08,640
habitable planet or anything but this

552
00:23:13,110 --> 00:23:11,120
was extremely exciting detection

553
00:23:15,830 --> 00:23:13,120
um of the first direct detection it was

554
00:23:18,230 --> 00:23:15,840
originally discovered in 2004 but it was

555
00:23:20,950 --> 00:23:18,240
ambiguous about whether um it was

556
00:23:23,830 --> 00:23:20,960
co-moving with its um host or not and

557
00:23:25,830 --> 00:23:23,840
then it was confirmed in 2005.

558
00:23:28,230 --> 00:23:25,840
so really these are a bit more

559
00:23:31,510 --> 00:23:28,240
representative of the kind of images

560
00:23:32,549 --> 00:23:31,520
that i look at day to day um

561
00:23:35,270 --> 00:23:32,559
so

562
00:23:37,750 --> 00:23:35,280
how do we actually go about finding

563
00:23:39,909 --> 00:23:37,760

these planets right how do we hunt for

564
00:23:41,909 --> 00:23:39,919
these distant worlds so there are many

565
00:23:43,350 --> 00:23:41,919
different ways that we can do this and

566
00:23:45,269 --> 00:23:43,360
the first of those i would like to

567
00:23:48,789 --> 00:23:45,279
describe to you today is the radial

568
00:23:50,950 --> 00:23:48,799
velocity method and so this was actually

569
00:23:53,830 --> 00:23:50,960
the method that was used to

570
00:23:56,390 --> 00:23:53,840
discover 51 pegby by michelle may and

571
00:23:57,590 --> 00:23:56,400
didier color in 1995 so i think this is

572
00:24:00,870 --> 00:23:57,600
an extremely

573
00:24:02,630 --> 00:24:00,880
um exciting uh one to kind of start off

574
00:24:04,549 --> 00:24:02,640
with

575
00:24:07,029 --> 00:24:04,559
so what we observe

576
00:24:09,110 --> 00:24:07,039
is as this star which is shown in the

577
00:24:11,430 --> 00:24:09,120
center there um

578
00:24:13,750 --> 00:24:11,440
shining away and then a companion or a

579
00:24:15,269 --> 00:24:13,760
planet orbiting around their center of

580
00:24:16,230 --> 00:24:15,279
mass and so

581
00:24:19,029 --> 00:24:16,240
it's not

582
00:24:21,669 --> 00:24:19,039
that the planets just orbit around a

583
00:24:23,669 --> 00:24:21,679
star um even though it may seem that way

584
00:24:25,830 --> 00:24:23,679
when we look at the sun and we look at

585
00:24:27,590 --> 00:24:25,840
the planets orbiting around the sun it's

586
00:24:29,990 --> 00:24:27,600
just that the star is usually so much

587
00:24:31,990 --> 00:24:30,000
more massive than the planet that the

588
00:24:33,750 --> 00:24:32,000

center of mass is so close to the star

589
00:24:36,149 --> 00:24:33,760
that it's essentially as if the planets

590
00:24:37,669 --> 00:24:36,159
are orbiting around or close to the

591
00:24:38,390 --> 00:24:37,679
center of the star

592
00:24:41,590 --> 00:24:38,400
but

593
00:24:44,549 --> 00:24:41,600
in fact actually the planets even true

594
00:24:47,269 --> 00:24:44,559
in our own solar system tug on the on

595
00:24:48,710 --> 00:24:47,279
the star on or on the sun in the case of

596
00:24:51,269 --> 00:24:48,720
the solar system

597
00:24:53,430 --> 00:24:51,279
and so as they orbit around the center

598
00:24:54,870 --> 00:24:53,440
of mass you kind of get pulled in this

599
00:24:56,549 --> 00:24:54,880
general direction as you can see that's

600
00:24:58,870 --> 00:24:56,559
going on here

601
00:25:00,789 --> 00:24:58,880
and in this way we can indirectly

602
00:25:02,870 --> 00:25:00,799
measure that there's a planet in this

603
00:25:04,630 --> 00:25:02,880
system so we don't directly see the

604
00:25:06,549 --> 00:25:04,640
planet what we measure

605
00:25:08,870 --> 00:25:06,559
are the stellar spectra and we can

606
00:25:10,789 --> 00:25:08,880
measure the spectral lines of the star

607
00:25:12,230 --> 00:25:10,799
and we know where we expect those petrol

608
00:25:14,310 --> 00:25:12,240
lines to sit

609
00:25:16,070 --> 00:25:14,320
and as the star gets tugged by the

610
00:25:18,950 --> 00:25:16,080
companion or the planet then it will

611
00:25:21,269 --> 00:25:18,960
move towards us and away from us and in

612
00:25:23,669 --> 00:25:21,279
this respect we call this a doppler

613
00:25:24,710 --> 00:25:23,679

shift or it gets red-shifted and blue

614
00:25:26,149 --> 00:25:24,720
shifted

615
00:25:28,149 --> 00:25:26,159
and we can measure

616
00:25:30,310 --> 00:25:28,159
how fast this is happening so we can

617
00:25:33,190 --> 00:25:30,320
measure like the orbital period of the

618
00:25:35,590 --> 00:25:33,200
companion as it orbits around the star

619
00:25:37,269 --> 00:25:35,600
and we can also measure things like the

620
00:25:39,190 --> 00:25:37,279
mass or the minimum mass of the

621
00:25:41,909 --> 00:25:39,200
companion that we're that we're looking

622
00:25:44,630 --> 00:25:41,919
at indirectly and so i think a clearer

623
00:25:45,750 --> 00:25:44,640
way to see it is with this animation

624
00:25:51,830 --> 00:25:45,760
here

625
00:25:53,430 --> 00:25:51,840
star represented by the yellow circle

626
00:25:54,710 --> 00:25:53,440
and then the planet represented by the

627
00:25:55,830 --> 00:25:54,720
blue circle

628
00:25:57,830 --> 00:25:55,840
and there's just two different

629
00:25:59,909 --> 00:25:57,840
orientations there so either we're

630
00:26:01,990 --> 00:25:59,919
looking at it face on or we're looking

631
00:26:03,669 --> 00:26:02,000
at it edge on and we don't necessarily

632
00:26:05,110 --> 00:26:03,679
know what the orientation

633
00:26:06,549 --> 00:26:05,120
would look like

634
00:26:08,470 --> 00:26:06,559
but in this case so you can see it's

635
00:26:10,549 --> 00:26:08,480
orbiting around the center of mass and

636
00:26:12,470 --> 00:26:10,559
then we have the stellar

637
00:26:14,630 --> 00:26:12,480
spectral lines or representation of them

638
00:26:16,789 --> 00:26:14,640

in the bottom right there as they get

639
00:26:17,590 --> 00:26:16,799
blue shifted and red shifted

640
00:26:20,950 --> 00:26:17,600
um

641
00:26:23,510 --> 00:26:20,960
and then what we measure is the velocity

642
00:26:24,630 --> 00:26:23,520
the radial velocity hence the name of

643
00:26:27,590 --> 00:26:24,640
the technique

644
00:26:30,230 --> 00:26:27,600
of the star and then that corresponds to

645
00:26:31,750 --> 00:26:30,240
the amount of time it takes to do this

646
00:26:33,430 --> 00:26:31,760
full kind of period that you're seeing

647
00:26:35,750 --> 00:26:33,440
there with the yellow dot going along

648
00:26:37,430 --> 00:26:35,760
its curve that's like the orbital period

649
00:26:39,350 --> 00:26:37,440
or how long it takes for that planet

650
00:26:41,510 --> 00:26:39,360
orbit around the star

651
00:26:44,470 --> 00:26:41,520
and so that would correspond to how far

652
00:26:47,510 --> 00:26:44,480
away the planet is away from this star

653
00:26:49,590 --> 00:26:47,520
and then also that speed is

654
00:26:52,710 --> 00:26:49,600
proportional or has

655
00:26:54,870 --> 00:26:52,720
is a function of the mass of the of the

656
00:26:58,230 --> 00:26:54,880
object so a more massive object would

657
00:26:59,909 --> 00:26:58,240
have a much larger radial velocity curve

658
00:27:03,430 --> 00:26:59,919
so i mentioned before

659
00:27:05,750 --> 00:27:03,440
that 51 peg b was discovered using this

660
00:27:07,909 --> 00:27:05,760
method and as you can see here this is

661
00:27:10,870 --> 00:27:07,919
the original radial velocity curve that

662
00:27:13,510 --> 00:27:10,880
was published back in 1995 by michelle

663
00:27:15,110 --> 00:27:13,520

mia and didi aquilo and as you can see

664
00:27:17,029 --> 00:27:15,120
we have this really

665
00:27:17,990 --> 00:27:17,039
neat radial velocity curve that's been

666
00:27:20,630 --> 00:27:18,000
measured

667
00:27:22,389 --> 00:27:20,640
um and we can see that full orbital uh

668
00:27:24,470 --> 00:27:22,399
coverage which is really exciting you

669
00:27:26,389 --> 00:27:24,480
can see the the error bars on each of

670
00:27:28,470 --> 00:27:26,399
the measurements there

671
00:27:30,950 --> 00:27:28,480
so that's the radial velocity technique

672
00:27:33,990 --> 00:27:30,960
and this has been a pretty successful uh

673
00:27:36,470 --> 00:27:34,000
technique in terms of discovering um

674
00:27:37,669 --> 00:27:36,480
hundreds of exoplanets over the recent

675
00:27:40,630 --> 00:27:37,679
years

676
00:27:42,470 --> 00:27:40,640
but another technique that is also um

677
00:27:44,710 --> 00:27:42,480
that has also been extremely successful

678
00:27:45,909 --> 00:27:44,720
and continues to do so is the transit

679
00:27:52,470 --> 00:27:45,919
technique

680
00:27:55,269 --> 00:27:52,480
we observe a star and again this is

681
00:27:56,870 --> 00:27:55,279
another indirect method of searching for

682
00:27:59,590 --> 00:27:56,880
exoplanets we're not observing the

683
00:28:01,510 --> 00:27:59,600
planet itself we observe a star and we

684
00:28:03,830 --> 00:28:01,520
know how much brightness we're receiving

685
00:28:05,110 --> 00:28:03,840
from the star on the flux

686
00:28:07,029 --> 00:28:05,120
and as

687
00:28:09,269 --> 00:28:07,039
a planet transits like we just seen

688
00:28:11,110 --> 00:28:09,279

there in front of the star then we get

689
00:28:12,310 --> 00:28:11,120
this dip in the brightness that we

690
00:28:14,230 --> 00:28:12,320
receive

691
00:28:17,110 --> 00:28:14,240
from from the star

692
00:28:19,110 --> 00:28:17,120
over time and then this corresponds to

693
00:28:21,190 --> 00:28:19,120
how long it takes for the planet to

694
00:28:23,669 --> 00:28:21,200
travel across the star and so that can

695
00:28:25,510 --> 00:28:23,679
give us an idea of um what the orbital

696
00:28:26,310 --> 00:28:25,520
period is like or what the separation is

697
00:28:28,389 --> 00:28:26,320
like

698
00:28:31,750 --> 00:28:28,399
and then we can also measure the radius

699
00:28:34,549 --> 00:28:31,760
of the planet by doing this um and so

700
00:28:36,710 --> 00:28:34,559
this is extremely powerful technique in

701
00:28:39,269 --> 00:28:36,720
order to understand what the composition

702
00:28:41,029 --> 00:28:39,279
of exoplanets is like because if you

703
00:28:43,190 --> 00:28:41,039
have an idea of what the mass is like

704
00:28:45,510 --> 00:28:43,200
and what the radius is like then you can

705
00:28:48,070 --> 00:28:45,520
look at the density and you can compare

706
00:28:50,630 --> 00:28:48,080
it to is it dense like a rocky planet

707
00:28:52,710 --> 00:28:50,640
like earth or mars or is it less dense

708
00:28:54,230 --> 00:28:52,720
like a gaseous planet like jupiter for

709
00:28:55,909 --> 00:28:54,240
example

710
00:28:57,830 --> 00:28:55,919
and so this has been

711
00:28:59,669 --> 00:28:57,840
the most successful detection technique

712
00:29:03,029 --> 00:28:59,679
of exoplanets to date

713
00:29:06,549 --> 00:29:03,039

and part of that has been due to kepler

714
00:29:09,350 --> 00:29:06,559
so kepler was launched back in 2009

715
00:29:11,510 --> 00:29:09,360
um and operated by nasa

716
00:29:14,549 --> 00:29:11,520
and kepler was a space telescope that

717
00:29:17,110 --> 00:29:14,559
was um extremely successful at staring

718
00:29:18,870 --> 00:29:17,120
at the sky for long periods of time in

719
00:29:20,470 --> 00:29:18,880
in different campaigns in different

720
00:29:23,669 --> 00:29:20,480
regions of the sky

721
00:29:27,029 --> 00:29:23,679
um in order to look for these transits

722
00:29:29,990 --> 00:29:27,039
and so it was kind of dubbed the kind of

723
00:29:32,149 --> 00:29:30,000
kepler era in in the exoplanet fields as

724
00:29:34,149 --> 00:29:32,159
we suddenly received thousands of

725
00:29:36,710 --> 00:29:34,159
exoplanet candidates that corresponded

726
00:29:38,230 --> 00:29:36,720
to transits that had been measured using

727
00:29:40,630 --> 00:29:38,240
kepler

728
00:29:41,430 --> 00:29:40,640
so when we look at transiting exoplanets

729
00:29:43,590 --> 00:29:41,440
um

730
00:29:45,350 --> 00:29:43,600
one of the things is we get

731
00:29:47,190 --> 00:29:45,360
different dips in the brightness

732
00:29:49,590 --> 00:29:47,200
corresponding to the different planets

733
00:29:51,510 --> 00:29:49,600
of the different stars we're looking at

734
00:29:52,710 --> 00:29:51,520
so first of all if we look at let's call

735
00:29:55,909 --> 00:29:52,720
this a

736
00:29:59,190 --> 00:29:55,919
solar type star it's the same radius as

737
00:30:01,909 --> 00:29:59,200
the sun then we might get this kind of

738
00:30:04,070 --> 00:30:01,919

dip from the black planet shown there

739
00:30:06,230 --> 00:30:04,080
going in front of the star

740
00:30:07,269 --> 00:30:06,240
but if we're to observe a much smaller

741
00:30:09,669 --> 00:30:07,279
star

742
00:30:11,830 --> 00:30:09,679
which there are many of in the universe

743
00:30:14,149 --> 00:30:11,840
and we call these m dwarfs

744
00:30:15,430 --> 00:30:14,159
then what we see is if the same size

745
00:30:17,830 --> 00:30:15,440
planet

746
00:30:20,470 --> 00:30:17,840
orbits in front of that star then we get

747
00:30:22,789 --> 00:30:20,480
a much much bigger dip in the brightness

748
00:30:25,510 --> 00:30:22,799
that we measure and that is far easier

749
00:30:28,549 --> 00:30:25,520
to measure than the same size planet

750
00:30:29,830 --> 00:30:28,559
around a bigger star um like for example

751
00:30:30,950 --> 00:30:29,840
our own sun

752
00:30:32,630 --> 00:30:30,960
and so

753
00:30:34,630 --> 00:30:32,640
and you can see it in the dips in the

754
00:30:37,590 --> 00:30:34,640
bottom there only

755
00:30:38,710 --> 00:30:37,600
over time and so this kind of led people

756
00:30:43,110 --> 00:30:38,720
to

757
00:30:46,389 --> 00:30:43,120
dwarfs and these smaller and smaller

758
00:30:48,310 --> 00:30:46,399
stars to kind of look for at transiting

759
00:30:51,029 --> 00:30:48,320
um exoplanets

760
00:30:51,990 --> 00:30:51,039
and so in 2017

761
00:30:55,269 --> 00:30:52,000
um

762
00:30:58,870 --> 00:30:55,279
very famous system called trappist-1 was

763
00:31:02,230 --> 00:30:58,880

actually um announced that kind of went

764
00:31:04,870 --> 00:31:02,240
along these lines so these planets um

765
00:31:07,909 --> 00:31:04,880
and these are all in the same system

766
00:31:09,830 --> 00:31:07,919
these are these seven planets orbit

767
00:31:12,070 --> 00:31:09,840
around an m dwarf star

768
00:31:14,070 --> 00:31:12,080
and so it's kind of this approach of

769
00:31:16,310 --> 00:31:14,080
okay if we look at a star this is much

770
00:31:20,149 --> 00:31:16,320
smaller then we'll be able to detect the

771
00:31:22,149 --> 00:31:20,159
signals of more earth-like smaller rocky

772
00:31:24,710 --> 00:31:22,159
planets that would otherwise be much

773
00:31:27,269 --> 00:31:24,720
much more difficult to detect

774
00:31:28,149 --> 00:31:27,279
and so this was outstanding this was

775
00:31:31,190 --> 00:31:28,159
seven

776
00:31:33,909 --> 00:31:31,200
earth-like planets um orbiting in the

777
00:31:35,590 --> 00:31:33,919
system and you start to think okay so

778
00:31:36,870 --> 00:31:35,600
this this is really interesting this is

779
00:31:40,230 --> 00:31:36,880
something that

780
00:31:41,750 --> 00:31:40,240
um kind of resembles or almost resembles

781
00:31:43,830 --> 00:31:41,760
our solar system

782
00:31:45,110 --> 00:31:43,840
and if you look at the

783
00:31:47,909 --> 00:31:45,120
transit

784
00:31:49,669 --> 00:31:47,919
curve and this is from 2015 when the

785
00:31:51,750 --> 00:31:49,679
first three planets were discovered

786
00:31:53,029 --> 00:31:51,760
before the rest of the system

787
00:31:55,110 --> 00:31:53,039
was discovered

788
00:31:57,269 --> 00:31:55,120

then you can see this really neat

789
00:32:00,389 --> 00:31:57,279
transit curve of all three of those as

790
00:32:03,029 --> 00:32:00,399
you as they go across the their star and

791
00:32:05,190 --> 00:32:03,039
so it's not always this one sort of neat

792
00:32:07,269 --> 00:32:05,200
dip that i showed you before but you can

793
00:32:09,190 --> 00:32:07,279
get like numerous planets that are

794
00:32:11,430 --> 00:32:09,200
transiting within themselves

795
00:32:13,990 --> 00:32:11,440
and you can see um along the bottom

796
00:32:16,870 --> 00:32:14,000
there so these are correspond to the

797
00:32:19,669 --> 00:32:16,880
planet names so one e one c one f those

798
00:32:22,310 --> 00:32:19,679
are the the names of the planets um as

799
00:32:23,750 --> 00:32:22,320
they travel in front of the star and you

800
00:32:25,750 --> 00:32:23,760
can kind of get this really really cool

801
00:32:27,110 --> 00:32:25,760
transit curve

802
00:32:29,909 --> 00:32:27,120
so

803
00:32:32,630 --> 00:32:29,919
like i say transiting exoplanets has

804
00:32:34,870 --> 00:32:32,640
been an extremely powerful technique in

805
00:32:36,710 --> 00:32:34,880
order to discover thousands of known

806
00:32:38,630 --> 00:32:36,720
exoplanets to date

807
00:32:42,310 --> 00:32:38,640
but another detection technique is

808
00:32:45,669 --> 00:32:42,320
actually the microlensing technique so

809
00:32:47,590 --> 00:32:45,679
the way that this works is you have a

810
00:32:51,190 --> 00:32:47,600
telescope you see the bottom there

811
00:32:53,750 --> 00:32:51,200
observing um a star in the distance

812
00:32:56,630 --> 00:32:53,760
and then this planet that kind of

813
00:32:59,029 --> 00:32:56,640

moves in the front of it and it acts as

814
00:33:00,710 --> 00:32:59,039
a lens when it does this and you can see

815
00:33:02,630 --> 00:33:00,720
in the bottom right there that over time

816
00:33:03,830 --> 00:33:02,640
we get this peak in the brightness as

817
00:33:05,430 --> 00:33:03,840
this happens

818
00:33:07,430 --> 00:33:05,440
and so again this can be a really really

819
00:33:10,470 --> 00:33:07,440
powerful and compelling technique in

820
00:33:11,990 --> 00:33:10,480
order to find these kind of planets

821
00:33:15,190 --> 00:33:12,000
it's a little bit more difficult because

822
00:33:17,990 --> 00:33:15,200
you need that chance alignment um

823
00:33:20,310 --> 00:33:18,000
so you know there's a difficulty in that

824
00:33:22,310 --> 00:33:20,320
but when you observe it then these

825
00:33:24,950 --> 00:33:22,320
things are these things have really

826
00:33:27,750 --> 00:33:24,960
strong signals that we're able to detect

827
00:33:29,350 --> 00:33:27,760
and so just show another animation here

828
00:33:30,389 --> 00:33:29,360
um from nasa that kind of shows a

829
00:33:33,110 --> 00:33:30,399
similar

830
00:33:34,630 --> 00:33:33,120
thing and so what we see on the right is

831
00:33:36,549 --> 00:33:34,640
kind of what i showed you before where

832
00:33:38,710 --> 00:33:36,559
you have that lensing effect as the

833
00:33:41,350 --> 00:33:38,720
planet moves between the between the

834
00:33:42,950 --> 00:33:41,360
telescope and the background object and

835
00:33:44,310 --> 00:33:42,960
then in the center is what you maybe

836
00:33:46,070 --> 00:33:44,320
expect it to look like if you were

837
00:33:47,430 --> 00:33:46,080
looking face on as if you were the

838
00:33:49,269 --> 00:33:47,440

telescope

839
00:33:51,509 --> 00:33:49,279
and then on the left is what you kind of

840
00:33:54,230 --> 00:33:51,519
expect the microlensing event to look

841
00:33:56,870 --> 00:33:54,240
like um in terms of the brightness over

842
00:33:58,549 --> 00:33:56,880
time and what we see as scientists when

843
00:33:59,509 --> 00:33:58,559
we look at the data

844
00:34:01,830 --> 00:33:59,519
and so

845
00:34:02,950 --> 00:34:01,840
it looks something like this

846
00:34:05,430 --> 00:34:02,960
where you kind of have that

847
00:34:07,350 --> 00:34:05,440
magnification by the stellar lens and

848
00:34:09,669 --> 00:34:07,360
then you get that deviation

849
00:34:11,909 --> 00:34:09,679
uh due to the planet and so this is a

850
00:34:13,190 --> 00:34:11,919
really awesome technique in order to use

851
00:34:16,149 --> 00:34:13,200
as well

852
00:34:18,950 --> 00:34:16,159
and um space telescope science institute

853
00:34:21,750 --> 00:34:18,960
will be launching the nancy grace roman

854
00:34:22,950 --> 00:34:21,760
space telescope um in the due to launch

855
00:34:24,069 --> 00:34:22,960
in the mid

856
00:34:26,790 --> 00:34:24,079
20s

857
00:34:29,109 --> 00:34:26,800
um which will be really amenable to this

858
00:34:32,389 --> 00:34:29,119
kind of technique in order to find lots

859
00:34:34,470 --> 00:34:32,399
of micro lensing events

860
00:34:36,950 --> 00:34:34,480
and it will also be amenable to finding

861
00:34:38,950 --> 00:34:36,960
lots of um planets to direct the image

862
00:34:42,310 --> 00:34:38,960
which brings me to my next

863
00:34:44,069 --> 00:34:42,320

uh technique that i will describe so i'm

864
00:34:46,230 --> 00:34:44,079
a little bit biased about this because

865
00:34:49,190 --> 00:34:46,240
direct imaging is what i primarily work

866
00:34:50,550 --> 00:34:49,200
on and so i will deem it to be the best

867
00:34:54,710 --> 00:34:50,560
exoplanet

868
00:34:56,470 --> 00:34:54,720
not necessarily true but that's how i

869
00:34:58,710 --> 00:34:56,480
that's how i will take it

870
00:34:59,829 --> 00:34:58,720
and so direct imaging

871
00:35:01,910 --> 00:34:59,839
kind of

872
00:35:03,750 --> 00:35:01,920
it does exactly what you expect it does

873
00:35:06,470 --> 00:35:03,760
what it says on the tin that you are

874
00:35:07,750 --> 00:35:06,480
directly imaging a planet and so the

875
00:35:09,589 --> 00:35:07,760
other techniques i've shown you before

876
00:35:13,270 --> 00:35:09,599
have all been indirect methods they've

877
00:35:16,630 --> 00:35:13,280
been what happens to the star or to um

878
00:35:18,230 --> 00:35:16,640
as a result of the star you know and and

879
00:35:20,230 --> 00:35:18,240
the signals that you observe from that

880
00:35:21,829 --> 00:35:20,240
but in this case we're actually not

881
00:35:23,349 --> 00:35:21,839
interested in the style we're trying to

882
00:35:26,310 --> 00:35:23,359
remove as much of the starlight as

883
00:35:27,910 --> 00:35:26,320
possible and look directly for a planet

884
00:35:29,910 --> 00:35:27,920
around that star

885
00:35:32,150 --> 00:35:29,920
and so this has led to some really

886
00:35:33,030 --> 00:35:32,160
interesting awesome results over recent

887
00:35:35,349 --> 00:35:33,040
years

888
00:35:37,990 --> 00:35:35,359

and so what i show here is on the left

889
00:35:40,390 --> 00:35:38,000
is hr8799

890
00:35:41,510 --> 00:35:40,400
unfortunately planetary systems don't

891
00:35:43,030 --> 00:35:41,520
have very

892
00:35:45,109 --> 00:35:43,040
exciting names

893
00:35:48,390 --> 00:35:45,119
but this is its catalog name

894
00:35:49,990 --> 00:35:48,400
and in this case we have four exoplanets

895
00:35:51,349 --> 00:35:50,000
that are orbiting around the central

896
00:35:54,390 --> 00:35:51,359
starter so what we're actually looking

897
00:35:56,870 --> 00:35:54,400
at is in the middle you've got the um

898
00:35:58,790 --> 00:35:56,880
that's the star that's the stellar host

899
00:36:00,550 --> 00:35:58,800
and that's been masked out we're not

900
00:36:02,069 --> 00:36:00,560
interested in the light from the star we

901
00:36:04,390 --> 00:36:02,079
want to suppress as much of that as

902
00:36:06,230 --> 00:36:04,400
possible but that's where the star is

903
00:36:08,470 --> 00:36:06,240
and then you kind of see these four

904
00:36:11,109 --> 00:36:08,480
blobs um orbiting

905
00:36:12,790 --> 00:36:11,119
anti-clockwise counterclockwise

906
00:36:13,829 --> 00:36:12,800
and there's those are the four planets

907
00:36:15,910 --> 00:36:13,839
that we see

908
00:36:17,510 --> 00:36:15,920
and again you know as i told you at the

909
00:36:19,270 --> 00:36:17,520
beginning what do you expect an

910
00:36:22,069 --> 00:36:19,280
exoplanet to look like versus what we

911
00:36:23,829 --> 00:36:22,079
actually observe it is just a blob of

912
00:36:25,750 --> 00:36:23,839
pixels but there's a lot of information

913
00:36:27,670 --> 00:36:25,760

that we can pull out from this

914
00:36:29,750 --> 00:36:27,680
and the gift head showing on the right

915
00:36:33,030 --> 00:36:29,760
there that's from bates pick which is

916
00:36:35,109 --> 00:36:33,040
another very um famously image system

917
00:36:37,190 --> 00:36:35,119
where it you can see it being observed

918
00:36:39,109 --> 00:36:37,200
there just before it goes behind its

919
00:36:41,109 --> 00:36:39,119
stellar host um

920
00:36:43,510 --> 00:36:41,119
so these wonderful

921
00:36:45,270 --> 00:36:43,520
um animations have been made by um jason

922
00:36:47,190 --> 00:36:45,280
wong who um you should go check out his

923
00:36:49,109 --> 00:36:47,200
webpage and he has a whole bunch of

924
00:36:50,790 --> 00:36:49,119
these um but we're not actually

925
00:36:52,550 --> 00:36:50,800
observing the this hasn't been observed

926
00:36:53,990 --> 00:36:52,560
in real time these are many different

927
00:36:55,910 --> 00:36:54,000
epochs of data that have been put

928
00:36:57,990 --> 00:36:55,920
together in order to generate these

929
00:37:00,470 --> 00:36:58,000
movies so you can see the dates there on

930
00:37:02,230 --> 00:37:00,480
the bottom run over several years when

931
00:37:04,310 --> 00:37:02,240
we're this isn't actually what we

932
00:37:05,990 --> 00:37:04,320
observe immediately this has to be

933
00:37:07,670 --> 00:37:06,000
strung together over a very long period

934
00:37:09,910 --> 00:37:07,680
of time to understand what the orbital

935
00:37:11,829 --> 00:37:09,920
motion looks like and to confirm

936
00:37:13,750 --> 00:37:11,839
that the planet that we're looking at is

937
00:37:15,030 --> 00:37:13,760
actually connected with the star that

938
00:37:16,069 --> 00:37:15,040

we're observing

939
00:37:17,990 --> 00:37:16,079
um

940
00:37:19,750 --> 00:37:18,000
so the way this kind of works is we have

941
00:37:22,230 --> 00:37:19,760
to take into account lots of different

942
00:37:25,109 --> 00:37:22,240
factors this is not an easy thing to do

943
00:37:27,990 --> 00:37:25,119
otherwise people would just do it right

944
00:37:30,390 --> 00:37:28,000
so the magnitude the brightness of the

945
00:37:32,390 --> 00:37:30,400
star compared to the brightness of the

946
00:37:35,349 --> 00:37:32,400
planet is huge

947
00:37:37,030 --> 00:37:35,359
millions of times so you really really

948
00:37:38,150 --> 00:37:37,040
need to remove as much as starlight as

949
00:37:40,710 --> 00:37:38,160
possible

950
00:37:42,069 --> 00:37:40,720
um and we have the added difficulty when

951
00:37:43,670 --> 00:37:42,079
we do this from the ground using

952
00:37:45,270 --> 00:37:43,680
ground-based telescopes which i'll speak

953
00:37:47,829 --> 00:37:45,280
a bit more about as well

954
00:37:49,990 --> 00:37:47,839
um but you know we look and we stare at

955
00:37:52,069 --> 00:37:50,000
a star and we hope that it has a nice

956
00:37:53,910 --> 00:37:52,079
friendly planet next to it like in this

957
00:37:55,270 --> 00:37:53,920
little image

958
00:37:56,790 --> 00:37:55,280
and then in the case that we're doing

959
00:37:59,109 --> 00:37:56,800
ground-based observations we have to

960
00:38:01,349 --> 00:37:59,119
take into account the earth's atmosphere

961
00:38:03,109 --> 00:38:01,359
and we do this using adaptive optics

962
00:38:04,390 --> 00:38:03,119
which i'm going to explain this is

963
00:38:06,310 --> 00:38:04,400

essentially like putting a pair of

964
00:38:07,589 --> 00:38:06,320
glasses onto a telescope

965
00:38:08,950 --> 00:38:07,599
and then the other really really

966
00:38:10,390 --> 00:38:08,960
important thing is using what's called a

967
00:38:12,710 --> 00:38:10,400
coronagraph

968
00:38:14,710 --> 00:38:12,720
and so chronograph is the thing the mask

969
00:38:16,790 --> 00:38:14,720
that sits in the middle that blocks out

970
00:38:18,710 --> 00:38:16,800
as much of that starlight as possible

971
00:38:20,470 --> 00:38:18,720
and so you can imagine if you were

972
00:38:22,310 --> 00:38:20,480
looking up to the sun you shouldn't

973
00:38:24,069 --> 00:38:22,320
actually do this but if you were to look

974
00:38:26,230 --> 00:38:24,079
up to the sun and put your thumb in

975
00:38:27,829 --> 00:38:26,240
front to cover the sun to cover the

976
00:38:29,510 --> 00:38:27,839
sunlight and you would see like the

977
00:38:30,950 --> 00:38:29,520
corona of the sun around the outside of

978
00:38:32,790 --> 00:38:30,960
it and that's where the name coronagraph

979
00:38:34,710 --> 00:38:32,800
comes from we basically do the same

980
00:38:36,230 --> 00:38:34,720
thing it's like doing that on a

981
00:38:37,750 --> 00:38:36,240
telescope putting your thumb up to

982
00:38:38,790 --> 00:38:37,760
remove as much of that starlight as

983
00:38:39,670 --> 00:38:38,800
possible

984
00:38:41,270 --> 00:38:39,680
um

985
00:38:42,390 --> 00:38:41,280
and then you kind of just get the

986
00:38:44,310 --> 00:38:42,400
residual

987
00:38:46,870 --> 00:38:44,320
uh starlight that's left around there

988
00:38:49,670 --> 00:38:46,880

and then this comes in through detector

989
00:38:52,710 --> 00:38:49,680
um as shown by a camera there

990
00:38:54,630 --> 00:38:52,720
so because this is so difficult to do

991
00:38:56,230 --> 00:38:54,640
because the contrast ratios that you're

992
00:38:59,109 --> 00:38:56,240
talking about between the star and the

993
00:39:00,470 --> 00:38:59,119
planet are really really extreme then

994
00:39:03,109 --> 00:39:00,480
often what we do is we end up

995
00:39:05,589 --> 00:39:03,119
discovering what's called brown dwarfs

996
00:39:07,910 --> 00:39:05,599
and so brown dwarfs are in this mass

997
00:39:10,790 --> 00:39:07,920
range that sit between

998
00:39:11,750 --> 00:39:10,800
they're less massive than the star so a

999
00:39:14,550 --> 00:39:11,760
star

1000
00:39:16,310 --> 00:39:14,560
is an object that confuses itself it's

1001
00:39:17,430 --> 00:39:16,320
massive enough to undergo hydrogen

1002
00:39:20,310 --> 00:39:17,440
fusion

1003
00:39:22,390 --> 00:39:20,320
but a brown dwarf is um more massive

1004
00:39:24,870 --> 00:39:22,400
than a planet so a brown dwarf is

1005
00:39:26,790 --> 00:39:24,880
massive enough to fuse deterium in its

1006
00:39:29,270 --> 00:39:26,800
core and so it sits in this kind of

1007
00:39:32,390 --> 00:39:29,280
obscure in between space where it's not

1008
00:39:34,950 --> 00:39:32,400
quite a planet it's not quite a star um

1009
00:39:37,190 --> 00:39:34,960
but these are so much more massive

1010
00:39:39,270 --> 00:39:37,200
and brighter than planets that these are

1011
00:39:42,069 --> 00:39:39,280
far easier to detect

1012
00:39:43,750 --> 00:39:42,079
um not just with direct imaging but um

1013
00:39:45,510 --> 00:39:43,760

certainly with direct imaging but also

1014
00:39:47,190 --> 00:39:45,520
with radio velocities and things as well

1015
00:39:48,710 --> 00:39:47,200
if they're close to the star

1016
00:39:50,790 --> 00:39:48,720
um and we kind of get a lot of these

1017
00:39:52,790 --> 00:39:50,800
objects that sit in the middle

1018
00:39:54,470 --> 00:39:52,800
but i do want to emphasize the

1019
00:39:55,829 --> 00:39:54,480
importance of actually observing these

1020
00:39:57,430 --> 00:39:55,839
things

1021
00:40:00,870 --> 00:39:57,440
so i know you came here for an exoplanet

1022
00:40:03,750 --> 00:40:00,880
talk um but in order to understand how

1023
00:40:06,470 --> 00:40:03,760
exoplanet atmospheres work brown dwarfs

1024
00:40:08,309 --> 00:40:06,480
are excellent analogues to do this

1025
00:40:10,950 --> 00:40:08,319
because they possess very similar

1026
00:40:13,270 --> 00:40:10,960
atmospheric properties to planets but

1027
00:40:15,270 --> 00:40:13,280
this is so much easier to detect and so

1028
00:40:17,750 --> 00:40:15,280
we can use these as analogs to try and

1029
00:40:19,270 --> 00:40:17,760
calibrate our exoplanet exoplanetary

1030
00:40:22,309 --> 00:40:19,280
atmospheric models

1031
00:40:24,870 --> 00:40:22,319
um of formation and evolution as well

1032
00:40:26,550 --> 00:40:24,880
and so i really love this excerpt which

1033
00:40:29,109 --> 00:40:26,560
was in the new york times

1034
00:40:31,349 --> 00:40:29,119
and face it in this town either you're a

1035
00:40:33,109 --> 00:40:31,359
star or you're just another brown dwarf

1036
00:40:35,750 --> 00:40:33,119
and this was kind of the view when brown

1037
00:40:37,109 --> 00:40:35,760
dwarfs were first discovered because it

1038
00:40:39,190 --> 00:40:37,119

was like

1039
00:40:39,990 --> 00:40:39,200
they're kind of in this in-between stage

1040
00:40:42,309 --> 00:40:40,000
like

1041
00:40:44,470 --> 00:40:42,319
you know it's in between mass range

1042
00:40:46,470 --> 00:40:44,480
how interesting is that well actually

1043
00:40:48,790 --> 00:40:46,480
over the recent years it's discovered

1044
00:40:53,270 --> 00:40:48,800
how important they really are in order

1045
00:40:55,910 --> 00:40:53,280
to understand exoplanetary atmospheres

1046
00:40:58,069 --> 00:40:55,920
and so i move on to another

1047
00:41:01,030 --> 00:40:58,079
detection technique which i'm also a

1048
00:41:03,190 --> 00:41:01,040
very big fan of and this is um the use

1049
00:41:05,910 --> 00:41:03,200
of astrometry

1050
00:41:09,030 --> 00:41:05,920
and so again this is another indirect

1051
00:41:11,190 --> 00:41:09,040
method of finding exoplanets and looking

1052
00:41:12,390 --> 00:41:11,200
at how the companion that you're trying

1053
00:41:15,270 --> 00:41:12,400
to detect

1054
00:41:16,870 --> 00:41:15,280
affects the the orbit of the star that

1055
00:41:18,069 --> 00:41:16,880
you're observing

1056
00:41:21,990 --> 00:41:18,079
and

1057
00:41:23,990 --> 00:41:22,000
what happens is we stare at a star as if

1058
00:41:26,950 --> 00:41:24,000
um and the path of this star moves

1059
00:41:28,950 --> 00:41:26,960
across the sky over several years

1060
00:41:31,829 --> 00:41:28,960
um and so we kind of get this linear

1061
00:41:33,349 --> 00:41:31,839
path and that's due to um stars moving

1062
00:41:35,510 --> 00:41:33,359
through the galaxy

1063
00:41:38,550 --> 00:41:35,520

and then we also get this kind of spiral

1064
00:41:40,309 --> 00:41:38,560
um motion and that's just due to

1065
00:41:42,870 --> 00:41:40,319
us observing from the earth as we move

1066
00:41:45,270 --> 00:41:42,880
around the sun so it kind of appears to

1067
00:41:47,190 --> 00:41:45,280
go in this spiral like motion but we

1068
00:41:49,430 --> 00:41:47,200
know the astrometry of these things of

1069
00:41:50,710 --> 00:41:49,440
these stars very well

1070
00:41:53,670 --> 00:41:50,720
and so

1071
00:41:54,630 --> 00:41:53,680
um if we notice any perturbations

1072
00:41:55,910 --> 00:41:54,640
between

1073
00:41:58,390 --> 00:41:55,920
the star

1074
00:42:00,230 --> 00:41:58,400
and and the path that we expect it to to

1075
00:42:01,910 --> 00:42:00,240
take which we can see

1076
00:42:03,510 --> 00:42:01,920
that's represented by this little brown

1077
00:42:05,670 --> 00:42:03,520
orange color on there then those

1078
00:42:08,230 --> 00:42:05,680
perturbations can be caused by an

1079
00:42:09,910 --> 00:42:08,240
orbiting companion and so it's kind of

1080
00:42:11,349 --> 00:42:09,920
so it has a similar essence in the

1081
00:42:13,990 --> 00:42:11,359
detection technique to the radial

1082
00:42:15,589 --> 00:42:14,000
velocity technique but it's using the

1083
00:42:16,790 --> 00:42:15,599
position on the sky

1084
00:42:19,349 --> 00:42:16,800
rather than

1085
00:42:21,510 --> 00:42:19,359
just the star itself and how it's

1086
00:42:23,270 --> 00:42:21,520
radially moving

1087
00:42:25,030 --> 00:42:23,280
and so in order to look at the

1088
00:42:26,710 --> 00:42:25,040

astrometry of such things there have

1089
00:42:28,630 --> 00:42:26,720
been some um

1090
00:42:31,510 --> 00:42:28,640
telescopes in recent times that have

1091
00:42:34,630 --> 00:42:31,520
enabled us to do this so for example

1092
00:42:37,109 --> 00:42:34,640
a gaia which is an isa um satellite that

1093
00:42:40,069 --> 00:42:37,119
was launched in 2013 has

1094
00:42:41,109 --> 00:42:40,079
been mapping out the astrometry of stars

1095
00:42:43,190 --> 00:42:41,119
um

1096
00:42:44,550 --> 00:42:43,200
yes since 2013 when it was launched and

1097
00:42:48,150 --> 00:42:44,560
has been doing an incredible job at

1098
00:42:51,430 --> 00:42:48,160
understanding the astrometry of um of

1099
00:42:53,430 --> 00:42:51,440
these stars and also prior to that it

1100
00:42:55,109 --> 00:42:53,440
was hipparchus which was another um

1101
00:42:57,430 --> 00:42:55,119
easter satellite that was launched back

1102
00:42:59,430 --> 00:42:57,440
in 1989

1103
00:43:01,829 --> 00:42:59,440
and and has been another really powerful

1104
00:43:04,309 --> 00:43:01,839
satellite in order to to enable us to

1105
00:43:06,470 --> 00:43:04,319
kind of use this detection technique

1106
00:43:08,470 --> 00:43:06,480
and the most powerful thing is combining

1107
00:43:11,270 --> 00:43:08,480
the two of them together in order to

1108
00:43:13,270 --> 00:43:11,280
understand how the astrometry of these

1109
00:43:16,230 --> 00:43:13,280
of these things changed over time over

1110
00:43:17,349 --> 00:43:16,240
the past 20 years or so

1111
00:43:19,270 --> 00:43:17,359
so

1112
00:43:21,670 --> 00:43:19,280
great we can observe and we can detect

1113
00:43:23,829 --> 00:43:21,680

all of these um wonderful things and

1114
00:43:25,910 --> 00:43:23,839
make all of these wonderful discoveries

1115
00:43:28,630 --> 00:43:25,920
but like what is it that we can actually

1116
00:43:31,030 --> 00:43:28,640
detect like is this representative of

1117
00:43:33,349 --> 00:43:31,040
our own solar system are we trying to

1118
00:43:35,270 --> 00:43:33,359
understand how these things form and

1119
00:43:38,150 --> 00:43:35,280
evolve and so

1120
00:43:39,190 --> 00:43:38,160
what i really wanted to emphasize here

1121
00:43:41,190 --> 00:43:39,200
was the

1122
00:43:43,750 --> 00:43:41,200
the first discovery now going back to

1123
00:43:46,309 --> 00:43:43,760
michelle may and didio colo with 51 peg

1124
00:43:49,109 --> 00:43:46,319
b or 51 pegas cb and what we can see

1125
00:43:52,630 --> 00:43:49,119
here is the comparison of the the radius

1126
00:43:54,790 --> 00:43:52,640
and the mass between earth our own earth

1127
00:43:56,150 --> 00:43:54,800
jupiter in our solar system and 51

1128
00:43:58,309 --> 00:43:56,160
pegbeat

1129
00:44:00,870 --> 00:43:58,319
and as you can see 51 pegb in the middle

1130
00:44:02,870 --> 00:44:00,880
there is huge it's bigger than jupiter

1131
00:44:04,550 --> 00:44:02,880
which is our largest um planet in the

1132
00:44:07,190 --> 00:44:04,560
solar system

1133
00:44:10,069 --> 00:44:07,200
and this planet sits really really close

1134
00:44:11,190 --> 00:44:10,079
to its host star but this is why it was

1135
00:44:16,230 --> 00:44:11,200
far

1136
00:44:17,910 --> 00:44:16,240
detect for example an earth-like planet

1137
00:44:20,470 --> 00:44:17,920
and because the signal the radial

1138
00:44:21,750 --> 00:44:20,480

velocity signal that we observe is much

1139
00:44:25,349 --> 00:44:21,760
more massive

1140
00:44:27,750 --> 00:44:25,359
companion so of course

1141
00:44:29,910 --> 00:44:27,760
but there's baffled astronomers

1142
00:44:32,550 --> 00:44:29,920
when when it was discovered because we

1143
00:44:35,430 --> 00:44:32,560
were not expecting to discover a

1144
00:44:37,109 --> 00:44:35,440
jupiter-like planet so close to its star

1145
00:44:39,829 --> 00:44:37,119
because that's not how our own solar

1146
00:44:42,950 --> 00:44:39,839
system is like so the first

1147
00:44:45,589 --> 00:44:42,960
extra solar planet that was discovered

1148
00:44:47,589 --> 00:44:45,599
kind of blew a lot of theories of

1149
00:44:49,190 --> 00:44:47,599
formation of our own solar system out of

1150
00:44:51,750 --> 00:44:49,200
the water and

1151
00:44:53,430 --> 00:44:51,760
kind of led to an array of trying to

1152
00:44:56,069 --> 00:44:53,440
understand how

1153
00:44:56,870 --> 00:44:56,079
planets form and evolve

1154
00:44:59,430 --> 00:44:56,880
and

1155
00:45:01,589 --> 00:44:59,440
this is you know we're amenable to

1156
00:45:03,589 --> 00:45:01,599
different to detecting kind of different

1157
00:45:04,630 --> 00:45:03,599
companions based on different detection

1158
00:45:06,069 --> 00:45:04,640
techniques

1159
00:45:07,670 --> 00:45:06,079
just because of the way that the

1160
00:45:09,349 --> 00:45:07,680
different um

1161
00:45:11,109 --> 00:45:09,359
techniques are set up

1162
00:45:14,150 --> 00:45:11,119
and so what happened

1163
00:45:15,109 --> 00:45:14,160

after 51 pegby was discovered and what

1164
00:45:19,910 --> 00:45:15,119
was

1165
00:45:21,910 --> 00:45:19,920
hot jupiter and that's because it's a

1166
00:45:24,309 --> 00:45:21,920
jupiter-like planet that's so close to

1167
00:45:26,710 --> 00:45:24,319
its star so it would be far far hotter

1168
00:45:29,190 --> 00:45:26,720
than jupiter it's a hot jupiter and

1169
00:45:31,510 --> 00:45:29,200
after 51 pegbe was discovered there was

1170
00:45:33,109 --> 00:45:31,520
a whole array of

1171
00:45:35,430 --> 00:45:33,119
so-called hot jupiters that were

1172
00:45:37,349 --> 00:45:35,440
discovered using the radial velocity

1173
00:45:39,349 --> 00:45:37,359
technique which were very amenable to

1174
00:45:41,910 --> 00:45:39,359
finding these hot jupiters and again

1175
00:45:44,069 --> 00:45:41,920
this kind of continued to to baffle how

1176
00:45:46,390 --> 00:45:44,079
how these things formed and evolved

1177
00:45:48,309 --> 00:45:46,400
if we look at like the number of planets

1178
00:45:51,349 --> 00:45:48,319
that have been discovered

1179
00:45:53,349 --> 00:45:51,359
over the years and how that's changed so

1180
00:45:54,870 --> 00:45:53,359
what we're seeing here

1181
00:45:58,309 --> 00:45:54,880
is the kind of

1182
00:45:59,910 --> 00:45:58,319
mass separation parameter space of of

1183
00:46:02,230 --> 00:45:59,920
planets and exoplanets that have been

1184
00:46:05,430 --> 00:46:02,240
discovered through all time so

1185
00:46:06,950 --> 00:46:05,440
to this point in up to 1995 we can just

1186
00:46:09,349 --> 00:46:06,960
see the solar system planets that are

1187
00:46:10,710 --> 00:46:09,359
put onto there so along the x-axis we

1188
00:46:13,270 --> 00:46:10,720

have the orbital period and that

1189
00:46:15,589 --> 00:46:13,280
corresponds to how far away that planet

1190
00:46:18,150 --> 00:46:15,599
is away from its stellar host

1191
00:46:19,990 --> 00:46:18,160
and then we have the mass on the y-axis

1192
00:46:22,230 --> 00:46:20,000
there so the more massive ones that are

1193
00:46:23,430 --> 00:46:22,240
at the top and less massive ones at the

1194
00:46:25,430 --> 00:46:23,440
bottom

1195
00:46:27,349 --> 00:46:25,440
and yes so what you can see here is the

1196
00:46:29,910 --> 00:46:27,359
the green points on there at the moment

1197
00:46:32,710 --> 00:46:29,920
those just correspond to um our own

1198
00:46:34,630 --> 00:46:32,720
solar system plants from our soil system

1199
00:46:37,990 --> 00:46:34,640
as as they were discovered

1200
00:46:40,710 --> 00:46:38,000
um across the 16 17 1700s

1201
00:46:43,430 --> 00:46:40,720
and then we hit at 1995

1202
00:46:45,750 --> 00:46:43,440
where there was this boom of exoplanets

1203
00:46:47,270 --> 00:46:45,760
and the field exploded literally so we

1204
00:46:48,790 --> 00:46:47,280
can see that the different colours there

1205
00:46:50,150 --> 00:46:48,800
correspond to the different detection

1206
00:46:51,109 --> 00:46:50,160
techniques that i've described to you

1207
00:46:53,510 --> 00:46:51,119
earlier

1208
00:46:55,030 --> 00:46:53,520
so we have the radial velocity ones we

1209
00:46:56,950 --> 00:46:55,040
have the transit ones we have the

1210
00:46:57,990 --> 00:46:56,960
microlensing ones we have the imaging

1211
00:46:59,910 --> 00:46:58,000
ones

1212
00:47:03,270 --> 00:46:59,920
and you can see they kind of probe

1213
00:47:05,030 --> 00:47:03,280

different populations right so the ones

1214
00:47:07,589 --> 00:47:05,040
that are much much further out at much

1215
00:47:09,670 --> 00:47:07,599
higher at longer periods those are the

1216
00:47:11,510 --> 00:47:09,680
imaged ones because it's far easier to

1217
00:47:14,069 --> 00:47:11,520
directly image something if it's further

1218
00:47:16,069 --> 00:47:14,079
away from its bright stellar host

1219
00:47:18,630 --> 00:47:16,079
but the ones that are closer to the

1220
00:47:20,630 --> 00:47:18,640
stars are the ones that uh that are

1221
00:47:22,069 --> 00:47:20,640
detected using transits and radio

1222
00:47:26,710 --> 00:47:22,079
velocities

1223
00:47:28,309 --> 00:47:26,720
signal if the if the planet is very

1224
00:47:30,230 --> 00:47:28,319
close to its star

1225
00:47:32,470 --> 00:47:30,240
transits you're much likely much more

1226
00:47:33,750 --> 00:47:32,480
likely to detect them if they're close

1227
00:47:36,470 --> 00:47:33,760
to their star

1228
00:47:38,150 --> 00:47:36,480
um and so it's interesting that you can

1229
00:47:40,069 --> 00:47:38,160
kind of get all this different probing

1230
00:47:41,670 --> 00:47:40,079
of different masses and different

1231
00:47:45,109 --> 00:47:41,680
orbital periods and building up this

1232
00:47:46,390 --> 00:47:45,119
picture over time of what the exoplanet

1233
00:47:48,150 --> 00:47:46,400
distribution

1234
00:47:50,470 --> 00:47:48,160
actually looks like and this is going to

1235
00:47:52,549 --> 00:47:50,480
be really exciting going forward

1236
00:47:55,349 --> 00:47:52,559
as we continue to find more and more

1237
00:47:57,349 --> 00:47:55,359
exoplanets and understand

1238
00:47:59,829 --> 00:47:57,359

where the observing bias ends and

1239
00:48:02,950 --> 00:47:59,839
whether um you know how these things

1240
00:48:06,309 --> 00:48:02,960
actually form and evolve um and so to

1241
00:48:09,109 --> 00:48:06,319
date there have been more than 4 000

1242
00:48:11,270 --> 00:48:09,119
exoplanets discovered and this is just

1243
00:48:14,470 --> 00:48:11,280
going to continue to increase over the

1244
00:48:16,390 --> 00:48:14,480
next few years or so and into the next

1245
00:48:18,150 --> 00:48:16,400
few decades

1246
00:48:19,910 --> 00:48:18,160
okay so

1247
00:48:22,309 --> 00:48:19,920
now that you're all experts on how to

1248
00:48:24,150 --> 00:48:22,319
find exoplanets you need the instruments

1249
00:48:26,390 --> 00:48:24,160
you need the telescopes to be able to do

1250
00:48:29,589 --> 00:48:26,400
this so what makes a good telescope

1251
00:48:31,990 --> 00:48:29,599
right so first of all we need giant

1252
00:48:33,430 --> 00:48:32,000
mirrors so telescopes typically use

1253
00:48:35,190 --> 00:48:33,440
mirrors

1254
00:48:36,870 --> 00:48:35,200
and refract light

1255
00:48:38,549 --> 00:48:36,880
to a focus point in which we can

1256
00:48:39,990 --> 00:48:38,559
actually observe

1257
00:48:41,670 --> 00:48:40,000
and this kind of contrary to popular

1258
00:48:43,510 --> 00:48:41,680
belief when i speak to people who think

1259
00:48:46,390 --> 00:48:43,520
that we have these giant lenses but it's

1260
00:48:49,270 --> 00:48:46,400
just so difficult to do that and

1261
00:48:51,109 --> 00:48:49,280
mirrors are much more efficient and much

1262
00:48:52,470 --> 00:48:51,119
much lighter in order for us to be able

1263
00:48:54,069 --> 00:48:52,480

to do this

1264
00:48:57,270 --> 00:48:54,079
but what we see here

1265
00:48:59,990 --> 00:48:57,280
is if we compare a much larger

1266
00:49:02,870 --> 00:49:00,000
mirror versus a much smaller one then

1267
00:49:05,510 --> 00:49:02,880
we're able to we kind of have the

1268
00:49:07,750 --> 00:49:05,520
light path going on there and where they

1269
00:49:09,910 --> 00:49:07,760
come to a focal point and what we call

1270
00:49:11,349 --> 00:49:09,920
the angular resolutions actually being

1271
00:49:12,790 --> 00:49:11,359
able to observe between two different

1272
00:49:13,910 --> 00:49:12,800
objects like two different stars for

1273
00:49:15,910 --> 00:49:13,920
example

1274
00:49:18,230 --> 00:49:15,920
um is much much

1275
00:49:19,829 --> 00:49:18,240
higher if we have a much more giant

1276
00:49:21,750 --> 00:49:19,839
mirror and so that's why we kind of

1277
00:49:23,270 --> 00:49:21,760
reach this point where we build a bigger

1278
00:49:25,510 --> 00:49:23,280
telescope a bigger telescope and a

1279
00:49:27,510 --> 00:49:25,520
bigger telescope is to get that angular

1280
00:49:28,950 --> 00:49:27,520
resolution that's required and that's

1281
00:49:31,030 --> 00:49:28,960
really important when you're doing

1282
00:49:32,630 --> 00:49:31,040
direct imaging of exoplanets because to

1283
00:49:35,030 --> 00:49:32,640
be able to observe

1284
00:49:37,109 --> 00:49:35,040
a planet that is close to its star from

1285
00:49:39,270 --> 00:49:37,119
direct imaging you have to have the

1286
00:49:41,030 --> 00:49:39,280
biggest mirror possible

1287
00:49:42,870 --> 00:49:41,040
and so

1288
00:49:46,069 --> 00:49:42,880

you're the european southern observatory

1289
00:49:47,829 --> 00:49:46,079
or eso are currently building uh what's

1290
00:49:49,349 --> 00:49:47,839
called the elt

1291
00:49:51,910 --> 00:49:49,359
and so astronomers are really bad at

1292
00:49:54,390 --> 00:49:51,920
naming things but the elt stands for

1293
00:49:56,870 --> 00:49:54,400
extremely large telescope

1294
00:49:58,470 --> 00:49:56,880
and you can see um an artist's

1295
00:50:01,750 --> 00:49:58,480
impression of it here

1296
00:50:03,349 --> 00:50:01,760
with big ben next to it um

1297
00:50:06,549 --> 00:50:03,359
very british of me of course but you can

1298
00:50:08,710 --> 00:50:06,559
see just how big this telescope is going

1299
00:50:09,430 --> 00:50:08,720
to be and how big that dome is going to

1300
00:50:14,870 --> 00:50:09,440
be

1301
00:50:16,069 --> 00:50:14,880
when this is uh on sky and it's

1302
00:50:17,430 --> 00:50:16,079
currently in the middle being

1303
00:50:19,190 --> 00:50:17,440
constructed

1304
00:50:21,670 --> 00:50:19,200
a couple of years ago i actually had the

1305
00:50:23,750 --> 00:50:21,680
pleasure to be invited to

1306
00:50:25,670 --> 00:50:23,760
the construction site of the elt and

1307
00:50:27,829 --> 00:50:25,680
this is what it currently looks like or

1308
00:50:30,230 --> 00:50:27,839
maybe it's a bit more built up since

1309
00:50:32,230 --> 00:50:30,240
since i went you can see me stood in the

1310
00:50:34,710 --> 00:50:32,240
middle there and

1311
00:50:36,150 --> 00:50:34,720
this is the foundation of where the dome

1312
00:50:38,950 --> 00:50:36,160
is going to sit

1313
00:50:42,150 --> 00:50:38,960

so this is 40 meters across and about

1314
00:50:44,150 --> 00:50:42,160
130 feet or so and this is going to be a

1315
00:50:46,790 --> 00:50:44,160
huge huge telescope that's going to be a

1316
00:50:48,790 --> 00:50:46,800
great uh game changer in the field of

1317
00:50:50,230 --> 00:50:48,800
um exoplanets

1318
00:50:52,630 --> 00:50:50,240
but another thing we have to take into

1319
00:50:54,790 --> 00:50:52,640
account and kind of mention this before

1320
00:50:57,190 --> 00:50:54,800
is the earth's atmosphere

1321
00:50:58,870 --> 00:50:57,200
and so when you look at the night sky

1322
00:51:00,950 --> 00:50:58,880
and you see all this really nice

1323
00:51:01,829 --> 00:51:00,960
twinkling of the stars

1324
00:51:03,910 --> 00:51:01,839
and

1325
00:51:05,589 --> 00:51:03,920
this isn't due to the stars themselves

1326
00:51:07,589 --> 00:51:05,599
this is due to the effect of the earth's

1327
00:51:09,349 --> 00:51:07,599
atmosphere and observing the stars

1328
00:51:12,230 --> 00:51:09,359
through the earth's atmosphere

1329
00:51:13,829 --> 00:51:12,240
um so although it looks very pretty for

1330
00:51:15,430 --> 00:51:13,839
any astronomer that's using ground-based

1331
00:51:17,349 --> 00:51:15,440
observations this can be extremely

1332
00:51:18,870 --> 00:51:17,359
annoying because it can blur our images

1333
00:51:21,270 --> 00:51:18,880
and make it very very difficult to

1334
00:51:22,790 --> 00:51:21,280
resolve things so even if you have the

1335
00:51:24,069 --> 00:51:22,800
most giant mirror

1336
00:51:26,390 --> 00:51:24,079
possible

1337
00:51:27,670 --> 00:51:26,400
if you can't correct for this then

1338
00:51:29,670 --> 00:51:27,680

you're still going to have a very very

1339
00:51:30,950 --> 00:51:29,680
blurry image and so the way that we

1340
00:51:33,829 --> 00:51:30,960
correct for this

1341
00:51:36,630 --> 00:51:33,839
is uh with adaptive optics

1342
00:51:39,109 --> 00:51:36,640
um so the way that this works

1343
00:51:41,910 --> 00:51:39,119
is we have a plane

1344
00:51:44,150 --> 00:51:41,920
wavefront that comes in from observing

1345
00:51:46,150 --> 00:51:44,160
some stars or galaxy or whatever it is

1346
00:51:47,430 --> 00:51:46,160
we're observing and if we were just in

1347
00:51:48,630 --> 00:51:47,440
space it would just be this plane

1348
00:51:50,069 --> 00:51:48,640
wavefront

1349
00:51:51,349 --> 00:51:50,079
but because we have to observe through

1350
00:51:53,670 --> 00:51:51,359
the atmosphere of the earth when we're

1351
00:51:56,230 --> 00:51:53,680
doing ground-based observations the

1352
00:51:58,710 --> 00:51:56,240
turbulence in the earth's atmosphere

1353
00:52:01,270 --> 00:51:58,720
causes this plane wavefront to then be

1354
00:52:03,270 --> 00:52:01,280
perturbed into this corrugated wavefront

1355
00:52:05,589 --> 00:52:03,280
that then enters the mirror of the

1356
00:52:07,510 --> 00:52:05,599
telescope so we can see the light beam

1357
00:52:09,109 --> 00:52:07,520
entering there coming in through the

1358
00:52:10,230 --> 00:52:09,119
primary and secondary mirror of the

1359
00:52:12,230 --> 00:52:10,240
telescope

1360
00:52:13,910 --> 00:52:12,240
but we can correct for this

1361
00:52:16,790 --> 00:52:13,920
and the way we do that

1362
00:52:18,950 --> 00:52:16,800
is we take a little bit of light away um

1363
00:52:20,710 --> 00:52:18,960

as it's observed using what's called a

1364
00:52:23,349 --> 00:52:20,720
beam splitter

1365
00:52:25,670 --> 00:52:23,359
and then this is fed into a wavefront

1366
00:52:26,870 --> 00:52:25,680
sensor and so this wavefront sensor

1367
00:52:28,710 --> 00:52:26,880
reads

1368
00:52:31,670 --> 00:52:28,720
what the wavefront is that we've just

1369
00:52:34,790 --> 00:52:31,680
observed coming in into the telescope

1370
00:52:37,270 --> 00:52:34,800
this is read into a real-time computer

1371
00:52:40,150 --> 00:52:37,280
and then this is looped back out to the

1372
00:52:42,150 --> 00:52:40,160
mirror that can be corrected to cancel

1373
00:52:44,470 --> 00:52:42,160
out the perturbed wavefront that's

1374
00:52:47,510 --> 00:52:44,480
coming into the telescope

1375
00:52:50,950 --> 00:52:47,520
and this is extremely exciting awesome

1376
00:52:53,910 --> 00:52:50,960
um optics that i i really really love

1377
00:52:55,990 --> 00:52:53,920
and so the remaining wavefront after

1378
00:52:57,990 --> 00:52:56,000
it's corrected then goes through into

1379
00:53:00,150 --> 00:52:58,000
the camera where we have a high

1380
00:53:02,390 --> 00:53:00,160
resolution image which is what we want

1381
00:53:04,950 --> 00:53:02,400
and so this continues to loop through

1382
00:53:06,950 --> 00:53:04,960
and in the cases of large telescopes um

1383
00:53:09,510 --> 00:53:06,960
where we have adaptive optics or extreme

1384
00:53:12,230 --> 00:53:09,520
adaptive optics this happens at tens of

1385
00:53:14,069 --> 00:53:12,240
thousands of times a second so kilohertz

1386
00:53:16,150 --> 00:53:14,079
and this is extremely important in us

1387
00:53:18,950 --> 00:53:16,160
for us to get those really high

1388
00:53:21,430 --> 00:53:18,960

resolution images um that we need in

1389
00:53:23,190 --> 00:53:21,440
order to do things like direct imaging

1390
00:53:24,790 --> 00:53:23,200
of exoplanets

1391
00:53:26,710 --> 00:53:24,800
and what you can see on the right there

1392
00:53:28,069 --> 00:53:26,720
is you go from having looking at

1393
00:53:30,150 --> 00:53:28,079
something where the intensity of the

1394
00:53:32,069 --> 00:53:30,160
light that we're looking at isn't

1395
00:53:34,230 --> 00:53:32,079
extremely high and isn't extremely well

1396
00:53:36,950 --> 00:53:34,240
focused to looking at something that has

1397
00:53:39,270 --> 00:53:36,960
this nice sort of pinprick of high

1398
00:53:41,430 --> 00:53:39,280
intensity light that enables us to look

1399
00:53:43,589 --> 00:53:41,440
at those high resolution images

1400
00:53:46,309 --> 00:53:43,599
and you see the difference that it makes

1401
00:53:49,109 --> 00:53:46,319
um and this this image is from eso

1402
00:53:51,670 --> 00:53:49,119
um so they actually observed uh uranus

1403
00:53:53,670 --> 00:53:51,680
um a couple years ago now i think and

1404
00:53:56,470 --> 00:53:53,680
you can see the image on the right

1405
00:53:59,109 --> 00:53:56,480
is without adaptive optics and this is a

1406
00:54:00,470 --> 00:53:59,119
planet in our own solar system so this

1407
00:54:01,990 --> 00:54:00,480
in theory shouldn't be the most

1408
00:54:04,230 --> 00:54:02,000
difficult thing to do

1409
00:54:05,270 --> 00:54:04,240
for comparing to the observations we

1410
00:54:07,670 --> 00:54:05,280
take for

1411
00:54:09,430 --> 00:54:07,680
planets outside of our system

1412
00:54:11,270 --> 00:54:09,440
but as soon as you turn on the adaptive

1413
00:54:12,950 --> 00:54:11,280

optics you can see that you obtain that

1414
00:54:13,990 --> 00:54:12,960
detail and that's due to the adaptive

1415
00:54:16,549 --> 00:54:14,000
optics

1416
00:54:19,190 --> 00:54:16,559
allowing us to get that high high

1417
00:54:22,470 --> 00:54:19,200
angular resolution

1418
00:54:25,109 --> 00:54:22,480
we can also compare this when we look at

1419
00:54:28,069 --> 00:54:25,119
stars as well so this is also from eso

1420
00:54:30,790 --> 00:54:28,079
and looking towards the galactic center

1421
00:54:32,150 --> 00:54:30,800
um and turning the adaptive optics on

1422
00:54:34,069 --> 00:54:32,160
from off and you can see you go from

1423
00:54:36,069 --> 00:54:34,079
that kind of blurred image there to that

1424
00:54:38,069 --> 00:54:36,079
much cleaner crisp image so this is

1425
00:54:39,750 --> 00:54:38,079
really really important for us to be

1426
00:54:41,910 --> 00:54:39,760
able to do this

1427
00:54:43,750 --> 00:54:41,920
so where do telescopes sit you know

1428
00:54:44,710 --> 00:54:43,760
where do they where do they exist around

1429
00:54:46,309 --> 00:54:44,720
the world

1430
00:54:47,990 --> 00:54:46,319
so here i'm just kind of highlighting

1431
00:54:50,950 --> 00:54:48,000
some of the um

1432
00:54:53,030 --> 00:54:50,960
most renowned largest telescopes um

1433
00:54:54,870 --> 00:54:53,040
across across the globe

1434
00:54:56,950 --> 00:54:54,880
and really we need to put telescopes in

1435
00:54:59,030 --> 00:54:56,960
places where we have

1436
00:55:00,789 --> 00:54:59,040
low light pollution so you don't want to

1437
00:55:01,829 --> 00:55:00,799
put a telescope in the middle of a city

1438
00:55:03,670 --> 00:55:01,839

of course

1439
00:55:06,069 --> 00:55:03,680
um because that makes it much much

1440
00:55:08,950 --> 00:55:06,079
harder to see faint objects so all of

1441
00:55:10,950 --> 00:55:08,960
these are pretty remote locations

1442
00:55:13,109 --> 00:55:10,960
you also need somewhere that has good

1443
00:55:15,349 --> 00:55:13,119
weather you don't want to deal with rain

1444
00:55:17,589 --> 00:55:15,359
or clouds because you wouldn't be able

1445
00:55:18,549 --> 00:55:17,599
to observe through um well through those

1446
00:55:19,910 --> 00:55:18,559
things

1447
00:55:22,150 --> 00:55:19,920
you also want somewhere that has a

1448
00:55:24,390 --> 00:55:22,160
really low humidity as well because that

1449
00:55:26,470 --> 00:55:24,400
can that can take away from the light

1450
00:55:27,829 --> 00:55:26,480
that we're receiving it can absorb at

1451
00:55:29,910 --> 00:55:27,839
those wavelengths that we're trying to

1452
00:55:31,910 --> 00:55:29,920
observe at um

1453
00:55:34,870 --> 00:55:31,920
and then of course that makes our images

1454
00:55:37,510 --> 00:55:34,880
even more difficult to look at

1455
00:55:39,990 --> 00:55:37,520
you also want to be in a place that has

1456
00:55:41,510 --> 00:55:40,000
a stable atmosphere as possible so you

1457
00:55:44,150 --> 00:55:41,520
don't have to correct using adaptive

1458
00:55:45,589 --> 00:55:44,160
optics as fast as if you were in a place

1459
00:55:48,470 --> 00:55:45,599
that has a really really unstable

1460
00:55:50,710 --> 00:55:48,480
atmosphere and so those places are often

1461
00:55:53,030 --> 00:55:50,720
high up on mountaintops but you have

1462
00:55:55,430 --> 00:55:53,040
less atmosphere to observe that's why

1463
00:55:56,710 --> 00:55:55,440

these observatories tend to be at high

1464
00:55:59,030 --> 00:55:56,720
altitudes

1465
00:56:03,589 --> 00:55:59,040
and also um mountains where you have

1466
00:56:05,910 --> 00:56:03,599
kind of this optimal configuration of

1467
00:56:06,870 --> 00:56:05,920
like flat landmass so or

1468
00:56:09,510 --> 00:56:06,880
ocean

1469
00:56:11,990 --> 00:56:09,520
and then kind of a sudden um rise up to

1470
00:56:13,670 --> 00:56:12,000
like a mountain and so that's why places

1471
00:56:16,390 --> 00:56:13,680
like hawaii or

1472
00:56:18,870 --> 00:56:16,400
along uh the andes or the atacama desert

1473
00:56:22,549 --> 00:56:18,880
in chile are really ideal places to to

1474
00:56:23,750 --> 00:56:22,559
have these telescopes to observe

1475
00:56:26,230 --> 00:56:23,760
so

1476
00:56:28,230 --> 00:56:26,240
we're able to detect all of these

1477
00:56:29,910 --> 00:56:28,240
wonderful planets how do we hunt for

1478
00:56:32,230 --> 00:56:29,920
aliens right that's the big question

1479
00:56:34,789 --> 00:56:32,240
that's the question that everyone always

1480
00:56:36,870 --> 00:56:34,799
asks me and wants to know the answer to

1481
00:56:38,789 --> 00:56:36,880
so it's not just about detecting planets

1482
00:56:40,150 --> 00:56:38,799
but it's about understanding them and so

1483
00:56:41,990 --> 00:56:40,160
i've spoken a little bit about

1484
00:56:44,230 --> 00:56:42,000
understanding their formation histories

1485
00:56:46,549 --> 00:56:44,240
or the evolution of them but how do we

1486
00:56:48,950 --> 00:56:46,559
also understand like their composition

1487
00:56:51,190 --> 00:56:48,960
of their atmospheres right

1488
00:56:53,829 --> 00:56:51,200

and how do we find the most ideal place

1489
00:56:56,309 --> 00:56:53,839
where we might expect to find life

1490
00:56:58,630 --> 00:56:56,319
so first of all we'll look for something

1491
00:57:00,309 --> 00:56:58,640
called the habitable zone and so the

1492
00:57:03,910 --> 00:57:00,319
habitable zone is kind of this

1493
00:57:05,990 --> 00:57:03,920
goldilocks zone where a planet orbits um

1494
00:57:07,910 --> 00:57:06,000
where in a place that it's not too hot

1495
00:57:09,270 --> 00:57:07,920
that you can't have liquid water but

1496
00:57:11,030 --> 00:57:09,280
it's not too cold that you can't have

1497
00:57:14,789 --> 00:57:11,040
liquid water so you don't want the water

1498
00:57:16,309 --> 00:57:14,799
to be um gaseous or or non-existent but

1499
00:57:18,309 --> 00:57:16,319
you don't want the water to just be

1500
00:57:20,789 --> 00:57:18,319
frozen and so

1501
00:57:22,549 --> 00:57:20,799
obviously our own earth where we have

1502
00:57:25,030 --> 00:57:22,559
plenty of water we sit within this

1503
00:57:27,589 --> 00:57:25,040
habitable zone this goldilocks zone

1504
00:57:28,549 --> 00:57:27,599
in the separation away from our own star

1505
00:57:29,990 --> 00:57:28,559
the sun

1506
00:57:31,030 --> 00:57:30,000
and so here what you can see is we have

1507
00:57:32,309 --> 00:57:31,040
the sun

1508
00:57:33,750 --> 00:57:32,319
and then we have each of the planets in

1509
00:57:35,510 --> 00:57:33,760
our solar system

1510
00:57:37,589 --> 00:57:35,520
and if you go so far away that we've

1511
00:57:40,549 --> 00:57:37,599
kind of got these um

1512
00:57:42,950 --> 00:57:40,559
gaseous um cold uh planets that would

1513
00:57:45,270 --> 00:57:42,960

not be ideal for life they also

1514
00:57:46,549 --> 00:57:45,280
do not don't have solid surfaces and

1515
00:57:48,069 --> 00:57:46,559
things like that but then if you go too

1516
00:57:50,549 --> 00:57:48,079
close to the sun and you're too hot like

1517
00:57:52,710 --> 00:57:50,559
mercury and venus then you kind of have

1518
00:57:54,950 --> 00:57:52,720
this difficulty of being too hot for to

1519
00:57:56,549 --> 00:57:54,960
be in this like habitable zone and so

1520
00:57:58,549 --> 00:57:56,559
mars kind of sits on the edge of that

1521
00:58:01,109 --> 00:57:58,559
habitable zone and it's kind of a

1522
00:58:04,630 --> 00:58:01,119
question about whether um there used to

1523
00:58:06,470 --> 00:58:04,640
be life on mars or not um but when we

1524
00:58:08,390 --> 00:58:06,480
look at exoplanets and we look at these

1525
00:58:09,430 --> 00:58:08,400
systems we kind of try to

1526
00:58:11,030 --> 00:58:09,440
look

1527
00:58:12,470 --> 00:58:11,040
does the planet is the planet we're

1528
00:58:14,069 --> 00:58:12,480
observing does it sit within that

1529
00:58:16,150 --> 00:58:14,079
habitable zone

1530
00:58:17,510 --> 00:58:16,160
and it's not to say that if we observe a

1531
00:58:19,190 --> 00:58:17,520
planet in the habitable zone that

1532
00:58:20,870 --> 00:58:19,200
there's definitely life on that planet

1533
00:58:22,230 --> 00:58:20,880
or even that there's definitely water on

1534
00:58:24,710 --> 00:58:22,240
that planet there are many different

1535
00:58:26,950 --> 00:58:24,720
factors that come into this um

1536
00:58:29,990 --> 00:58:26,960
like its own its own atmosphere and

1537
00:58:31,750 --> 00:58:30,000
things and water does not necessarily

1538
00:58:34,549 --> 00:58:31,760

mean that there is life on that planet

1539
00:58:36,710 --> 00:58:34,559
but this is just a strong indicator that

1540
00:58:39,270 --> 00:58:36,720
there could be because if there's one

1541
00:58:41,190 --> 00:58:39,280
thing that we agree on is that all life

1542
00:58:44,309 --> 00:58:41,200
on earth has this kind of

1543
00:58:46,230 --> 00:58:44,319
water base one way or another and so

1544
00:58:48,630 --> 00:58:46,240
this can just be a strong indicator for

1545
00:58:50,470 --> 00:58:48,640
how we look for planets that may

1546
00:58:52,390 --> 00:58:50,480
host some form

1547
00:58:54,870 --> 00:58:52,400
of alien life

1548
00:58:56,309 --> 00:58:54,880
and recently in the news

1549
00:58:58,710 --> 00:58:56,319
there was a

1550
00:59:01,750 --> 00:58:58,720
report of the

1551
00:59:03,430 --> 00:59:01,760
the molecule phosphine on venus and so

1552
00:59:04,870 --> 00:59:03,440
this is really exciting because this is

1553
00:59:05,990 --> 00:59:04,880
a molecule that

1554
00:59:11,190 --> 00:59:06,000
is

1555
00:59:13,109 --> 00:59:11,200
um without

1556
00:59:15,829 --> 00:59:13,119
there being for example life or

1557
00:59:18,390 --> 00:59:15,839
something that is causing it to to exist

1558
00:59:21,349 --> 00:59:18,400
and so i won't comment too much on this

1559
00:59:23,190 --> 00:59:21,359
but this is even trying to understand

1560
00:59:24,870 --> 00:59:23,200
the atmospheres of the planets

1561
00:59:26,870 --> 00:59:24,880
within our own solar system with our own

1562
00:59:29,109 --> 00:59:26,880
neighbors can be an extremely difficult

1563
00:59:30,549 --> 00:59:29,119

thing to do um but this is a really

1564
00:59:32,069 --> 00:59:30,559
exciting result that's kind of being

1565
00:59:34,069 --> 00:59:32,079
followed up

1566
00:59:35,589 --> 00:59:34,079
and trying to be understood

1567
00:59:37,109 --> 00:59:35,599
but i think it's a really worthwhile

1568
00:59:39,030 --> 00:59:37,119
thing to think about

1569
00:59:40,789 --> 00:59:39,040
so how do we actually look at the

1570
00:59:43,030 --> 00:59:40,799
atmospheres of these planets so i'm

1571
00:59:45,589 --> 00:59:43,040
going to take you back to the transiting

1572
00:59:47,430 --> 00:59:45,599
technique that i told you about earlier

1573
00:59:48,870 --> 00:59:47,440
and what we can do is we can observe in

1574
00:59:51,270 --> 00:59:48,880
different wavelengths when we observe

1575
00:59:52,710 --> 00:59:51,280
the transits of these exoplanets and

1576
00:59:54,950 --> 00:59:52,720
this is different wavelengths there

1577
00:59:57,430 --> 00:59:54,960
corresponding to

1578
00:59:59,510 --> 00:59:57,440
1.8 2.1 213 microns so that's just

1579
01:00:00,470 --> 00:59:59,520
across different wavelengths we can

1580
01:00:03,349 --> 01:00:00,480
measure

1581
01:00:04,789 --> 01:00:03,359
the the depth of the transit at each of

1582
01:00:07,030 --> 01:00:04,799
these wavelengths

1583
01:00:08,470 --> 01:00:07,040
and because certain molecules in an

1584
01:00:10,390 --> 01:00:08,480
atmosphere will observe at certain

1585
01:00:11,430 --> 01:00:10,400
wavelengths then we get different depths

1586
01:00:12,950 --> 01:00:11,440
when we observe in these different

1587
01:00:15,349 --> 01:00:12,960
wavelengths and that can give us clues

1588
01:00:17,349 --> 01:00:15,359

about whether we're observing a certain

1589
01:00:19,109 --> 01:00:17,359
molecule in the atmosphere or something

1590
01:00:21,910 --> 01:00:19,119
we're looking at so this is a really

1591
01:00:24,950 --> 01:00:21,920
powerful technique in order to do this

1592
01:00:26,470 --> 01:00:24,960
so that's transmission spectroscopy

1593
01:00:28,710 --> 01:00:26,480
but if we go to the emission

1594
01:00:30,870 --> 01:00:28,720
spectroscopy side of things

1595
01:00:34,069 --> 01:00:30,880
which is what i work on so again we can

1596
01:00:36,630 --> 01:00:34,079
take you back to direct imaging of a

1597
01:00:40,069 --> 01:00:36,640
companion and so we see on the left is

1598
01:00:41,990 --> 01:00:40,079
beta pic and the direct image of it

1599
01:00:44,390 --> 01:00:42,000
and what we see there is as we go across

1600
01:00:45,750 --> 01:00:44,400
the different wavelengths um so we're

1601
01:00:47,910 --> 01:00:45,760
observing it lots and lots and lots of

1602
01:00:49,829 --> 01:00:47,920
those different wavelengths

1603
01:00:52,390 --> 01:00:49,839
the plot on the right there corresponds

1604
01:00:53,510 --> 01:00:52,400
to how much brightness how much flux

1605
01:00:55,750 --> 01:00:53,520
we're observing at each of those

1606
01:00:58,549 --> 01:00:55,760
wavelengths and so the emission of those

1607
01:01:00,309 --> 01:00:58,559
things can correspond to different

1608
01:01:03,190 --> 01:01:00,319
absorption features that can be caused

1609
01:01:05,349 --> 01:01:03,200
by certain molecules for example methane

1610
01:01:07,910 --> 01:01:05,359
water that is another way to look at the

1611
01:01:09,990 --> 01:01:07,920
atmospheres exoplanets

1612
01:01:11,990 --> 01:01:10,000
and what can be really exciting as well

1613
01:01:15,270 --> 01:01:12,000

and i've stolen this from

1614
01:01:17,589 --> 01:01:15,280
exoplanet pete so i hope that's okay um

1615
01:01:19,510 --> 01:01:17,599
but go go and follow him on twitter

1616
01:01:21,910 --> 01:01:19,520
is um you can look

1617
01:01:23,589 --> 01:01:21,920
at the different uh like altitudes in

1618
01:01:25,349 --> 01:01:23,599
the atmosphere that correspond to the

1619
01:01:27,750 --> 01:01:25,359
different pressures and temperatures in

1620
01:01:30,309 --> 01:01:27,760
the atmosphere and how

1621
01:01:31,510 --> 01:01:30,319
the spectra that we look at so the flux

1622
01:01:33,750 --> 01:01:31,520
or the brightness that we're observing

1623
01:01:35,589 --> 01:01:33,760
looks at at different wavelengths and so

1624
01:01:37,910 --> 01:01:35,599
we can get these kind of stronger

1625
01:01:39,990 --> 01:01:37,920
stronger molecular features as we go to

1626
01:01:41,990 --> 01:01:40,000
like colder um

1627
01:01:43,750 --> 01:01:42,000
temperatures for example where we kind

1628
01:01:46,390 --> 01:01:43,760
of expect those mapping and things like

1629
01:01:48,230 --> 01:01:46,400
that so this is a really really cool and

1630
01:01:50,630 --> 01:01:48,240
technique and this is very much at the

1631
01:01:53,670 --> 01:01:50,640
beginning of looking at exoplanet

1632
01:01:57,109 --> 01:01:53,680
atmospheres this is still a very young

1633
01:01:58,390 --> 01:01:57,119
early field as as said previously and so

1634
01:01:59,829 --> 01:01:58,400
really just starting to get to this

1635
01:02:02,789 --> 01:01:59,839
point of understanding how we can do

1636
01:02:04,870 --> 01:02:02,799
this um and using like i said before

1637
01:02:07,750 --> 01:02:04,880
brown dwarfs are a really strong analog

1638
01:02:10,549 --> 01:02:07,760

that can be used and much far easier to

1639
01:02:12,549 --> 01:02:10,559
to detect directly in order to help us

1640
01:02:15,029 --> 01:02:12,559
understand and calibrate our models of

1641
01:02:18,230 --> 01:02:15,039
exoplanetary atmospheres so this is very

1642
01:02:20,470 --> 01:02:18,240
much a stay tuned as we kind of

1643
01:02:21,910 --> 01:02:20,480
investigate how we do this well

1644
01:02:24,470 --> 01:02:21,920
um

1645
01:02:26,470 --> 01:02:24,480
so just wanted to mention a couple of

1646
01:02:29,349 --> 01:02:26,480
obviously the the trademark of space

1647
01:02:31,430 --> 01:02:29,359
telescope um hubble space telescope that

1648
01:02:32,870 --> 01:02:31,440
was launched back in 1990 which has been

1649
01:02:34,630 --> 01:02:32,880
responsible for

1650
01:02:35,910 --> 01:02:34,640
observing many of these wonderful uh

1651
01:02:38,150 --> 01:02:35,920
planets and brown dwarfs that i've

1652
01:02:40,710 --> 01:02:38,160
mentioned today using uh

1653
01:02:43,190 --> 01:02:40,720
these kind of techniques um and

1654
01:02:45,670 --> 01:02:43,200
continues to be a massive player in

1655
01:02:47,349 --> 01:02:45,680
observing the atmospheres of these

1656
01:02:49,430 --> 01:02:47,359
of these objects

1657
01:02:51,829 --> 01:02:49,440
and what's even more exciting is the

1658
01:02:54,069 --> 01:02:51,839
upcoming james webb space telescope

1659
01:02:56,870 --> 01:02:54,079
which we'll be launching later this year

1660
01:02:57,750 --> 01:02:56,880
um and this is going to be an incredible

1661
01:02:59,910 --> 01:02:57,760
um

1662
01:03:01,510 --> 01:02:59,920
feat of engineering that will enable us

1663
01:03:04,069 --> 01:03:01,520

to look even

1664
01:03:05,990 --> 01:03:04,079
at even more exoplanets and look at the

1665
01:03:07,510 --> 01:03:06,000
atmospheres and even more depth and

1666
01:03:09,109 --> 01:03:07,520
truly understand what it is we're

1667
01:03:10,950 --> 01:03:09,119
looking at and to try to understand the

1668
01:03:13,990 --> 01:03:10,960
formation and evolution

1669
01:03:17,029 --> 01:03:14,000
of planets both of exoplanet systems and

1670
01:03:18,230 --> 01:03:17,039
planets in our own solar system and so

1671
01:03:19,750 --> 01:03:18,240
james webb

1672
01:03:21,990 --> 01:03:19,760
will um

1673
01:03:23,589 --> 01:03:22,000
has this incredible sun shield that you

1674
01:03:25,430 --> 01:03:23,599
can see there the big grey kind of

1675
01:03:28,549 --> 01:03:25,440
sunshield there that's going to open up

1676
01:03:30,390 --> 01:03:28,559
to protect it from um as much of the of

1677
01:03:31,190 --> 01:03:30,400
the sunlight as possible and then it has

1678
01:03:32,470 --> 01:03:31,200
this

1679
01:03:34,390 --> 01:03:32,480
huge um

1680
01:03:36,309 --> 01:03:34,400
mirror that is going to open up

1681
01:03:37,510 --> 01:03:36,319
hopefully well and hopefully everything

1682
01:03:39,029 --> 01:03:37,520
will go well

1683
01:03:40,710 --> 01:03:39,039
and so this will be a really exciting

1684
01:03:42,870 --> 01:03:40,720
thing to follow over the next um coming

1685
01:03:46,069 --> 01:03:42,880
months after it launches

1686
01:03:48,069 --> 01:03:46,079
and so with that i will um wrap up

1687
01:03:50,710 --> 01:03:48,079
and i just want to say

1688
01:03:53,430 --> 01:03:50,720

you can be a planet hunter too and there

1689
01:03:55,430 --> 01:03:53,440
are many interesting citizen science

1690
01:03:57,589 --> 01:03:55,440
projects um that are related to

1691
01:04:00,069 --> 01:03:57,599
exoplanets i've just highlighted two

1692
01:04:01,029 --> 01:04:00,079
here that are both under the xuniverse

1693
01:04:02,950 --> 01:04:01,039
links

1694
01:04:04,789 --> 01:04:02,960
you can go to that website

1695
01:04:06,630 --> 01:04:04,799
and you can have a play around and we've

1696
01:04:07,470 --> 01:04:06,640
had um people

1697
01:04:10,069 --> 01:04:07,480
just

1698
01:04:11,670 --> 01:04:10,079
non-scientists members of the public who

1699
01:04:13,270 --> 01:04:11,680
have ended up being on published

1700
01:04:15,510 --> 01:04:13,280
peer-reviewed journals and because

1701
01:04:17,990 --> 01:04:15,520
they've helped to find signals in our

1702
01:04:20,230 --> 01:04:18,000
data using these projects and so i

1703
01:04:21,990 --> 01:04:20,240
strongly encourage you if you are

1704
01:04:24,390 --> 01:04:22,000
interested in this kind of thing that

1705
01:04:27,029 --> 01:04:24,400
you should go ahead and check out those

1706
01:04:28,950 --> 01:04:27,039
those websites and do

1707
01:04:30,950 --> 01:04:28,960
go and do some planet hunting

1708
01:04:33,829 --> 01:04:30,960
and with that i'm happy to take any

1709
01:04:36,870 --> 01:04:33,839
questions that you may have

1710
01:04:40,630 --> 01:04:36,880
ah thank you emily that was wonderful

1711
01:04:43,670 --> 01:04:40,640
and we have had an amazing number of

1712
01:04:45,829 --> 01:04:43,680
questions and comments on our chat today

1713
01:04:47,430 --> 01:04:45,839

uh you really you know you touched a lot

1714
01:04:49,270 --> 01:04:47,440
of people here today

1715
01:04:52,150 --> 01:04:49,280
this was great

1716
01:04:54,789 --> 01:04:52,160
let me ask the first question which sort

1717
01:04:57,029 --> 01:04:54,799
of kind of always comes up uh when you

1718
01:04:59,670 --> 01:04:57,039
talk about the radio velocity technique

1719
01:05:02,150 --> 01:04:59,680
uh because uh you showed that you know

1720
01:05:03,589 --> 01:05:02,160
you mentioned that uh you know the the

1721
01:05:06,069 --> 01:05:03,599
sun and jupiter are pulling on each

1722
01:05:07,510 --> 01:05:06,079
other and so our sun does wobble too so

1723
01:05:10,069 --> 01:05:07,520
the natural question that people often

1724
01:05:10,950 --> 01:05:10,079
ask is hey

1725
01:05:13,990 --> 01:05:10,960
would

1726
01:05:16,549 --> 01:05:14,000
to see

1727
01:05:18,950 --> 01:05:16,559
our detect our planets um when looking

1728
01:05:20,950 --> 01:05:18,960
at our sun with jupiter's motion causing

1729
01:05:22,549 --> 01:05:20,960
a little bit of wobble in the sun how

1730
01:05:24,710 --> 01:05:22,559
would our solar system look to some

1731
01:05:26,710 --> 01:05:24,720
alien astronomers

1732
01:05:28,789 --> 01:05:26,720
yeah that's a fantastic question so

1733
01:05:31,190 --> 01:05:28,799
there are some people and

1734
01:05:33,910 --> 01:05:31,200
that that work on this that kind of

1735
01:05:36,789 --> 01:05:33,920
observing observing the sun as if it was

1736
01:05:37,829 --> 01:05:36,799
an explanatory system um

1737
01:05:40,150 --> 01:05:37,839
and

1738
01:05:43,349 --> 01:05:40,160

the answer at the moment is no it would

1739
01:05:45,190 --> 01:05:43,359
not be possible if if they had the same

1740
01:05:47,029 --> 01:05:45,200
telescopes and the same instruments as

1741
01:05:49,430 --> 01:05:47,039
us just because the precision that you

1742
01:05:52,950 --> 01:05:49,440
need of the radial velocities is so

1743
01:05:54,309 --> 01:05:52,960
um so high that it's just jupiter is so

1744
01:05:56,309 --> 01:05:54,319
far away from the sun compared to the

1745
01:05:58,470 --> 01:05:56,319
typical systems that we look at that the

1746
01:06:01,190 --> 01:05:58,480
signal is just so small but you need

1747
01:06:03,349 --> 01:06:01,200
that really really fine precision but

1748
01:06:06,309 --> 01:06:03,359
we're just reaching that tipping point

1749
01:06:08,630 --> 01:06:06,319
now and so there's this um spectrograph

1750
01:06:11,990 --> 01:06:08,640
um which merges radial velocities called

1751
01:06:14,710 --> 01:06:12,000
espresso that was just put onto the vlt

1752
01:06:16,710 --> 01:06:14,720
in chile which is a paranal observatory

1753
01:06:18,230 --> 01:06:16,720
and it's kind of just starting to reach

1754
01:06:21,109 --> 01:06:18,240
that precision that's required that

1755
01:06:23,029 --> 01:06:21,119
would be required to do that and so

1756
01:06:25,510 --> 01:06:23,039
assuming that the alien life that would

1757
01:06:28,470 --> 01:06:25,520
be observing us or the radial velocities

1758
01:06:30,549 --> 01:06:28,480
of our sun had access to that same

1759
01:06:32,470 --> 01:06:30,559
precision level instrument then yes they

1760
01:06:34,309 --> 01:06:32,480
would be able to but they would have to

1761
01:06:35,430 --> 01:06:34,319
have that technology in order to do so

1762
01:06:37,589 --> 01:06:35,440
yes

1763
01:06:38,950 --> 01:06:37,599

right that's great because i mean that

1764
01:06:41,349 --> 01:06:38,960
also touches on another question that

1765
01:06:43,029 --> 01:06:41,359
people had it was just how fine are

1766
01:06:45,029 --> 01:06:43,039
these radial velocity shifts you know

1767
01:06:46,870 --> 01:06:45,039
when you show those animations they tend

1768
01:06:49,589 --> 01:06:46,880
to be really big and it's obvious so

1769
01:06:51,510 --> 01:06:49,599
that the public can see it but uh these

1770
01:06:54,230 --> 01:06:51,520
these radiology shifts are really really

1771
01:06:55,910 --> 01:06:54,240
tiny i mean we had to develop several

1772
01:06:57,670 --> 01:06:55,920
new new techniques in order to be able

1773
01:06:59,430 --> 01:06:57,680
to find these just uh when we first did

1774
01:07:02,230 --> 01:06:59,440
back in the 90s right

1775
01:07:05,349 --> 01:07:02,240
yeah absolutely and so we're really

1776
01:07:08,309 --> 01:07:05,359
starting to push down towards the 10

1777
01:07:11,270 --> 01:07:08,319
centimeters per second precision that's

1778
01:07:14,789 --> 01:07:11,280
insane i mean measuring a star

1779
01:07:16,390 --> 01:07:14,799
at 10 centimeters per second um that's

1780
01:07:18,150 --> 01:07:16,400
in another system however many light

1781
01:07:19,670 --> 01:07:18,160
years away and

1782
01:07:21,190 --> 01:07:19,680
yeah the techniques that are required to

1783
01:07:23,029 --> 01:07:21,200
do this are

1784
01:07:25,589 --> 01:07:23,039
absolutely incredible and the technology

1785
01:07:28,069 --> 01:07:25,599
that has advanced so far in just a short

1786
01:07:30,549 --> 01:07:28,079
period of time in in the past 20 to 30

1787
01:07:32,710 --> 01:07:30,559
years has been absolutely incredible so

1788
01:07:34,870 --> 01:07:32,720

i can say this um new spectrograph

1789
01:07:36,630 --> 01:07:34,880
espresso has been has been doing just

1790
01:07:39,029 --> 01:07:36,640
that and it's it's going to continue as

1791
01:07:40,549 --> 01:07:39,039
we go towards the elt which i mentioned

1792
01:07:43,109 --> 01:07:40,559
before and

1793
01:07:45,910 --> 01:07:43,119
yeah it's going to be incredible

1794
01:07:47,190 --> 01:07:45,920
okay yeah so i just just for everyone's

1795
01:07:48,710 --> 01:07:47,200
reference astronomers are used to

1796
01:07:50,710 --> 01:07:48,720
measuring things in kilometers per

1797
01:07:52,390 --> 01:07:50,720
second all right in terms of velocities

1798
01:07:53,829 --> 01:07:52,400
and this getting down to 10 centimeters

1799
01:07:55,829 --> 01:07:53,839
per second that's you know factor of 100

1800
01:07:57,510 --> 01:07:55,839
increase and such and so this is just

1801
01:07:59,270 --> 01:07:57,520
like amazing

1802
01:08:00,870 --> 01:07:59,280
um so emily why don't you stop your

1803
01:08:03,430 --> 01:08:00,880
share screen

1804
01:08:04,950 --> 01:08:03,440
and let's bring in grant justice grant

1805
01:08:06,950 --> 01:08:04,960
has been monitoring the chat a little

1806
01:08:10,230 --> 01:08:06,960
bit more carefully than i have

1807
01:08:12,630 --> 01:08:10,240
and i'm sure grant has found a number of

1808
01:08:14,710 --> 01:08:12,640
really cool questions for today so what

1809
01:08:17,189 --> 01:08:14,720
do you got for us grant yeah we have had

1810
01:08:19,349 --> 01:08:17,199
a really great chat today so thank you

1811
01:08:21,030 --> 01:08:19,359
all for uh

1812
01:08:23,110 --> 01:08:21,040
participating and being here for the

1813
01:08:25,189 --> 01:08:23,120

live part as a reminder to everyone it

1814
01:08:28,149 --> 01:08:25,199
will be up again afterwards if you did

1815
01:08:30,149 --> 01:08:28,159
miss any part of it including the q a

1816
01:08:32,309 --> 01:08:30,159
so um starting us off

1817
01:08:34,630 --> 01:08:32,319
and this one i really like what are ways

1818
01:08:37,189 --> 01:08:34,640
that you could see exoplanets or

1819
01:08:38,390 --> 01:08:37,199
extrasolar whatever it might be

1820
01:08:40,630 --> 01:08:38,400
its bodies

1821
01:08:43,030 --> 01:08:40,640
in the future based on what we are doing

1822
01:08:45,749 --> 01:08:43,040
here today

1823
01:08:47,669 --> 01:08:45,759
i think that we're going to see a real

1824
01:08:49,749 --> 01:08:47,679
combination of all of these different

1825
01:08:51,110 --> 01:08:49,759
measurement techniques come together so

1826
01:08:52,870 --> 01:08:51,120
all of the different detection

1827
01:08:55,669 --> 01:08:52,880
techniques that i mentioned

1828
01:08:57,349 --> 01:08:55,679
um i think they're all being so the

1829
01:08:59,110 --> 01:08:57,359
radial velocities we're going further

1830
01:09:00,630 --> 01:08:59,120
and further out to longer and longer

1831
01:09:02,309 --> 01:09:00,640
orbital periods

1832
01:09:04,229 --> 01:09:02,319
and on the imaging side we're coming

1833
01:09:06,709 --> 01:09:04,239
further and further in towards smaller

1834
01:09:07,829 --> 01:09:06,719
inner working angles closer to the star

1835
01:09:08,950 --> 01:09:07,839
and i think

1836
01:09:10,709 --> 01:09:08,960
things like that where we're going to

1837
01:09:13,110 --> 01:09:10,719
end up combining all of these different

1838
01:09:15,030 --> 01:09:13,120

detection techniques and that is really

1839
01:09:17,189 --> 01:09:15,040
powerful because from each of the

1840
01:09:18,950 --> 01:09:17,199
different detection techniques you get

1841
01:09:20,309 --> 01:09:18,960
different characteristics of the planet

1842
01:09:22,390 --> 01:09:20,319
that you're looking at or the orbital

1843
01:09:23,990 --> 01:09:22,400
characteristics so for example with

1844
01:09:25,910 --> 01:09:24,000
radial velocities you only get the

1845
01:09:27,510 --> 01:09:25,920
minimum mass because you don't know the

1846
01:09:29,510 --> 01:09:27,520
orbital inclination of the system that

1847
01:09:30,550 --> 01:09:29,520
you're looking at it could be faison or

1848
01:09:32,470 --> 01:09:30,560
edge on

1849
01:09:34,470 --> 01:09:32,480
but if you combine that with direct

1850
01:09:36,950 --> 01:09:34,480
imaging for example you remove that

1851
01:09:38,950 --> 01:09:36,960
degeneracy and you're able to fit for

1852
01:09:40,950 --> 01:09:38,960
the orbital inclination and so i think

1853
01:09:43,829 --> 01:09:40,960
what's going to happen over time is i'm

1854
01:09:45,749 --> 01:09:43,839
showing that detection um map earlier

1855
01:09:47,510 --> 01:09:45,759
with all of these different planets is

1856
01:09:49,510 --> 01:09:47,520
all of those are going to kind of like

1857
01:09:50,789 --> 01:09:49,520
shrinking together and we're going to be

1858
01:09:52,149 --> 01:09:50,799
able to have all of this incredible

1859
01:09:54,070 --> 01:09:52,159
information these really well

1860
01:09:55,270 --> 01:09:54,080
characterized exoplanets and that's

1861
01:09:56,470 --> 01:09:55,280
going to be really important to

1862
01:09:58,790 --> 01:09:56,480
understand

1863
01:10:01,030 --> 01:09:58,800

uh the mass the radius and to look at

1864
01:10:03,270 --> 01:10:01,040
the atmospheres of these things and

1865
01:10:05,189 --> 01:10:03,280
really reveal uh the truths about what

1866
01:10:07,350 --> 01:10:05,199
we're looking at because often when we

1867
01:10:09,750 --> 01:10:07,360
get the detections we're like okay we're

1868
01:10:12,310 --> 01:10:09,760
looking at something that's however many

1869
01:10:13,750 --> 01:10:12,320
jupiter masses thing that's maybe this

1870
01:10:15,590 --> 01:10:13,760
far away from the star and that's all we

1871
01:10:16,550 --> 01:10:15,600
can really say but when you combine it

1872
01:10:18,229 --> 01:10:16,560
all together

1873
01:10:20,630 --> 01:10:18,239
that's going to just change the field of

1874
01:10:23,350 --> 01:10:20,640
exoplanets massively

1875
01:10:26,070 --> 01:10:23,360
so emily what about the idea of a star

1876
01:10:28,950 --> 01:10:26,080
shade um that was proposed for various

1877
01:10:31,189 --> 01:10:28,960
space telescopes that we we float out

1878
01:10:33,270 --> 01:10:31,199
a shade to act as a

1879
01:10:36,149 --> 01:10:33,280
chronographic spot basically floating

1880
01:10:38,870 --> 01:10:36,159
out in in free space uh things is that

1881
01:10:41,510 --> 01:10:38,880
it can happen uh because that offers uh

1882
01:10:43,669 --> 01:10:41,520
quite a quite a bit of advantage

1883
01:10:45,830 --> 01:10:43,679
yeah i mean i say let's do it like you

1884
01:10:47,910 --> 01:10:45,840
know fungus nasa and easter if you're

1885
01:10:50,070 --> 01:10:47,920
listening whoever has the money please

1886
01:10:51,590 --> 01:10:50,080
give it to us that would be fantastic

1887
01:10:54,070 --> 01:10:51,600
i think another exciting thing is going

1888
01:10:55,830 --> 01:10:54,080

to be um potentially putting a telescope

1889
01:10:57,669 --> 01:10:55,840
on the moon on the far side of the moon

1890
01:10:59,189 --> 01:10:57,679
i mean you wouldn't have to deal with

1891
01:11:01,030 --> 01:10:59,199
the atmosphere of the earth you wouldn't

1892
01:11:03,270 --> 01:11:01,040
have to deal with light pollution

1893
01:11:04,550 --> 01:11:03,280
i think that would be an incredible

1894
01:11:06,070 --> 01:11:04,560
thing to do as well so yeah i think

1895
01:11:07,510 --> 01:11:06,080
there's lots of exciting technology

1896
01:11:08,790 --> 01:11:07,520
that's being um

1897
01:11:10,870 --> 01:11:08,800
concepts that are being thought about

1898
01:11:12,470 --> 01:11:10,880
things like these star shades that of

1899
01:11:14,709 --> 01:11:12,480
course it always comes down to funding

1900
01:11:16,470 --> 01:11:14,719
but um this would be a game changer as

1901
01:11:19,510 --> 01:11:16,480
well yeah absolutely

1902
01:11:22,390 --> 01:11:19,520
all right great what else we got grant

1903
01:11:25,510 --> 01:11:22,400
all right so next one up and this is one

1904
01:11:26,870 --> 01:11:25,520
we get asked a lot about hst because

1905
01:11:29,030 --> 01:11:26,880
everyone wants to know why it can't

1906
01:11:32,870 --> 01:11:29,040
observe our own universe while our own

1907
01:11:34,630 --> 01:11:32,880
universe our own galaxy images or bodies

1908
01:11:36,229 --> 01:11:34,640
that are closer to it what are some of

1909
01:11:37,590 --> 01:11:36,239
the complications that you have on the

1910
01:11:39,750 --> 01:11:37,600
opposite end of the spectrum with

1911
01:11:43,110 --> 01:11:39,760
searching for exoplanets surging outside

1912
01:11:45,990 --> 01:11:44,470
i think you just broke up for a minute

1913
01:11:47,750 --> 01:11:46,000

though i broke up for a minute how would

1914
01:11:49,830 --> 01:11:47,760
you mind just

1915
01:11:52,709 --> 01:11:49,840
sure sure sure

1916
01:11:54,149 --> 01:11:52,719
um there are a lot of things that we

1917
01:11:56,630 --> 01:11:54,159
deal with and a lot of things we talk

1918
01:11:59,430 --> 01:11:56,640
about with hst because it's long range

1919
01:12:00,950 --> 01:11:59,440
observing short range like in system

1920
01:12:02,790 --> 01:12:00,960
what are some of the challenges that you

1921
01:12:05,270 --> 01:12:02,800
have with the existing telescopes

1922
01:12:06,950 --> 01:12:05,280
observing exoplanets observing long

1923
01:12:09,510 --> 01:12:06,960
range

1924
01:12:12,390 --> 01:12:09,520
yeah so one of the

1925
01:12:15,030 --> 01:12:12,400
specific difficulties with hst is just

1926
01:12:18,149 --> 01:12:15,040
the wavelength coverage for exoplanet

1927
01:12:20,709 --> 01:12:18,159
science so hst is perfect for many

1928
01:12:23,510 --> 01:12:20,719
different types of um subfields in

1929
01:12:25,750 --> 01:12:23,520
astronomy but with exoplanets we tend to

1930
01:12:27,750 --> 01:12:25,760
observe in the longer wavelength range

1931
01:12:30,470 --> 01:12:27,760
so sort of towards the very long end of

1932
01:12:33,430 --> 01:12:30,480
the optical into the infrared

1933
01:12:34,950 --> 01:12:33,440
um hst doesn't really

1934
01:12:37,189 --> 01:12:34,960
it's not optimized to probe that

1935
01:12:39,110 --> 01:12:37,199
wavelength range and that's going to be

1936
01:12:41,270 --> 01:12:39,120
the big game changer with jwst and

1937
01:12:42,870 --> 01:12:41,280
exoplanetary science because we've got a

1938
01:12:44,229 --> 01:12:42,880

handful of instruments on there that are

1939
01:12:46,070 --> 01:12:44,239
really going to target that wavelength

1940
01:12:47,910 --> 01:12:46,080
range so like neospec and nyokam and

1941
01:12:49,750 --> 01:12:47,920
miri they're going to be fantastic

1942
01:12:51,990 --> 01:12:49,760
improving those longer wavelengths

1943
01:12:53,830 --> 01:12:52,000
that's required to do the science that

1944
01:12:57,510 --> 01:12:53,840
we want to do i mean also bearing in

1945
01:13:00,149 --> 01:12:57,520
mind that hst was um sort of the concept

1946
01:13:01,990 --> 01:13:00,159
of hst and the launch of it was way back

1947
01:13:03,430 --> 01:13:02,000
when exactly there were only a handful

1948
01:13:05,350 --> 01:13:03,440
of exoplanets had even been discovered

1949
01:13:06,870 --> 01:13:05,360
and of course these missions take years

1950
01:13:08,630 --> 01:13:06,880
and years and years to design and put

1951
01:13:11,910 --> 01:13:08,640
together and launch and so

1952
01:13:14,390 --> 01:13:11,920
it probably wasn't even at the center of

1953
01:13:15,750 --> 01:13:14,400
the scientific output that was that was

1954
01:13:18,310 --> 01:13:15,760
being thought about when you think about

1955
01:13:19,990 --> 01:13:18,320
hst and so jwst is going to be a game

1956
01:13:21,590 --> 01:13:20,000
changer and there's also other mission

1957
01:13:23,750 --> 01:13:21,600
concepts that we're thinking about like

1958
01:13:25,910 --> 01:13:23,760
habex and luvoir which are nasa mission

1959
01:13:27,910 --> 01:13:25,920
concepts that are going to be probing

1960
01:13:30,830 --> 01:13:27,920
those wavelength ranges that are more

1961
01:13:33,750 --> 01:13:30,840
amenable to um observing

1962
01:13:36,149 --> 01:13:33,760
exoplanets and you mentioned adaptive

1963
01:13:38,070 --> 01:13:36,159

optics in your talk um and that's really

1964
01:13:40,870 --> 01:13:38,080
helping ground-based observatories

1965
01:13:42,470 --> 01:13:40,880
approach what we can see from space

1966
01:13:43,750 --> 01:13:42,480
but generally i mean this is that

1967
01:13:45,189 --> 01:13:43,760
infrared

1968
01:13:46,709 --> 01:13:45,199
correct me if i'm wrong but i've always

1969
01:13:48,790 --> 01:13:46,719
understood to be basically at infrared

1970
01:13:50,790 --> 01:13:48,800
wavelengths and over a relatively small

1971
01:13:52,470 --> 01:13:50,800
field of view how is that progressing

1972
01:13:54,550 --> 01:13:52,480
and where do we see that going in this

1973
01:13:58,310 --> 01:13:54,560
in this uh discovery

1974
01:14:00,550 --> 01:13:58,320
yeah so um it's primarily yeah over over

1975
01:14:04,229 --> 01:14:00,560
the visible and infrared wavelength

1976
01:14:06,470 --> 01:14:04,239
range um it's well i mean so the kind of

1977
01:14:09,590 --> 01:14:06,480
concept of adaptive optics is now being

1978
01:14:12,390 --> 01:14:09,600
taken into space even with the roman

1979
01:14:14,550 --> 01:14:12,400
space telescope and so it is that

1980
01:14:15,590 --> 01:14:14,560
technology is then being enhanced to

1981
01:14:17,270 --> 01:14:15,600
something

1982
01:14:20,310 --> 01:14:17,280
corrections for not obviously for the

1983
01:14:22,630 --> 01:14:20,320
atmosphere but in order to um actively

1984
01:14:25,030 --> 01:14:22,640
correct the optics for a telescope in

1985
01:14:27,830 --> 01:14:25,040
space so i think the technology that's

1986
01:14:30,950 --> 01:14:27,840
being um worked upon improved upon

1987
01:14:34,390 --> 01:14:30,960
research down here on earth is now being

1988
01:14:36,709 --> 01:14:34,400

used to refine our space images even

1989
01:14:38,790 --> 01:14:36,719
even further and you know the technology

1990
01:14:40,390 --> 01:14:38,800
that we're able to do with this like um

1991
01:14:42,950 --> 01:14:40,400
increase the frequency at which we make

1992
01:14:44,709 --> 01:14:42,960
these corrections um

1993
01:14:46,870 --> 01:14:44,719
so and the attenuators that are on the

1994
01:14:48,709 --> 01:14:46,880
mirrors is kind of increasing over time

1995
01:14:50,229 --> 01:14:48,719
the reason yeah the reason you have to

1996
01:14:52,550 --> 01:14:50,239
do this primarily in the visible and

1997
01:14:53,910 --> 01:14:52,560
infrared is just because that's the

1998
01:14:55,110 --> 01:14:53,920
that's where you get the most kind of

1999
01:14:56,630 --> 01:14:55,120
refraction

2000
01:14:58,470 --> 01:14:56,640
from the earth's atmosphere when you

2001
01:14:59,830 --> 01:14:58,480
observe those wavelengths um it's not

2002
01:15:02,070 --> 01:14:59,840
such it's not an issue if you're

2003
01:15:03,430 --> 01:15:02,080
observing for example in the radio uh

2004
01:15:05,990 --> 01:15:03,440
wavelength range because you're not

2005
01:15:07,910 --> 01:15:06,000
affected by the refraction

2006
01:15:09,990 --> 01:15:07,920
right and you know the idea of a

2007
01:15:10,870 --> 01:15:10,000
multi-mirror telescope like james webb

2008
01:15:11,910 --> 01:15:10,880
was

2009
01:15:13,510 --> 01:15:11,920
i mean

2010
01:15:15,510 --> 01:15:13,520
we were just starting creating

2011
01:15:18,310 --> 01:15:15,520
multi-mirror telescopes in the 90s right

2012
01:15:20,470 --> 01:15:18,320
the 80s and 90s um you know so

2013
01:15:21,910 --> 01:15:20,480

none of that even

2014
01:15:23,990 --> 01:15:21,920
could possibly have been thought of for

2015
01:15:26,310 --> 01:15:24,000
hubble which launched in 1990.

2016
01:15:27,990 --> 01:15:26,320
absolutely exactly one of the things

2017
01:15:29,510 --> 01:15:28,000
that the comments were talking about

2018
01:15:33,030 --> 01:15:29,520
quite a bit are the differences between

2019
01:15:34,470 --> 01:15:33,040
hst and jwst and roman and so on and so

2020
01:15:37,030 --> 01:15:34,480
forth and

2021
01:15:39,189 --> 01:15:37,040
the interactivity between them and hst

2022
01:15:40,709 --> 01:15:39,199
and jwsd because they observe there is a

2023
01:15:42,070 --> 01:15:40,719
little bit of overlap but they observe

2024
01:15:44,950 --> 01:15:42,080
like different

2025
01:15:46,790 --> 01:15:44,960
spectrum like ranges they actually can

2026
01:15:48,630 --> 01:15:46,800
work in concert which is what we were

2027
01:15:50,870 --> 01:15:48,640
telling the chat

2028
01:15:53,110 --> 01:15:50,880
but that brings us to another one and

2029
01:15:56,390 --> 01:15:53,120
this immediately made me think of the

2030
01:15:59,350 --> 01:15:56,400
nano apertures but how are

2031
01:16:01,830 --> 01:15:59,360
like physical barriers in used in the

2032
01:16:05,590 --> 01:16:01,840
telescope for like lithography machines

2033
01:16:08,950 --> 01:16:07,510
so that's basically the whole concept

2034
01:16:10,149 --> 01:16:08,960
but if you would like to elaborate a

2035
01:16:12,790 --> 01:16:10,159
little more

2036
01:16:14,550 --> 01:16:12,800
yeah um well i mean so well one of the

2037
01:16:18,630 --> 01:16:14,560
most interesting concepts of this will

2038
01:16:20,470 --> 01:16:18,640

be the giants to sun shade on jwst and

2039
01:16:21,830 --> 01:16:20,480
that's going to be that is going to be a

2040
01:16:23,350 --> 01:16:21,840
huge huge thing and we're all going to

2041
01:16:25,189 --> 01:16:23,360
be crossing our fingers and praying and

2042
01:16:26,390 --> 01:16:25,199
hoping that this all goes smoothly not

2043
01:16:28,790 --> 01:16:26,400
that it's going to be a long two weeks

2044
01:16:31,990 --> 01:16:28,800
to believe otherwise yes

2045
01:16:34,390 --> 01:16:32,000
um but yes so definitely utilizing

2046
01:16:36,630 --> 01:16:34,400
things like this in order to um

2047
01:16:39,750 --> 01:16:36,640
remove as much of the sunlight as

2048
01:16:41,669 --> 01:16:39,760
possible um and yeah

2049
01:16:43,750 --> 01:16:41,679
you have you have run into different

2050
01:16:46,070 --> 01:16:43,760
issues of things like hst where it's

2051
01:16:48,070 --> 01:16:46,080
orbiting low earth orbit and

2052
01:16:50,470 --> 01:16:48,080
um but then you have to deal with the

2053
01:16:53,510 --> 01:16:50,480
breathing of hst as it goes in and out

2054
01:16:55,830 --> 01:16:53,520
of the sun um it expands and shrinks

2055
01:16:57,990 --> 01:16:55,840
down because of the thermal

2056
01:17:00,470 --> 01:16:58,000
um energy it's receiving from the sun so

2057
01:17:03,669 --> 01:17:00,480
yeah um but i am i'm extremely excited

2058
01:17:05,910 --> 01:17:03,679
to see the the star shade be deployed

2059
01:17:07,830 --> 01:17:05,920
and and how this how this goes and

2060
01:17:11,430 --> 01:17:07,840
hopefully everything will go smoothly as

2061
01:17:15,990 --> 01:17:13,750
all right and uh i'll go to this one

2062
01:17:19,110 --> 01:17:16,000
next before i lose it in the chain of

2063
01:17:21,030 --> 01:17:19,120

comments what is your personal

2064
01:17:22,950 --> 01:17:21,040
favorite or most interesting mystery

2065
01:17:26,149 --> 01:17:22,960
about exoplanets that you have found

2066
01:17:28,229 --> 01:17:26,159
thus far or would like to solve

2067
01:17:29,510 --> 01:17:28,239
that is an amazing question

2068
01:17:32,470 --> 01:17:29,520
i don't know if i thought too long and

2069
01:17:34,470 --> 01:17:32,480
hard about this yeah so i

2070
01:17:36,470 --> 01:17:34,480
i'm very biased towards the upper end of

2071
01:17:38,229 --> 01:17:36,480
planets um upper like mass range of

2072
01:17:40,470 --> 01:17:38,239
planets and things just because of the

2073
01:17:42,630 --> 01:17:40,480
stuff that i primarily work on and so i

2074
01:17:45,030 --> 01:17:42,640
think i'm a secret lover of the gas

2075
01:17:48,070 --> 01:17:45,040
giants planets that are a lot more like

2076
01:17:49,510 --> 01:17:48,080
do certain things like this and i'm just

2077
01:17:51,990 --> 01:17:49,520
hoping that we find some really

2078
01:17:54,070 --> 01:17:52,000
interesting obscure like atmospheric

2079
01:17:55,590 --> 01:17:54,080
properties of a planet like that that

2080
01:17:58,070 --> 01:17:55,600
have some really i don't know maybe

2081
01:18:00,390 --> 01:17:58,080
strange molecular features of things so

2082
01:18:02,310 --> 01:18:00,400
that's what i see is an exciting thing

2083
01:18:04,390 --> 01:18:02,320
more in general though i hope that

2084
01:18:06,630 --> 01:18:04,400
within i hope within my lifetime that

2085
01:18:08,149 --> 01:18:06,640
there is some strong evidence to suggest

2086
01:18:10,310 --> 01:18:08,159
that there is life on another planet

2087
01:18:12,470 --> 01:18:10,320
that would be the most incredible thing

2088
01:18:13,510 --> 01:18:12,480

to live through and i really think that

2089
01:18:16,070 --> 01:18:13,520
we're getting

2090
01:18:17,110 --> 01:18:16,080
closer and closer to to that revolution

2091
01:18:20,229 --> 01:18:17,120
so yeah

2092
01:18:23,510 --> 01:18:20,239
okay so i'm going to say that i kind of

2093
01:18:25,350 --> 01:18:23,520
am really really really intrigued by the

2094
01:18:27,510 --> 01:18:25,360
super earth

2095
01:18:29,350 --> 01:18:27,520
yeah yeah all right so we we're starting

2096
01:18:31,030 --> 01:18:29,360
to see the categories of planets that we

2097
01:18:32,950 --> 01:18:31,040
see in our solar system

2098
01:18:35,990 --> 01:18:32,960
replicated out throughout the universe

2099
01:18:38,470 --> 01:18:36,000
but there's these five earth mass

2100
01:18:39,350 --> 01:18:38,480
objects out there you know and i'm like

2101
01:18:40,790 --> 01:18:39,360
well

2102
01:18:43,510 --> 01:18:40,800
that doesn't fit with what we've got

2103
01:18:45,430 --> 01:18:43,520
here that's a whole new class of planet

2104
01:18:46,950 --> 01:18:45,440
uh these mini neptunes or these super

2105
01:18:49,189 --> 01:18:46,960
earths so i don't know which which we

2106
01:18:51,430 --> 01:18:49,199
want to call them but that's the kind of

2107
01:18:54,390 --> 01:18:51,440
ones that intrigue me the most because

2108
01:18:56,070 --> 01:18:54,400
it's uh like this is something brand new

2109
01:18:57,510 --> 01:18:56,080
and so when we get statistics on that

2110
01:18:59,590 --> 01:18:57,520
and really start to understand those i

2111
01:19:01,350 --> 01:18:59,600
think that's going to be you know that's

2112
01:19:03,510 --> 01:19:01,360
going to be an eye opener yeah i

2113
01:19:05,750 --> 01:19:03,520

completely agree and i'm really looking

2114
01:19:08,149 --> 01:19:05,760
forward to seeing how that um shapes and

2115
01:19:10,630 --> 01:19:08,159
evolves our own views on our own solar

2116
01:19:12,550 --> 01:19:10,640
system like are we really unique in the

2117
01:19:13,350 --> 01:19:12,560
way that our own solar system is set up

2118
01:19:15,830 --> 01:19:13,360
or

2119
01:19:17,590 --> 01:19:15,840
i as we go towards being able to observe

2120
01:19:19,430 --> 01:19:17,600
more of these things i'll be more

2121
01:19:21,030 --> 01:19:19,440
representative of what an average

2122
01:19:22,950 --> 01:19:21,040
stellar system looks like and i think

2123
01:19:24,870 --> 01:19:22,960
that super f1 is a great

2124
01:19:26,630 --> 01:19:24,880
um question that's involved in that

2125
01:19:29,750 --> 01:19:26,640
because we just don't have anything like

2126
01:19:31,750 --> 01:19:29,760
that in our own solar system

2127
01:19:32,550 --> 01:19:31,760
absolutely all right it's true all right

2128
01:19:34,630 --> 01:19:32,560
um

2129
01:19:37,750 --> 01:19:34,640
continuing on from where we are sorry

2130
01:19:39,590 --> 01:19:37,760
i'm looking at multiple screens here um

2131
01:19:41,510 --> 01:19:39,600
so first off

2132
01:19:43,270 --> 01:19:41,520
shout out to you from space tv they are

2133
01:19:45,350 --> 01:19:43,280
looking forward to the launch of the

2134
01:19:48,310 --> 01:19:45,360
emily rickman space telescope to study

2135
01:19:52,229 --> 01:19:48,320
gas giants that would be incredible um

2136
01:19:57,350 --> 01:19:55,910
um and uh secondarily to that and this

2137
01:19:58,709 --> 01:19:57,360
is something that's already ongoing but

2138
01:19:59,830 --> 01:19:58,719

i would like for us to elaborate a

2139
01:20:01,350 --> 01:19:59,840
little bit more for the people in the

2140
01:20:03,510 --> 01:20:01,360
audience who haven't seen it there's

2141
01:20:04,470 --> 01:20:03,520
another talk all about

2142
01:20:07,590 --> 01:20:04,480
tests

2143
01:20:10,149 --> 01:20:07,600
and a lot of the um efforts undergoing

2144
01:20:12,310 --> 01:20:10,159
to catalog planets that we want to

2145
01:20:14,950 --> 01:20:12,320
point at later kind of like a

2146
01:20:17,910 --> 01:20:14,960
rangefinding sort of satellite which i

2147
01:20:19,270 --> 01:20:17,920
find infinitely interesting um but a lot

2148
01:20:20,709 --> 01:20:19,280
of that is already going underway so

2149
01:20:24,149 --> 01:20:20,719
would you elaborate a little bit more

2150
01:20:25,990 --> 01:20:24,159
about the classifications of planets of

2151
01:20:28,310 --> 01:20:26,000
exoplanets and like

2152
01:20:29,910 --> 01:20:28,320
what specifically we look for and i know

2153
01:20:31,350 --> 01:20:29,920
infrared will help us with atmospheres

2154
01:20:32,470 --> 01:20:31,360
and whatnot but everyone wants to know a

2155
01:20:34,070 --> 01:20:32,480
little bit more about the search for

2156
01:20:35,430 --> 01:20:34,080
like habitable worlds and what that

2157
01:20:37,590 --> 01:20:35,440
looks like

2158
01:20:38,790 --> 01:20:37,600
yeah yeah so i think categorizing is a

2159
01:20:40,629 --> 01:20:38,800
really um

2160
01:20:42,310 --> 01:20:40,639
is an interesting way to put it yes i

2161
01:20:43,510 --> 01:20:42,320
didn't i actually didn't mention tess

2162
01:20:45,110 --> 01:20:43,520
but that's just because i ran out of

2163
01:20:47,669 --> 01:20:45,120

space on a number of space telescopes i

2164
01:20:50,149 --> 01:20:47,679
could mention in one talk but yes tess

2165
01:20:52,629 --> 01:20:50,159
is the translating exoplanet and

2166
01:20:54,390 --> 01:20:52,639
survey satellite and it has a very

2167
01:20:56,470 --> 01:20:54,400
similar job to kepler but on an even

2168
01:20:58,550 --> 01:20:56,480
bigger scale and actually one of the

2169
01:21:00,070 --> 01:20:58,560
links i put on the very last slide if

2170
01:21:01,830 --> 01:21:00,080
people want to get involved with this is

2171
01:21:03,669 --> 01:21:01,840
actually looking at tests like curves

2172
01:21:05,430 --> 01:21:03,679
and so if people are interested in that

2173
01:21:08,390 --> 01:21:05,440
then absolutely go and go and check that

2174
01:21:11,110 --> 01:21:08,400
out and be involved in it but yeah so

2175
01:21:13,430 --> 01:21:11,120
tess is doing a huge job of looking at

2176
01:21:16,070 --> 01:21:13,440
thousands and thousands of and both new

2177
01:21:19,590 --> 01:21:16,080
exoplanets and ones that have um well

2178
01:21:21,669 --> 01:21:19,600
it's staring into the sky to find um

2179
01:21:23,750 --> 01:21:21,679
both stars that may be already that we

2180
01:21:25,030 --> 01:21:23,760
know already host planets and also new

2181
01:21:25,750 --> 01:21:25,040
planets

2182
01:21:27,830 --> 01:21:25,760
and

2183
01:21:30,550 --> 01:21:27,840
those kind of statistics that we've got

2184
01:21:32,629 --> 01:21:30,560
from kepler but also tess are really

2185
01:21:34,390 --> 01:21:32,639
enabling the categorization of those

2186
01:21:35,910 --> 01:21:34,400
planets because you can't categorize

2187
01:21:38,390 --> 01:21:35,920
something that you have like

2188
01:21:40,070 --> 01:21:38,400

10 planets for like it doesn't mean

2189
01:21:41,590 --> 01:21:40,080
anything and so we're really starting to

2190
01:21:43,750 --> 01:21:41,600
get to this point now where we can say

2191
01:21:46,070 --> 01:21:43,760
okay this thing has a composition that's

2192
01:21:47,510 --> 01:21:46,080
similar it's rocky it's similar to earth

2193
01:21:48,870 --> 01:21:47,520
or something like that and what i was

2194
01:21:50,950 --> 01:21:48,880
saying before that you could get the

2195
01:21:52,709 --> 01:21:50,960
radius from the transit technique and

2196
01:21:54,149 --> 01:21:52,719
masses by combining

2197
01:21:56,070 --> 01:21:54,159
like radial velocity information for

2198
01:21:58,070 --> 01:21:56,080
example so that's really important and

2199
01:21:59,590 --> 01:21:58,080
once once you've got that constraint on

2200
01:22:01,270 --> 01:21:59,600
the mass and the radius and you can get

2201
01:22:04,629 --> 01:22:01,280
an idea of its composition of its

2202
01:22:06,390 --> 01:22:04,639
density um and so the categorizing is

2203
01:22:07,990 --> 01:22:06,400
going more beyond

2204
01:22:09,990 --> 01:22:08,000
what it used to be of like oh this thing

2205
01:22:11,350 --> 01:22:10,000
is this certain size it's now like oh

2206
01:22:12,790 --> 01:22:11,360
this thing maybe has this kind of

2207
01:22:15,189 --> 01:22:12,800
atmosphere or this thing has this kind

2208
01:22:17,430 --> 01:22:15,199
of composition um and it's really trying

2209
01:22:18,870 --> 01:22:17,440
to understand that um also the

2210
01:22:20,149 --> 01:22:18,880
connection between that as well between

2211
01:22:21,990 --> 01:22:20,159
the composition and the atmosphere and

2212
01:22:23,350 --> 01:22:22,000
that's something that's kind of new um

2213
01:22:25,510 --> 01:22:23,360

but yeah so

2214
01:22:28,070 --> 01:22:25,520
um as frank mentioned before super earth

2215
01:22:29,510 --> 01:22:28,080
is a category of these giant um

2216
01:22:31,830 --> 01:22:29,520
earth-like planets that are really

2217
01:22:34,390 --> 01:22:31,840
incredible and a bit of a mystery to us

2218
01:22:36,070 --> 01:22:34,400
and then the interesting fight thing i

2219
01:22:38,070 --> 01:22:36,080
find with the categories is where you

2220
01:22:39,990 --> 01:22:38,080
kind of draw the line at hot jupiters so

2221
01:22:42,070 --> 01:22:40,000
the jupiter-like planets are extremely

2222
01:22:44,470 --> 01:22:42,080
close to the star and then the warm

2223
01:22:47,350 --> 01:22:44,480
jupiters and then you start to go into

2224
01:22:50,390 --> 01:22:47,360
like warm neptunes and hot neptunes and

2225
01:22:53,270 --> 01:22:50,400
and one that really annoys me

2226
01:22:55,110 --> 01:22:53,280
is the when people start saying cold

2227
01:22:57,910 --> 01:22:55,120
jupiters but they mean something that's

2228
01:23:00,709 --> 01:22:57,920
maybe um has an orbital period of a few

2229
01:23:02,390 --> 01:23:00,719
years when i say a cold jupiter i mean

2230
01:23:04,550 --> 01:23:02,400
something that has an orbital period of

2231
01:23:06,070 --> 01:23:04,560
tens of years and so

2232
01:23:08,229 --> 01:23:06,080
there's still a bit of a discussion

2233
01:23:09,590 --> 01:23:08,239
within the exoplanets from astronomy

2234
01:23:11,669 --> 01:23:09,600
community about how we even really

2235
01:23:13,830 --> 01:23:11,679
categorize these things but yeah tess is

2236
01:23:16,149 --> 01:23:13,840
really driving forward a lot of that

2237
01:23:18,390 --> 01:23:16,159
because it's such a big survey satellite

2238
01:23:19,830 --> 01:23:18,400

it's able to stay it has a really

2239
01:23:21,669 --> 01:23:19,840
wide field of view it's able to stir a

2240
01:23:23,350 --> 01:23:21,679
lot of stars is able to

2241
01:23:25,350 --> 01:23:23,360
kind of constantly monitor a lot of

2242
01:23:27,910 --> 01:23:25,360
these things and and that will also be

2243
01:23:29,030 --> 01:23:27,920
true for the uh roman space telescope as

2244
01:23:30,950 --> 01:23:29,040
well

2245
01:23:31,750 --> 01:23:30,960
yeah and you know what i really love

2246
01:23:34,950 --> 01:23:31,760
about

2247
01:23:36,870 --> 01:23:34,960
that

2248
01:23:39,669 --> 01:23:36,880
you can see the succession of the the

2249
01:23:41,830 --> 01:23:39,679
missions in that uh kepler really stared

2250
01:23:44,070 --> 01:23:41,840
at one spot in the sky and got lots and

2251
01:23:45,750 --> 01:23:44,080
lots of statistics to say all right well

2252
01:23:47,830 --> 01:23:45,760
how many of these exoplanets do we

2253
01:23:49,510 --> 01:23:47,840
expect out there and then tess does

2254
01:23:50,629 --> 01:23:49,520
follow up and it's all sky and it's

2255
01:23:52,629 --> 01:23:50,639
looking all over the place and it's

2256
01:23:54,870 --> 01:23:52,639
getting the closer ones but it's finding

2257
01:23:56,870 --> 01:23:54,880
the ones that you know james webb can

2258
01:23:58,629 --> 01:23:56,880
then follow up and study in detail

2259
01:24:00,709 --> 01:23:58,639
because you know almost all of the stars

2260
01:24:03,590 --> 01:24:00,719
that almost all starts with exoplanets

2261
01:24:06,149 --> 01:24:03,600
found by kepler are too far away for

2262
01:24:08,790 --> 01:24:06,159
webb to study but the ones found by tess

2263
01:24:11,110 --> 01:24:08,800

will be perfect uh for web to study and

2264
01:24:13,110 --> 01:24:11,120
so this that's the succession of these

2265
01:24:14,790 --> 01:24:13,120
missions and the way they work together

2266
01:24:16,870 --> 01:24:14,800
you know that's exactly how we plan it

2267
01:24:18,629 --> 01:24:16,880
out and it's it's it's working out great

2268
01:24:20,790 --> 01:24:18,639
yeah that kind of mission optimization

2269
01:24:23,750 --> 01:24:20,800
is really interesting to watch um and

2270
01:24:25,430 --> 01:24:23,760
has sped up a lot um in in well at least

2271
01:24:27,189 --> 01:24:25,440
for the optimization of exoplanetary

2272
01:24:30,070 --> 01:24:27,199
science and as we've seen with the

2273
01:24:32,310 --> 01:24:30,080
mission concepts with habex and levoir

2274
01:24:33,750 --> 01:24:32,320
as you would really they designed to go

2275
01:24:35,750 --> 01:24:33,760
span across many many different

2276
01:24:37,590 --> 01:24:35,760
wavelengths across the wide wavelength

2277
01:24:40,470 --> 01:24:37,600
range and we just don't really have that

2278
01:24:42,149 --> 01:24:40,480
um at the moment on one telescope so

2279
01:24:44,070 --> 01:24:42,159
those will be game changes that

2280
01:24:45,910 --> 01:24:44,080
hopefully come about in the future um

2281
01:24:48,390 --> 01:24:45,920
and not too not too distant future

2282
01:24:50,310 --> 01:24:48,400
hopefully not too distant yes yeah

2283
01:24:51,669 --> 01:24:50,320
all of the telescopes working together

2284
01:24:53,110 --> 01:24:51,679
and everything was

2285
01:24:54,390 --> 01:24:53,120
where i kind of wanted to get this

2286
01:24:56,629 --> 01:24:54,400
because so

2287
01:24:59,430 --> 01:24:56,639
i mean we take it for granted in the

2288
01:25:01,110 --> 01:24:59,440

astronomy community but different

2289
01:25:03,510 --> 01:25:01,120
missions by different agencies and

2290
01:25:04,470 --> 01:25:03,520
whatnot there's a lot more cross working

2291
01:25:06,229 --> 01:25:04,480
to like

2292
01:25:07,910 --> 01:25:06,239
working together than you would explain

2293
01:25:10,390 --> 01:25:07,920
than you would think from the outside

2294
01:25:11,990 --> 01:25:10,400
looking in on a lot of these projects

2295
01:25:13,669 --> 01:25:12,000
okay grant we got time for one more

2296
01:25:15,110 --> 01:25:13,679
question you got that you got one last

2297
01:25:16,570 --> 01:25:15,120
one

2298
01:25:19,590 --> 01:25:16,580
no i'll leave that to you frank

2299
01:25:21,510 --> 01:25:19,600
[Laughter]

2300
01:25:23,750 --> 01:25:21,520
no i don't i don't have one oh you don't

2301
01:25:26,870 --> 01:25:23,760
have one i think i've uh i think we've

2302
01:25:28,310 --> 01:25:26,880
gone through all the ones i notated okay

2303
01:25:29,189 --> 01:25:28,320
all right so

2304
01:25:30,470 --> 01:25:29,199
um

2305
01:25:33,590 --> 01:25:30,480
oh here we go

2306
01:25:35,669 --> 01:25:33,600
um once they are located uh

2307
01:25:39,270 --> 01:25:35,679
they can they can be studied for

2308
01:25:41,350 --> 01:25:39,280
atmosphere um not well to some extent

2309
01:25:42,950 --> 01:25:41,360
now but obviously once james webb

2310
01:25:44,870 --> 01:25:42,960
launches and we're able to look further

2311
01:25:46,229 --> 01:25:44,880
into the spectrum that will be a case

2312
01:25:47,189 --> 01:25:46,239
that's more or less what we just talked

2313
01:25:48,629 --> 01:25:47,199

about

2314
01:25:52,149 --> 01:25:48,639
ah here's a good one

2315
01:25:54,790 --> 01:25:52,159
how long after the launch of james webb

2316
01:25:57,750 --> 01:25:54,800
can we start to expect to see any data

2317
01:25:59,189 --> 01:25:57,760
or any studies

2318
01:26:01,590 --> 01:25:59,199
so there's going to be a commissioning

2319
01:26:04,149 --> 01:26:01,600
period um well well first of all the

2320
01:26:06,790 --> 01:26:04,159
telescope james space telescope has to

2321
01:26:09,590 --> 01:26:06,800
get to its uh launch point and then it

2322
01:26:10,870 --> 01:26:09,600
has to deploy its sunshield and its

2323
01:26:12,870 --> 01:26:10,880
mirrors and everything else and then

2324
01:26:14,149 --> 01:26:12,880
we'll go for a commissioning period and

2325
01:26:15,430 --> 01:26:14,159
where all of the instrument teams will

2326
01:26:16,950 --> 01:26:15,440
make sure that everything is up and

2327
01:26:19,830 --> 01:26:16,960
running as expected

2328
01:26:22,149 --> 01:26:19,840
um and then we're gonna be on early

2329
01:26:22,950 --> 01:26:22,159
release science so the first data coming

2330
01:26:23,910 --> 01:26:22,960
through

2331
01:26:27,110 --> 01:26:23,920
will be

2332
01:26:29,430 --> 01:26:27,120
uh plus six months or so after launch um

2333
01:26:31,270 --> 01:26:29,440
don't quote my exact number on that

2334
01:26:33,110 --> 01:26:31,280
i'm sure someone who works for jwsu is

2335
01:26:34,950 --> 01:26:33,120
screaming at me right now um but it will

2336
01:26:37,030 --> 01:26:34,960
be it will be about six months or so

2337
01:26:38,870 --> 01:26:37,040
after launch will be

2338
01:26:40,070 --> 01:26:38,880

when the first first data starts coming

2339
01:26:42,950 --> 01:26:40,080
through yeah

2340
01:26:45,669 --> 01:26:42,960
and don't worry you can hear our anxiety

2341
01:26:47,910 --> 01:26:45,679
from miles away during that period i

2342
01:26:50,550 --> 01:26:47,920
have my own anxiety about it so

2343
01:26:52,790 --> 01:26:50,560
everything's gonna be fine we will all

2344
01:26:54,550 --> 01:26:52,800
have our lucky talismans in our ways to

2345
01:26:56,149 --> 01:26:54,560
deal with all this yes

2346
01:26:58,470 --> 01:26:56,159
actually i did find a question that i

2347
01:27:01,430 --> 01:26:58,480
wrote down that um bring it on pretty

2348
01:27:04,550 --> 01:27:01,440
good it says um when a planet is

2349
01:27:06,070 --> 01:27:04,560
entitled lock with its star

2350
01:27:07,990 --> 01:27:06,080
how does that affect the chances for

2351
01:27:09,830 --> 01:27:08,000
finding life on that planet

2352
01:27:11,669 --> 01:27:09,840
yeah that's a that's actually a really

2353
01:27:13,830 --> 01:27:11,679
interesting question so

2354
01:27:16,229 --> 01:27:13,840
in that case you would have a planet

2355
01:27:17,910 --> 01:27:16,239
that's orbiting very close to its star

2356
01:27:19,510 --> 01:27:17,920
and so close that it gets tightly locked

2357
01:27:20,709 --> 01:27:19,520
so one side is always staring at the

2358
01:27:22,870 --> 01:27:20,719
star and the other side is always

2359
01:27:24,790 --> 01:27:22,880
staring um out from the star but the

2360
01:27:26,870 --> 01:27:24,800
problem with that is the side that's

2361
01:27:29,750 --> 01:27:26,880
tightly locked and staring at the star

2362
01:27:31,510 --> 01:27:29,760
is gonna be super super hot and super

2363
01:27:32,709 --> 01:27:31,520

probably inhabitable and then on the

2364
01:27:34,629 --> 01:27:32,719
other side you're gonna have the very

2365
01:27:35,669 --> 01:27:34,639
much the opposite problem uh where

2366
01:27:37,750 --> 01:27:35,679
you're gonna have this extremely

2367
01:27:39,910 --> 01:27:37,760
extremely cold side um that's

2368
01:27:41,510 --> 01:27:39,920
potentially not habitable so

2369
01:27:43,669 --> 01:27:41,520
it's a little bit more complicated than

2370
01:27:46,709 --> 01:27:43,679
that but these aren't the most amenable

2371
01:27:48,629 --> 01:27:46,719
planets to look for for habitability um

2372
01:27:50,149 --> 01:27:48,639
the conversation is a bit more complex

2373
01:27:52,550 --> 01:27:50,159
than that but that's kind of the bottom

2374
01:27:55,030 --> 01:27:52,560
line is probably not the best ones to

2375
01:27:57,110 --> 01:27:55,040
look at um but yeah

2376
01:28:00,470 --> 01:27:57,120
yeah okay that's fantastic

2377
01:28:03,590 --> 01:28:00,480
all right so emily fantastic talk a

2378
01:28:05,430 --> 01:28:03,600
fantastic subject that we will be

2379
01:28:09,030 --> 01:28:05,440
revisiting over and over again through

2380
01:28:10,550 --> 01:28:09,040
the public lecture series um next month

2381
01:28:13,910 --> 01:28:10,560
on july

2382
01:28:17,270 --> 01:28:13,920
6th uh quinn hart will be talking on

2383
01:28:20,550 --> 01:28:17,280
armchair astrophysics volume 2.