

1
00:00:00,000 --> 00:00:07,859
oh good evening ladies and gentlemen and

2
00:00:05,219 --> 00:00:10,620
welcome to the Space Telescope public

3
00:00:07,859 --> 00:00:12,780
lecture series it is my joy and pleasure

4
00:00:10,619 --> 00:00:15,480
to be your host I'm dr. Frank summers of

5
00:00:12,779 --> 00:00:17,579
the office of public outreach on your

6
00:00:15,480 --> 00:00:20,640
way in you could have grabbed a

7
00:00:17,579 --> 00:00:24,028
lithograph tonight's lithograph is the

8
00:00:20,640 --> 00:00:26,820
interacting galaxies are one four seven

9
00:00:24,028 --> 00:00:29,219
there are a lot of interacting galaxies

10
00:00:26,820 --> 00:00:31,948
that have these are planes because art

11
00:00:29,219 --> 00:00:33,689
created the catalogue okay if you want

12
00:00:31,949 --> 00:00:35,579
to learn more about interacting galaxies

13
00:00:33,689 --> 00:00:37,709
you can turn over on the back and read

14
00:00:35,579 --> 00:00:38,429
about them if you did not get one on

15
00:00:37,710 --> 00:00:40,320
your way in

16
00:00:38,429 --> 00:00:45,378
they are down here on both sides grab

17
00:00:40,320 --> 00:00:48,450
one on your way out tonight I guess my

18
00:00:45,378 --> 00:00:51,718
pointers down tonight we have the

19
00:00:48,450 --> 00:00:53,789
wildest weather in the universe a very

20
00:00:51,719 --> 00:00:55,558
catchy title which i think is partly

21
00:00:53,789 --> 00:00:56,270
responsible for so many of you showing

22
00:00:55,558 --> 00:01:00,509
up today

23
00:00:56,270 --> 00:01:03,449
my Hannah wake furred next month we have

24
00:01:00,509 --> 00:01:05,700
another very catchy title mapping the

25
00:01:03,448 --> 00:01:08,340
United Federation of Planets an

26
00:01:05,700 --> 00:01:10,920
astronomers guide to the galaxy and yes

27
00:01:08,340 --> 00:01:14,490
that is a Star Trek reference and yes

28
00:01:10,920 --> 00:01:17,099
Star Trek will be part of the talk next

29

00:01:14,489 --> 00:01:19,560
month although it will be used in a

30
00:01:17,099 --> 00:01:24,089
scientific context for mapping the

31
00:01:19,560 --> 00:01:26,159
galaxy in April Oh we do not actually

32
00:01:24,090 --> 00:01:30,000
have a title so I gave it the title

33
00:01:26,159 --> 00:01:31,469
lovely plumage on Europa Susanna and I

34
00:01:30,000 --> 00:01:34,200
chatted on the phone today she said I'll

35
00:01:31,469 --> 00:01:36,629
talk about the the plumes on Europa and

36
00:01:34,200 --> 00:01:38,549
I said oh the lovely plumage story and

37
00:01:36,629 --> 00:01:41,158
so I wrote that as a placeholder and she

38
00:01:38,549 --> 00:01:45,149
was supposed to email me I'm an actual

39
00:01:41,159 --> 00:01:47,490
title and I forgot the I don't know if

40
00:01:45,149 --> 00:01:50,040
she actually did because I forgot to

41
00:01:47,489 --> 00:01:52,739
check so it's about the plumes on the

42
00:01:50,040 --> 00:01:55,170
Europa okay it'll be a cool talk Susanna

43
00:01:52,739 --> 00:01:57,509

is a very good speaker all right and in

44

00:01:55,170 --> 00:01:58,469

May a talk that I've been trying to get

45

00:01:57,509 --> 00:02:00,989

for a while

46

00:01:58,468 --> 00:02:05,459

Andy Frucht er has agreed to talk about

47

00:02:00,989 --> 00:02:08,189

gravitational wave astronomy the new-new

48

00:02:05,459 --> 00:02:11,250

of way we're going to view the universe

49

00:02:08,189 --> 00:02:13,240

with gravitational ways so you can find

50

00:02:11,250 --> 00:02:17,080

all about all our upcoming

51

00:02:13,240 --> 00:02:19,510

on our website that has on the right the

52

00:02:17,080 --> 00:02:22,900

list of the upcoming talks on the left

53

00:02:19,509 --> 00:02:25,840

we have links to our webcasting and our

54

00:02:22,900 --> 00:02:27,520

recordings of them on YouTube when we

55

00:02:25,840 --> 00:02:30,159

are live you can click those and go

56

00:02:27,520 --> 00:02:32,320

directly to those you can also sign up

57

00:02:30,159 --> 00:02:34,900

for email if you just go to your

58
00:02:32,319 --> 00:02:37,030
favorite search engine and type in

59
00:02:34,900 --> 00:02:40,170
Hubbell public talks or Space Telescope

60
00:02:37,030 --> 00:02:43,870
public talks you will find this webpage

61
00:02:40,169 --> 00:02:46,389
if you would like email announcements

62
00:02:43,870 --> 00:02:48,520
actually you don't you you sign up at

63
00:02:46,389 --> 00:02:51,899
the website I mentioned that that down

64
00:02:48,520 --> 00:02:53,950
the lower left is our email server

65
00:02:51,900 --> 00:02:57,819
listserv so you can subscribe or

66
00:02:53,949 --> 00:02:59,199
unsubscribe there if you have comments

67
00:02:57,819 --> 00:03:01,750
or questions you can send it to the

68
00:02:59,199 --> 00:03:07,539
email address public lecture at STScI

69
00:03:01,750 --> 00:03:09,689
dot edu social media last month i said

70
00:03:07,539 --> 00:03:12,609
i'd start including the Webb telescope

71
00:03:09,689 --> 00:03:14,379
accounts and here they are for you we

72
00:03:12,610 --> 00:03:17,140
have Facebook Twitter YouTube Instagram

73
00:03:14,379 --> 00:03:19,060
and and probably more for both Hubble

74
00:03:17,139 --> 00:03:21,609
and Webb and some for the Space

75
00:03:19,060 --> 00:03:25,060
Telescope Science Institute as well I do

76
00:03:21,610 --> 00:03:27,280
a tiny bit of social media on a blog and

77
00:03:25,060 --> 00:03:29,050
Facebook and Google and Twitter so if

78
00:03:27,280 --> 00:03:30,069
you want to hear more from me you can do

79
00:03:29,050 --> 00:03:33,040
that

80
00:03:30,069 --> 00:03:35,439
the observatory the question is whether

81
00:03:33,039 --> 00:03:36,939
or not the weather is permitting did

82
00:03:35,439 --> 00:03:39,400
somebody notice whether their clouds

83
00:03:36,939 --> 00:03:42,340
were up when they came in Oh somebody's

84
00:03:39,400 --> 00:03:46,210
giving me the thumbs down okay it was a

85
00:03:42,340 --> 00:03:48,879
questionable and arene ii may have may

86

00:03:46,210 --> 00:03:51,010
have emailed me her decision by now but

87
00:03:48,879 --> 00:03:54,659
the audience gives us a thumbs down so

88
00:03:51,009 --> 00:03:57,639
it probably will not happen okay but

89
00:03:54,659 --> 00:04:00,219
they do do an open house on Friday

90
00:03:57,639 --> 00:04:02,949
evenings if you go to MD dot space grant

91
00:04:00,219 --> 00:04:04,599
dot o RG you'll find that webpage over

92
00:04:02,949 --> 00:04:05,949
there on the right

93
00:04:04,599 --> 00:04:08,949
and in that box where it says

94
00:04:05,949 --> 00:04:11,530
observatory status each Friday by like

95
00:04:08,949 --> 00:04:13,539
five or six pm they update it with

96
00:04:11,530 --> 00:04:15,069
weather the information as to whether

97
00:04:13,539 --> 00:04:18,849
they're going to be open that Friday

98
00:04:15,069 --> 00:04:20,409
evening okay so check that out sorry

99
00:04:18,850 --> 00:04:23,680
that we probably won't be able to get

100
00:04:20,410 --> 00:04:26,400

that in tonight and now news from the

101

00:04:23,680 --> 00:04:30,228
universe for February 2000 and

102

00:04:26,399 --> 00:04:33,599
18 in which we answer that amazingly

103

00:04:30,228 --> 00:04:39,629
scientifically detailed question do

104

00:04:33,600 --> 00:04:42,840
black holes burp now massive galaxies

105

00:04:39,629 --> 00:04:46,079
are known to have supermassive black

106

00:04:42,839 --> 00:04:47,810
holes at their very core this is a

107

00:04:46,079 --> 00:04:51,329
massive galaxy and there is a

108

00:04:47,810 --> 00:04:52,949
supermassive black hole at its core but

109

00:04:51,329 --> 00:04:55,199
of course you can't see it because the

110

00:04:52,949 --> 00:04:57,449
supermassive black hole is tiny compared

111

00:04:55,199 --> 00:05:02,129
to the galaxy but these supermassive

112

00:04:57,449 --> 00:05:05,160
black holes can cause huge emission this

113

00:05:02,129 --> 00:05:10,439
one is called Hercules a and when viewed

114

00:05:05,160 --> 00:05:12,960
in radio light it looks like that from

115
00:05:10,439 --> 00:05:16,168
that tiny supermassive black hole in the

116
00:05:12,959 --> 00:05:18,629
core are emitted huge jets of emission

117
00:05:16,168 --> 00:05:21,120
that spew out across the galaxy and

118
00:05:18,629 --> 00:05:24,598
beyond the galaxies to form these giant

119
00:05:21,120 --> 00:05:28,288
radio lobes now not every supermassive

120
00:05:24,598 --> 00:05:30,120
black hole is in this phase when when

121
00:05:28,288 --> 00:05:32,668
there's giant Jets of emission coming

122
00:05:30,120 --> 00:05:34,949
from them sometimes it's a little harder

123
00:05:32,668 --> 00:05:38,159
to find they're not always in this

124
00:05:34,949 --> 00:05:40,470
emission phase and what we want to know

125
00:05:38,160 --> 00:05:43,470
when we look at the cosmological history

126
00:05:40,470 --> 00:05:46,650
of these supermassive black holes is how

127
00:05:43,470 --> 00:05:48,449
often are they on when they are when

128
00:05:46,649 --> 00:05:50,819
when there's material falling in and

129
00:05:48,449 --> 00:05:53,280
stuff that's being emitted back out and

130
00:05:50,819 --> 00:05:54,478
how often are they quiescent how often

131
00:05:53,279 --> 00:05:56,219
are they quiet and they're not really

132
00:05:54,478 --> 00:05:57,899
emitting that's one of the things that

133
00:05:56,220 --> 00:05:59,970
we that the cosmologists really want to

134
00:05:57,899 --> 00:06:03,959
understand about these black holes over

135
00:05:59,970 --> 00:06:09,650
time so here is a Hubble image of a

136
00:06:03,959 --> 00:06:12,060
galaxy sdss J one three five four okay

137
00:06:09,649 --> 00:06:14,609
that's just its catalog number in the

138
00:06:12,060 --> 00:06:16,348
Sloan Digital Sky Survey and this is the

139
00:06:14,610 --> 00:06:18,180
Hubble image of the galaxies and the

140
00:06:16,348 --> 00:06:20,459
galaxies were interested is not the one

141
00:06:18,180 --> 00:06:23,750
at the top but it's actually the one at

142
00:06:20,459 --> 00:06:26,728
the bottom okay the one at the bottom

143

00:06:23,750 --> 00:06:29,610
has a supermassive black hole that's

144
00:06:26,728 --> 00:06:31,139
active now what you will notice between

145
00:06:29,610 --> 00:06:33,449
the top and the bottom is that there's

146
00:06:31,139 --> 00:06:35,430
sort of a striation material that seems

147
00:06:33,449 --> 00:06:37,860
to be flowing down from the one at the

148
00:06:35,430 --> 00:06:40,129
top these two galaxies are believed to

149
00:06:37,860 --> 00:06:42,408
be interacting okay and

150
00:06:40,129 --> 00:06:45,649
galaxies interact sometimes material

151
00:06:42,408 --> 00:06:49,248
from one galaxy can accrete onto the

152
00:06:45,649 --> 00:06:52,129
other galaxy and so what we wanted to

153
00:06:49,249 --> 00:06:55,610
know what we found out when looking in

154
00:06:52,129 --> 00:06:58,639
x-rays is that the supermassive black

155
00:06:55,610 --> 00:07:00,919
hole on the bottom galaxy is turned on

156
00:06:58,639 --> 00:07:03,319
it is in an emission of phase because

157
00:07:00,918 --> 00:07:05,088

here is the spits they at the Chandra

158

00:07:03,319 --> 00:07:07,550

x-ray Observatory now you got to look

159

00:07:05,088 --> 00:07:10,249

carefully all right there's Hubble

160

00:07:07,550 --> 00:07:12,499

there's Hubble dance and Chandra okay

161

00:07:10,249 --> 00:07:15,379

you can see that purple x-ray emission

162

00:07:12,499 --> 00:07:17,360

that identifies what's coming from that

163

00:07:15,379 --> 00:07:19,699

supermassive black hole

164

00:07:17,360 --> 00:07:22,939

so let's magnify that and give you a

165

00:07:19,699 --> 00:07:27,259

little bit of context here what we see

166

00:07:22,939 --> 00:07:32,149

here is that the x-ray is coming from it

167

00:07:27,259 --> 00:07:34,399

and that white burst above it appears to

168

00:07:32,149 --> 00:07:36,499

be material spewed out of the

169

00:07:34,399 --> 00:07:39,019

supermassive black hole matter of fact

170

00:07:36,499 --> 00:07:40,519

what they tell me and it's kind of hard

171

00:07:39,019 --> 00:07:43,879

I can't I couldn't really see it in the

172
00:07:40,519 --> 00:07:46,639
image is that there are two periods of

173
00:07:43,879 --> 00:07:49,519
emission and given the speed that this

174
00:07:46,639 --> 00:07:51,769
material is traveling away they had they

175
00:07:49,519 --> 00:07:53,749
that it was in emission and then a

176
00:07:51,769 --> 00:07:58,550
hundred thousand years of being quiet

177
00:07:53,749 --> 00:08:01,338
and then another emission the hypothesis

178
00:07:58,550 --> 00:08:04,550
the best explanation for it is that

179
00:08:01,338 --> 00:08:07,848
these two galaxies interacted material

180
00:08:04,550 --> 00:08:09,528
flowed in all right and started to

181
00:08:07,848 --> 00:08:12,588
spiral in on the supermassive black hole

182
00:08:09,528 --> 00:08:14,749
some was spewed out and then it went

183
00:08:12,588 --> 00:08:18,019
quiet for a while and then some more was

184
00:08:14,749 --> 00:08:21,379
spewed out alright and in the press

185
00:08:18,019 --> 00:08:24,559
release they call these burps from a

186
00:08:21,379 --> 00:08:26,269
supermassive black hole I kid you not in

187
00:08:24,559 --> 00:08:30,740
the actual press release they use the

188
00:08:26,269 --> 00:08:34,158
word burp but is it really a burp and I

189
00:08:30,740 --> 00:08:36,589
would say no because when you or I burp

190
00:08:34,158 --> 00:08:41,088
it comes from inside us and spews out

191
00:08:36,589 --> 00:08:43,639
right but material doesn't come out of a

192
00:08:41,089 --> 00:08:46,430
black hole right even light can't escape

193
00:08:43,639 --> 00:08:48,350
from a black hole it's not the

194
00:08:46,429 --> 00:08:51,349
supermassive black hole that is burping

195
00:08:48,350 --> 00:08:52,300
but rather the material is falling onto

196
00:08:51,350 --> 00:08:53,920
the super

197
00:08:52,299 --> 00:08:56,079
onto an accretion disk around the

198
00:08:53,919 --> 00:08:58,689
supermassive black hole some of that

199
00:08:56,080 --> 00:09:00,970
material goes into the black hole some

200

00:08:58,690 --> 00:09:02,529
of the material gets flung back out from

201
00:09:00,970 --> 00:09:05,769
the accretion disk

202
00:09:02,528 --> 00:09:07,778
okay so I would say just to be a little

203
00:09:05,769 --> 00:09:10,539
technical that it's the accretion disk

204
00:09:07,778 --> 00:09:13,778
that is burping and not the supermassive

205
00:09:10,539 --> 00:09:18,069
black hole so that's my answer to that

206
00:09:13,778 --> 00:09:22,778
question our second story tonight the

207
00:09:18,070 --> 00:09:25,450
launch of a new era way back in the 60s

208
00:09:22,778 --> 00:09:29,110
in the Apollo era we had the Saturn 5

209
00:09:25,450 --> 00:09:31,329
rocket the most powerful launch vehicle

210
00:09:29,110 --> 00:09:35,169
that America has ever had and this

211
00:09:31,328 --> 00:09:37,689
actually is the launch of Apollo 11 from

212
00:09:35,169 --> 00:09:41,708
Kennedy and the Saturn 5 rocket was

213
00:09:37,690 --> 00:09:44,980
retired back in 1973 it was followed by

214
00:09:41,708 --> 00:09:46,359

the space shuttle this by the way is the

215

00:09:44,980 --> 00:09:49,028

launch that carried the Hubble Space

216

00:09:46,360 --> 00:09:51,310

Telescope into orbit and you can see the

217

00:09:49,028 --> 00:09:55,028

space that the launch on the right but

218

00:09:51,309 --> 00:09:56,799

also you can see another STS are

219

00:09:55,028 --> 00:09:59,379

actually testing on another launch pad

220

00:09:56,799 --> 00:10:02,740

at the same time ok and this was also

221

00:09:59,379 --> 00:10:05,708

incredibly powerful but it had to carry

222

00:10:02,740 --> 00:10:07,539

the Space Shuttle up so the payload that

223

00:10:05,708 --> 00:10:10,569

could be inside the space shuttle was

224

00:10:07,539 --> 00:10:13,019

considerably smaller and so what people

225

00:10:10,570 --> 00:10:16,510

have been looking for is a really big

226

00:10:13,019 --> 00:10:20,078

boost to get into space and so nASA has

227

00:10:16,509 --> 00:10:22,480

plans for a wonderful system coming up

228

00:10:20,078 --> 00:10:26,828

but in the meantime we have developed

229
00:10:22,480 --> 00:10:30,339
commercial companies such as SpaceX Elon

230
00:10:26,828 --> 00:10:36,519
Musk company SpaceX and this is their

231
00:10:30,339 --> 00:10:38,649
workhorse the Falcon 9 launch booster so

232
00:10:36,519 --> 00:10:41,889
called 9 because there are nine engines

233
00:10:38,649 --> 00:10:44,350
in this booster ok and they have been

234
00:10:41,889 --> 00:10:46,179
launching these for several years and

235
00:10:44,350 --> 00:10:51,370
putting satellites into orbit with it

236
00:10:46,179 --> 00:10:53,828
but it wasn't powerful enough so what

237
00:10:51,370 --> 00:10:56,289
Elon Musk is a little bit ambitious and

238
00:10:53,828 --> 00:10:57,819
what does he want to do he wants to take

239
00:10:56,289 --> 00:11:01,299
he wants to make the world's most

240
00:10:57,820 --> 00:11:04,060
powerful rocket this one is the Falcon

241
00:11:01,299 --> 00:11:05,539
Heavy and you will notice it looks very

242
00:11:04,059 --> 00:11:08,958
much like the

243
00:11:05,539 --> 00:11:12,469
Falcon nine except it has outboard

244
00:11:08,958 --> 00:11:15,198
motors on it which are in fact two other

245
00:11:12,470 --> 00:11:18,759
boosters identical boosters so there are

246
00:11:15,198 --> 00:11:21,708
27 engines on this three-pronged rocket

247
00:11:18,759 --> 00:11:23,870
and they did a test firing a week or so

248
00:11:21,708 --> 00:11:25,458
ago and they didn't actually launch

249
00:11:23,870 --> 00:11:26,750
anything they didn't actually go off lot

250
00:11:25,458 --> 00:11:30,049
they did a test firing show that they

251
00:11:26,750 --> 00:11:33,649
could launch all 27 they could fire all

252
00:11:30,049 --> 00:11:38,990
27 engines together and today they did

253
00:11:33,649 --> 00:11:41,509
the test launch what was the payload the

254
00:11:38,990 --> 00:11:45,139
payload was from Elon Musk's other

255
00:11:41,509 --> 00:11:49,250
company the Tesla cars and it was a

256
00:11:45,139 --> 00:11:52,639
Tesla Roadster a cherry-red Tesla

257

00:11:49,250 --> 00:11:55,100
Roadster with a dummy in a one of the

258
00:11:52,639 --> 00:11:58,399
SpaceX space suits in the driver's seat

259
00:11:55,100 --> 00:12:00,740
okay this is the actual roadster that

260
00:11:58,399 --> 00:12:06,740
was on the payload today okay

261
00:12:00,740 --> 00:12:09,399
and did it work oh yeah yes it did here

262
00:12:06,740 --> 00:12:13,789
is the footage released by SpaceX

263
00:12:09,399 --> 00:12:20,179
showing the Falcon Heavy launching from

264
00:12:13,789 --> 00:12:23,028
the space pad and once it got up the two

265
00:12:20,179 --> 00:12:28,479
side boosters separated all right and

266
00:12:23,028 --> 00:12:31,389
they came back and landed vertically I

267
00:12:28,480 --> 00:12:34,459
never get tired of seeing that okay

268
00:12:31,389 --> 00:12:36,139
welcome to SpaceX has been doing this

269
00:12:34,458 --> 00:12:39,500
for a while never get tired of watching

270
00:12:36,139 --> 00:12:41,709
this now the center booster was supposed

271
00:12:39,500 --> 00:12:44,809

to land on a platform out at sea which

272

00:12:41,708 --> 00:12:47,568

SpaceX has done before but they're ours

273

00:12:44,809 --> 00:12:50,629

no confirmation from SpaceX that it

274

00:12:47,568 --> 00:12:52,309

landed safely there was a disruption in

275

00:12:50,629 --> 00:12:55,220

the video feed that makes people a lot

276

00:12:52,309 --> 00:12:57,409

of speculate that it did not land

277

00:12:55,220 --> 00:12:59,089

successfully but there has been no

278

00:12:57,409 --> 00:12:59,750

confirmation as far as I've heard from

279

00:12:59,089 --> 00:13:04,130

SpaceX

280

00:12:59,750 --> 00:13:06,980

okay and then then they had the payload

281

00:13:04,129 --> 00:13:10,639

deployment so this is footage of the

282

00:13:06,980 --> 00:13:12,370

Tesla Roadster being deployed into space

283

00:13:10,639 --> 00:13:20,320

okay when

284

00:13:12,370 --> 00:13:24,089

yes all right and this is my favorite

285

00:13:20,320 --> 00:13:27,879

shot this is a shot over the shoulder of

286
00:13:24,089 --> 00:13:31,270
king of the Tesla Roadster

287
00:13:27,879 --> 00:13:33,220
in orbit around Earth right now and

288
00:13:31,269 --> 00:13:35,278
you'll notice it says on the dashboard

289
00:13:33,220 --> 00:13:37,410
dope panic which is an homage to

290
00:13:35,278 --> 00:13:40,929
Hitchhiker's Guide to the galaxy and

291
00:13:37,409 --> 00:13:41,980
Elon Musk says yes there is a towel in

292
00:13:40,929 --> 00:13:45,939
the glove box

293
00:13:41,980 --> 00:13:46,659
for those who know wow this is a lot of

294
00:13:45,940 --> 00:13:49,600
fun

295
00:13:46,659 --> 00:13:51,519
it actually makes for a really

296
00:13:49,600 --> 00:13:55,360
interesting point in our history of

297
00:13:51,519 --> 00:13:58,059
space because right now the most

298
00:13:55,360 --> 00:14:01,960
powerful launch vehicle on the planet is

299
00:13:58,059 --> 00:14:04,559
not from a nationalized space agency but

300
00:14:01,960 --> 00:14:08,769
it's from a commercial space company and

301
00:14:04,559 --> 00:14:11,409
that's that's a new era in space flight

302
00:14:08,769 --> 00:14:14,019
all right now of course you know NASA

303
00:14:11,409 --> 00:14:15,639
has planned the SLS which will be more

304
00:14:14,019 --> 00:14:16,299
powerful in the Falcon Heavy when it

305
00:14:15,639 --> 00:14:19,870
when it goes

306
00:14:16,299 --> 00:14:21,969
but for now SpaceX has the most powerful

307
00:14:19,870 --> 00:14:23,799
launch vehicle and if you want to get

308
00:14:21,970 --> 00:14:25,810
something heavy into space there are the

309
00:14:23,799 --> 00:14:28,958
people to go to so this

310
00:14:25,809 --> 00:14:30,909
I love the audacity of Elon Musk and I

311
00:14:28,958 --> 00:14:35,679
love that he has a sense of humor so

312
00:14:30,909 --> 00:14:37,569
this was fantastic alright so yeah I'm

313
00:14:35,679 --> 00:14:39,370
not exactly sure the timing of it it's

314

00:14:37,570 --> 00:14:42,160
got to get out past the Van Allen belts

315
00:14:39,370 --> 00:14:43,959
and then the second stage will fire and

316
00:14:42,159 --> 00:14:46,870
try to put it into orbit around the Sun

317
00:14:43,958 --> 00:14:49,619
that goes out to the orbit of Mars so

318
00:14:46,870 --> 00:14:52,330
we'll have a Tesla Roadster orbiting

319
00:14:49,620 --> 00:14:54,549
driving around the solar system you know

320
00:14:52,330 --> 00:14:57,690
sort of like interplanetary NASCAR

321
00:14:54,549 --> 00:15:01,359
uh-huh but it's only a one vehicle race

322
00:14:57,690 --> 00:15:02,770
and actually it's a little trial it'll

323
00:15:01,360 --> 00:15:04,839
have quite some some frequent flyer

324
00:15:02,769 --> 00:15:07,860
miles but it's still actually a low

325
00:15:04,839 --> 00:15:07,860
mileage car right

326
00:15:09,149 --> 00:15:17,110
you want to go back where here that okay

327
00:15:15,399 --> 00:15:18,519
you want a picture of that okay it's

328
00:15:17,110 --> 00:15:25,060

available on the internet because that's

329

00:15:18,519 --> 00:15:27,939

where I grabbed it today okay our final

330

00:15:25,059 --> 00:15:30,189

story for tonight you have to imagine

331

00:15:27,940 --> 00:15:32,790

that the Falcon Heavy could not only go

332

00:15:30,190 --> 00:15:36,570

interplanetary but could go interstellar

333

00:15:32,789 --> 00:15:41,769

all right and could shift wavelengths

334

00:15:36,570 --> 00:15:43,930

our outreach program is now called the

335

00:15:41,769 --> 00:15:46,480

universe of learning NASA's universe of

336

00:15:43,929 --> 00:15:48,399

learning we used to be funded as the

337

00:15:46,480 --> 00:15:49,810

Hubble outreach program or the james

338

00:15:48,399 --> 00:15:52,389

webb space up reach program of the

339

00:15:49,809 --> 00:15:53,889

spitzer outreach program or the chandra

340

00:15:52,389 --> 00:15:55,870

x-ray observatory outreach program they

341

00:15:53,889 --> 00:15:59,769

were associated with the missions well

342

00:15:55,870 --> 00:16:02,830

NASA refunded things in a multi-mission

343
00:15:59,769 --> 00:16:05,379
way where our outreach is about the

344
00:16:02,830 --> 00:16:07,870
astronomy and it covers all the various

345
00:16:05,379 --> 00:16:09,330
wavelengths and so for example one of

346
00:16:07,870 --> 00:16:11,440
the things we've been doing for years

347
00:16:09,330 --> 00:16:13,570
and actually the Spitzer folks have been

348
00:16:11,440 --> 00:16:16,089
doing a lot of too is doing sort of a

349
00:16:13,570 --> 00:16:18,700
slider here where you can slide from the

350
00:16:16,089 --> 00:16:20,410
visible light view on the left to the

351
00:16:18,700 --> 00:16:22,720
infrared view on the right and as you

352
00:16:20,409 --> 00:16:25,389
move that slider across the screen it go

353
00:16:22,720 --> 00:16:27,100
it shows you how how the universe looks

354
00:16:25,389 --> 00:16:30,220
invisible and infrared and we found this

355
00:16:27,100 --> 00:16:32,528
to be a very powerful thing to do all

356
00:16:30,220 --> 00:16:37,389
right but you know that's doing it in

357
00:16:32,528 --> 00:16:40,570
two dimensions we wanted to take these

358
00:16:37,389 --> 00:16:42,370
two images of the Orion Nebula on the

359
00:16:40,570 --> 00:16:44,320
left from the Hubble Space Telescope and

360
00:16:42,370 --> 00:16:47,259
on the right from the Spitzer Space

361
00:16:44,320 --> 00:16:51,820
Telescope and we wanted to do that same

362
00:16:47,259 --> 00:16:54,519
thing in 3d so one thing you notice

363
00:16:51,820 --> 00:16:56,770
automatically is that the Spitzer image

364
00:16:54,519 --> 00:16:59,230
covers a much larger area it's infrared

365
00:16:56,769 --> 00:17:02,199
radiation which comes from cooler gas

366
00:16:59,230 --> 00:17:03,639
which spreads out further in the nebula

367
00:17:02,200 --> 00:17:06,818
you can actually see the whole bowl of

368
00:17:03,639 --> 00:17:09,639
the Orion Nebula over there there's also

369
00:17:06,818 --> 00:17:11,609
more stars in the infrared because

370
00:17:09,640 --> 00:17:14,880
you're seeing the fainter cooler stars

371

00:17:11,609 --> 00:17:17,229
that only shine mostly in the infrared

372
00:17:14,880 --> 00:17:19,780
but when you get down into the detail

373
00:17:17,230 --> 00:17:22,000
Hubble has higher resolution and you can

374
00:17:19,779 --> 00:17:24,599
see those bow shocks and those proto

375
00:17:22,000 --> 00:17:27,130
Terry discs and all sorts of cool

376
00:17:24,599 --> 00:17:28,119
fine-grained structures and Hubbell of

377
00:17:27,130 --> 00:17:30,370
course you can't see it at this

378
00:17:28,119 --> 00:17:32,529
resolution and that but you'll see it in

379
00:17:30,369 --> 00:17:35,949
a second that you can't see in Spitzer

380
00:17:32,529 --> 00:17:37,720
so what we did is we built a model of

381
00:17:35,950 --> 00:17:41,140
the Orion Nebula for the IMAX film

382
00:17:37,720 --> 00:17:44,019
Hubble 3d using visible light then we

383
00:17:41,140 --> 00:17:48,100
rebuilt the model using the Spitzer data

384
00:17:44,019 --> 00:17:48,730
in infrared and then we're gonna fly you

385
00:17:48,099 --> 00:17:50,949

into it

386

00:17:48,730 --> 00:17:54,779

so Thomas can we take the lights down a

387

00:17:50,950 --> 00:17:54,779

little bit all right

388

00:17:58,230 --> 00:19:15,788

[Music]

389

00:19:18,210 --> 00:20:12,900

[Music]

390

00:20:09,849 --> 00:20:12,899

[Applause]

391

00:20:17,859 --> 00:20:22,149

[Music]

392

00:20:19,019 --> 00:20:22,150

[Applause]

393

00:20:23,039 --> 00:20:32,368

[Music]

394

00:20:24,509 --> 00:20:32,368

[Applause]

395

00:20:34,640 --> 00:20:40,220

[Applause]

396

00:20:34,980 --> 00:20:41,630

[Music]

397

00:20:40,220 --> 00:20:41,850

[Applause]

398

00:20:41,630 --> 00:20:44,920

[Music]

399

00:20:41,849 --> 00:20:44,919

[Applause]

400
00:20:50,700 --> 00:20:52,759
you

401
00:20:58,230 --> 00:21:02,130
[Applause]

402
00:21:04,319 --> 00:21:10,319
so we thought that was a considerable

403
00:21:07,079 --> 00:21:12,449
success being able to show you in 3d

404
00:21:10,319 --> 00:21:14,369
that what it looks like from the Hubble

405
00:21:12,450 --> 00:21:16,500
visible light image what it looks like

406
00:21:14,369 --> 00:21:18,899
in the this the Spitzer infrared image

407
00:21:16,500 --> 00:21:20,970
and you get a real feel for the

408
00:21:18,900 --> 00:21:24,060
different structures that we see and

409
00:21:20,970 --> 00:21:27,690
inherently the value of multi-wavelength

410
00:21:24,059 --> 00:21:30,839
astronomy all right so now we go to our

411
00:21:27,690 --> 00:21:33,230
featured speaker tonight and our

412
00:21:30,839 --> 00:21:36,990
featured speaker is Hannah wake fir'd

413
00:21:33,230 --> 00:21:39,750
she got Horacio let me just find things

414
00:21:36,990 --> 00:21:43,470
all right she got her PhD in physics

415
00:21:39,750 --> 00:21:44,880
from the University of Exeter previous

416
00:21:43,470 --> 00:21:47,490
to that you were at the University of

417
00:21:44,880 --> 00:21:50,250
Wales in some city that I'm not sure I

418
00:21:47,490 --> 00:21:50,700
can pronounce so you'll have yeah you

419
00:21:50,250 --> 00:21:52,079
have to

420
00:21:50,700 --> 00:21:55,590
you'll have to pronounce it yourself

421
00:21:52,079 --> 00:21:58,710
okay and she also worked at the

422
00:21:55,589 --> 00:22:02,539
University Center in Svalbard in the

423
00:21:58,710 --> 00:22:05,039
Arctic at 78 degrees north latitude

424
00:22:02,539 --> 00:22:07,649
yeah that's further north and I'm sure

425
00:22:05,039 --> 00:22:09,420
most anybody of us have ever been she

426
00:22:07,650 --> 00:22:12,660
can tell you about that if you thought

427
00:22:09,420 --> 00:22:16,259
it was cold here last week no you don't

428

00:22:12,660 --> 00:22:19,350
know could she has worked at the NASA

429
00:22:16,259 --> 00:22:21,750
Goddard Space Flight Center as a NASA

430
00:22:19,349 --> 00:22:25,559
postdoctoral fellow after getting her

431
00:22:21,750 --> 00:22:30,359
PhD and she came here as the 2017

432
00:22:25,559 --> 00:22:32,339
giacconi fellow here and one of the most

433
00:22:30,359 --> 00:22:34,969
important things is that she has

434
00:22:32,339 --> 00:22:37,829
extensive experience in public outreach

435
00:22:34,970 --> 00:22:41,430
working on a podcast called XO cast

436
00:22:37,829 --> 00:22:45,539
about exoplanets as you might guess as

437
00:22:41,430 --> 00:22:47,640
well as writing a blog called stellar

438
00:22:45,539 --> 00:22:49,950
planet all right

439
00:22:47,640 --> 00:22:51,810
and she can tell you more about that but

440
00:22:49,950 --> 00:22:53,850
I'm looking forward to seeing how she

441
00:22:51,809 --> 00:22:55,559
performs the the hearing here tonight

442
00:22:53,849 --> 00:22:58,069

lady week ladies and gentlemen Hannah

443

00:22:55,559 --> 00:22:58,069
wake furred

444

00:23:03,089 --> 00:23:07,480
and we just switched this over for

445

00:23:05,500 --> 00:23:11,160
everybody and you can watch me type in

446

00:23:07,480 --> 00:23:11,160
my password apparently no we're good

447

00:23:15,700 --> 00:23:21,569
oh all right then hello everybody this

448

00:23:19,299 --> 00:23:24,940
is a great crowd

449

00:23:21,569 --> 00:23:26,529
brilliant loving it uh so I'm going to

450

00:23:24,940 --> 00:23:30,850
take you on a little bit of a journey

451

00:23:26,529 --> 00:23:32,170
across our galaxy through different

452

00:23:30,849 --> 00:23:35,559
worlds and looking at some of the

453

00:23:32,170 --> 00:23:40,840
wildest weather that we have actually

454

00:23:35,559 --> 00:23:42,339
been able to look at and understand I'm

455

00:23:40,839 --> 00:23:45,250
going to start our journey a little bit

456

00:23:42,339 --> 00:23:47,529
closer to home this is our wonderful

457
00:23:45,250 --> 00:23:50,619
solar system to scale and I love this

458
00:23:47,529 --> 00:23:54,389
picture because it really puts a good

459
00:23:50,619 --> 00:23:58,659
perspective on our planets and ourself

460
00:23:54,390 --> 00:24:02,890
right down here tiny little dot poor

461
00:23:58,660 --> 00:24:04,830
Pluto and the two toys out there this

462
00:24:02,890 --> 00:24:07,990
really kind of this is our solar system

463
00:24:04,829 --> 00:24:09,759
encapsulated in a single image and I'm

464
00:24:07,990 --> 00:24:11,710
going to take you through what makes up

465
00:24:09,759 --> 00:24:15,910
these planets what's really interesting

466
00:24:11,710 --> 00:24:19,000
about these planets and where ever comes

467
00:24:15,910 --> 00:24:23,350
from now you can't have weather without

468
00:24:19,000 --> 00:24:26,710
a little bit of gas mercury has really

469
00:24:23,349 --> 00:24:29,409
only got a little bit of gas Mercury's

470
00:24:26,710 --> 00:24:33,730
weather comes from when the Sun bombards

471
00:24:29,410 --> 00:24:36,220
it with particles the sun's particles

472
00:24:33,730 --> 00:24:38,289
come out in the solar wind and they hit

473
00:24:36,220 --> 00:24:40,120
the surface of mercury there's nothing

474
00:24:38,289 --> 00:24:42,519
getting in the way of that just slams

475
00:24:40,119 --> 00:24:44,500
into the surface that actually then

476
00:24:42,519 --> 00:24:47,170
causes other particles to be lifted up

477
00:24:44,500 --> 00:24:49,720
from the rock and that forms Mercury's

478
00:24:47,170 --> 00:24:51,580
atmosphere it's not permanent it's very

479
00:24:49,720 --> 00:24:54,579
intermittent it only happens

480
00:24:51,579 --> 00:24:56,169
it only has this gas around mercury at

481
00:24:54,579 --> 00:24:58,929
very specific points where the solar

482
00:24:56,170 --> 00:25:02,440
wind has hit it we don't really call

483
00:24:58,930 --> 00:25:05,410
that an atmosphere so it doesn't really

484
00:25:02,440 --> 00:25:07,509
have whether what mercury has is the

485

00:25:05,410 --> 00:25:11,380
sun's weather and it lives inside the

486
00:25:07,509 --> 00:25:15,119
sun's answer then Venus on the other

487
00:25:11,380 --> 00:25:18,970
hand has something very very different

488
00:25:15,119 --> 00:25:22,209
Venus has an atmosphere which contains

489
00:25:18,970 --> 00:25:23,980
lots of different materials but it's one

490
00:25:22,210 --> 00:25:28,840
of these smallest percentages of these

491
00:25:23,980 --> 00:25:31,528
materials this so2 sulfuric acid

492
00:25:28,839 --> 00:25:35,589
that causes the most trouble for Venus

493
00:25:31,528 --> 00:25:38,369
this is a gorgeous image of Venus from

494
00:25:35,589 --> 00:25:40,569
the JAXA the Japanese Space Agency

495
00:25:38,369 --> 00:25:44,139
satellite which is an orbit around it

496
00:25:40,569 --> 00:25:46,839
now called at Kazuki and if I just take

497
00:25:44,140 --> 00:25:49,028
a next look at that we can zoom in on

498
00:25:46,839 --> 00:25:50,918
these cloud structures that you have in

499
00:25:49,028 --> 00:25:53,409

the atmosphere this image is taken in

500

00:25:50,919 --> 00:25:56,770

the infrared and what you're seeing from

501

00:25:53,409 --> 00:26:01,240

those dark bits there is this sulfuric

502

00:25:56,769 --> 00:26:05,349

acid in the atmosphere it extends for

503

00:26:01,240 --> 00:26:09,130

hundreds of kilometers it makes up point

504

00:26:05,349 --> 00:26:13,028

zero one five percent of the material in

505

00:26:09,130 --> 00:26:14,919

the atmosphere but if we were sitting in

506

00:26:13,028 --> 00:26:16,470

the atmosphere of Venus at the same

507

00:26:14,919 --> 00:26:18,820

pressure as we're all feeling right now

508

00:26:16,470 --> 00:26:21,519

it's centimeter per square inch

509

00:26:18,819 --> 00:26:24,849

we'd be sitting right in the clouds and

510

00:26:21,519 --> 00:26:28,480

we would have melted away this stuff is

511

00:26:24,849 --> 00:26:30,730

horrible it would melt through your skin

512

00:26:28,480 --> 00:26:34,179

in less than a minute it would get down

513

00:26:30,730 --> 00:26:36,038

to the bone in two minutes and there

514
00:26:34,179 --> 00:26:37,390
wouldn't be much left of us so it's

515
00:26:36,038 --> 00:26:39,398
incredibly difficult for us to

516
00:26:37,390 --> 00:26:42,909
understand and study Venus because it's

517
00:26:39,398 --> 00:26:46,269
such a horrid harsh environment when you

518
00:26:42,909 --> 00:26:49,690
get down to the surface of Venus it's 90

519
00:26:46,269 --> 00:26:53,019
times the pressure that we feel here 90

520
00:26:49,690 --> 00:26:56,110
times that's going down very deep into

521
00:26:53,019 --> 00:26:58,210
the ocean now humans have scuba dive

522
00:26:56,109 --> 00:26:59,139
just that deep so the pressure is not

523
00:26:58,210 --> 00:27:00,340
the thing that's going to kill you

524
00:26:59,140 --> 00:27:03,190
you've got to get through the sulfuric

525
00:27:00,339 --> 00:27:08,829
acid first but it's also really hot down

526
00:27:03,190 --> 00:27:12,759
there it's 700 degrees ugly little

527
00:27:08,829 --> 00:27:16,178
sister right there it's not a nice place

528
00:27:12,759 --> 00:27:18,190
and that's some very strange weather but

529
00:27:16,179 --> 00:27:20,500
it's not the strangest in our solar

530
00:27:18,190 --> 00:27:23,169
system some of the strangest phenomenon

531
00:27:20,500 --> 00:27:25,240
that we have aren't permanent like Venus

532
00:27:23,169 --> 00:27:26,890
is sulfuric haze that extends throughout

533
00:27:25,240 --> 00:27:28,870
the atmosphere but they're intermittent

534
00:27:26,890 --> 00:27:31,299
they only happen every now and again and

535
00:27:28,869 --> 00:27:34,658
one of these we actually see on our

536
00:27:31,298 --> 00:27:37,240
neighbor Mars what happens on Mars every

537
00:27:34,659 --> 00:27:39,490
now and again is a global dust storm

538
00:27:37,240 --> 00:27:42,099
what you're looking at is two images

539
00:27:39,490 --> 00:27:42,819
that were taken just months apart one

540
00:27:42,099 --> 00:27:44,648
which is nice

541
00:27:42,819 --> 00:27:47,829
labeled for us we can see all of these

542

00:27:44,648 --> 00:27:50,548
different features on Mars and the next

543
00:27:47,829 --> 00:27:53,230
one just a couple of months later

544
00:27:50,548 --> 00:27:56,470
everything is wiped out you can just see

545
00:27:53,230 --> 00:28:00,880
the shadow of the edge of this Eden

546
00:27:56,470 --> 00:28:04,929
region a global dust storm can encompass

547
00:28:00,880 --> 00:28:07,509
Mars in just a week and we're actually

548
00:28:04,929 --> 00:28:09,309
expecting another one quite soon so I

549
00:28:07,509 --> 00:28:12,490
don't know how curiosity is going to be

550
00:28:09,308 --> 00:28:14,888
feeling about that one but these storms

551
00:28:12,490 --> 00:28:17,288
are intermittent and they go away so

552
00:28:14,888 --> 00:28:20,378
it's a very strange phenomenon that we

553
00:28:17,288 --> 00:28:21,519
don't actually understand it's we think

554
00:28:20,378 --> 00:28:24,668
it's got something to do with the

555
00:28:21,519 --> 00:28:26,409
gravity but people are still trying to

556
00:28:24,669 --> 00:28:27,639

work that out and it's really great that

557

00:28:26,409 --> 00:28:29,110

we've got these different missions that

558

00:28:27,638 --> 00:28:30,308

are going into orbit around Mars and

559

00:28:29,109 --> 00:28:33,128

we've got missions on the surface that

560

00:28:30,308 --> 00:28:35,888

can monitor these long time.the for a

561

00:28:33,128 --> 00:28:38,709

long time so we can see these chance

562

00:28:35,888 --> 00:28:40,928

occurrences so that's just another

563

00:28:38,710 --> 00:28:42,669

strange thing those are our terrestrial

564

00:28:40,929 --> 00:28:44,200

planets these are small rocky worlds

565

00:28:42,669 --> 00:28:46,870

what happens when we stick a load of gas

566

00:28:44,200 --> 00:28:50,230

on top of that well you get something

567

00:28:46,869 --> 00:28:52,869

like Jupiter in the night gorgeous I

568

00:28:50,230 --> 00:28:56,230

want pictures like this of everything

569

00:28:52,869 --> 00:28:58,268

this is a beautiful image that was taken

570

00:28:56,230 --> 00:29:02,889

with Juno which is currently in orbit

571
00:28:58,269 --> 00:29:07,179
around Jupiter and you could fit free

572
00:29:02,888 --> 00:29:09,758
earths in the side of that storm that is

573
00:29:07,179 --> 00:29:12,278
a hurricane the size of free earth

574
00:29:09,759 --> 00:29:14,579
that's hard to imagine it's not

575
00:29:12,278 --> 00:29:17,349
something you can really put a scale to

576
00:29:14,579 --> 00:29:19,569
to try and help out this is Jupiter

577
00:29:17,349 --> 00:29:22,000
looking down and it's pole where you can

578
00:29:19,569 --> 00:29:24,250
see these gorgeous vortices this is just

579
00:29:22,000 --> 00:29:29,048
dynamics in action this is fluid

580
00:29:24,250 --> 00:29:33,069
dynamics that it's had its core and you

581
00:29:29,048 --> 00:29:36,278
can fit 11 Earth's across that so the

582
00:29:33,069 --> 00:29:38,349
storm around near the equator just south

583
00:29:36,278 --> 00:29:41,079
of the equator on Jupiter is 3 times the

584
00:29:38,349 --> 00:29:42,730
size of the earth Jupiter itself is 11

585
00:29:41,079 --> 00:29:45,759
times the size of the earth that is a

586
00:29:42,730 --> 00:29:48,490
humongous storm you do not want to be

587
00:29:45,759 --> 00:29:50,169
caught in there not only is it a huge

588
00:29:48,490 --> 00:29:51,788
storm but actually some of the

589
00:29:50,169 --> 00:29:54,639
scientific evidence has shown that it's

590
00:29:51,788 --> 00:29:56,529
heating up the atmosphere above it so

591
00:29:54,638 --> 00:29:58,899
the storm itself is

592
00:29:56,529 --> 00:30:01,180
colder than the air that it's generating

593
00:29:58,900 --> 00:30:02,769
above and that's really interesting for

594
00:30:01,180 --> 00:30:06,400
us to try and understand that this

595
00:30:02,769 --> 00:30:09,009
massive hurricane is generating heat

596
00:30:06,400 --> 00:30:10,900
high up in the atmosphere how is it

597
00:30:09,009 --> 00:30:12,359
transferring that here and where is it

598
00:30:10,900 --> 00:30:14,620
going afterwards is that what's

599

00:30:12,359 --> 00:30:17,139
sustaining the fact that the storm is

600
00:30:14,619 --> 00:30:19,239
still there now Hubble Space Telescope

601
00:30:17,140 --> 00:30:21,520
images have shown that this storm is

602
00:30:19,240 --> 00:30:25,240
changing size it's kind of fluctuating

603
00:30:21,519 --> 00:30:26,950
but that's over many years timescale it

604
00:30:25,240 --> 00:30:28,960
gets bigger and smaller and we're like

605
00:30:26,950 --> 00:30:30,819
it's going away it's going away and then

606
00:30:28,960 --> 00:30:32,799
it comes back full force and you get a

607
00:30:30,819 --> 00:30:35,859
picture like this which was taken just

608
00:30:32,799 --> 00:30:40,629
last year so it's a truly amazing

609
00:30:35,859 --> 00:30:42,339
phenomenon in our solar system but you

610
00:30:40,630 --> 00:30:46,450
can see the pole here and I want you to

611
00:30:42,339 --> 00:30:49,299
really focus on that pole look at all of

612
00:30:46,450 --> 00:30:51,880
these gorgeous vortices look how small

613
00:30:49,299 --> 00:30:55,089

some of them are look at them spiraling

614

00:30:51,880 --> 00:30:58,420

down this is the pole of Jupiter if we

615

00:30:55,089 --> 00:31:01,149

go to the next planet Saturn the pole

616

00:30:58,420 --> 00:31:05,890

looks very different there's a strange

617

00:31:01,150 --> 00:31:10,560

giant feature and if we zoom in take a

618

00:31:05,890 --> 00:31:14,170

look at that it's formed a beehive shape

619

00:31:10,559 --> 00:31:16,419

Nature does this very naturally and it's

620

00:31:14,170 --> 00:31:19,720

all about the way material cools and

621

00:31:16,420 --> 00:31:22,090

expands but if we zoom in even further

622

00:31:19,720 --> 00:31:24,430

we can see that there's this hurricane

623

00:31:22,089 --> 00:31:26,199

right at the center we didn't see that

624

00:31:24,430 --> 00:31:29,799

on Jupiter there wasn't this central

625

00:31:26,200 --> 00:31:32,019

storm this vortex in the center of the

626

00:31:29,799 --> 00:31:33,399

pole like we would expect everything's

627

00:31:32,019 --> 00:31:36,069

spinning around there was lots of them

628
00:31:33,400 --> 00:31:39,519
lots of little bowls here we've got this

629
00:31:36,069 --> 00:31:45,099
ginormous storm right at the pole of

630
00:31:39,519 --> 00:31:47,379
Saturn inside this weird shape and that

631
00:31:45,099 --> 00:31:49,719
really threw people for a while we're

632
00:31:47,380 --> 00:31:52,150
trying to still work on simulations to

633
00:31:49,720 --> 00:31:53,769
see why this is forming what temperature

634
00:31:52,150 --> 00:31:56,769
the material would have to be what would

635
00:31:53,769 --> 00:31:58,779
it be made of to form this perfect shape

636
00:31:56,769 --> 00:32:03,369
and this came from the Cassini

637
00:31:58,779 --> 00:32:05,289
spacecraft these are modified color so

638
00:32:03,369 --> 00:32:07,389
this is an infrared image this is an

639
00:32:05,289 --> 00:32:09,019
optical image and this is very much

640
00:32:07,390 --> 00:32:11,330
modified the blue that you

641
00:32:09,019 --> 00:32:13,339
there actually is the Rings so we're

642
00:32:11,329 --> 00:32:15,319
looking at a slant edge there and you're

643
00:32:13,339 --> 00:32:17,689
seeing the Rings in the distance in this

644
00:32:15,319 --> 00:32:21,349
image so these are all enhanced color

645
00:32:17,690 --> 00:32:27,380
images of Saturn this one's a little bit

646
00:32:21,349 --> 00:32:29,179
closer to the truth but that's not the

647
00:32:27,380 --> 00:32:33,460
coolest place in our solar system I'm

648
00:32:29,180 --> 00:32:38,590
biased but the coolest place is Neptune

649
00:32:33,460 --> 00:32:40,150
Neptune has winds that reach up to 13

650
00:32:38,589 --> 00:32:47,149
Wow

651
00:32:40,150 --> 00:32:48,920
1300 miles per hour 1300 miles per hour

652
00:32:47,150 --> 00:32:51,320
and that's what you're seeing here this

653
00:32:48,920 --> 00:32:55,160
image was taken by Voyager 2 when it

654
00:32:51,319 --> 00:32:56,990
went past and it took this image I'm not

655
00:32:55,160 --> 00:33:02,210
ashamed to say just two months after I

656

00:32:56,990 --> 00:33:05,539
was born I'm as old as this images and

657
00:33:02,210 --> 00:33:08,779
it's a fantastic picture of our most

658
00:33:05,539 --> 00:33:12,289
distant giant Neptune is an ice giant

659
00:33:08,779 --> 00:33:15,680
and these this cloud that we're seeing

660
00:33:12,289 --> 00:33:17,960
here that is solid ammonia particles in

661
00:33:15,680 --> 00:33:20,750
the atmosphere it's so cold out there

662
00:33:17,960 --> 00:33:23,829
almost everything freezes and these

663
00:33:20,750 --> 00:33:26,690
storms are whipping around the planet

664
00:33:23,829 --> 00:33:28,519
whopping speeds those are the fastest

665
00:33:26,690 --> 00:33:33,170
winds in the solar system

666
00:33:28,519 --> 00:33:35,720
it can't get faster than that but that's

667
00:33:33,170 --> 00:33:38,630
just our solar system that's a statistic

668
00:33:35,720 --> 00:33:41,329
of one we can't deal with that in

669
00:33:38,630 --> 00:33:42,740
astronomy we want lots of things we need

670
00:33:41,329 --> 00:33:44,960

to start looking at all of the other

671

00:33:42,740 --> 00:33:47,750

stars what else is out there whatever

672

00:33:44,960 --> 00:33:54,230

kind of phenomena have we not discovered

673

00:33:47,750 --> 00:33:58,160

yet so how about that that's just an

674

00:33:54,230 --> 00:34:00,259

artist's impression of just a handful of

675

00:33:58,160 --> 00:34:04,090

the planets that have been discovered in

676

00:34:00,259 --> 00:34:06,609

the last two decades there are now over

677

00:34:04,089 --> 00:34:09,110

4,000 planets that have been discovered

678

00:34:06,609 --> 00:34:11,359

outside of our solar system orbiting

679

00:34:09,110 --> 00:34:14,840

other stars if you look up in the night

680

00:34:11,360 --> 00:34:17,409

sky over 50% of them will have planets

681

00:34:14,840 --> 00:34:20,960

and those are just the ones we can see

682

00:34:17,409 --> 00:34:21,710

the stars that we can't see have planets

683

00:34:20,960 --> 00:34:24,679

that number

684

00:34:21,710 --> 00:34:27,108

in the billions more planets than there

685
00:34:24,679 --> 00:34:28,878
are stars and we're just trying to look

686
00:34:27,108 --> 00:34:31,190
for them and trying to understand them

687
00:34:28,878 --> 00:34:34,159
that really helps us try and understand

688
00:34:31,190 --> 00:34:36,470
our own solar system now there's very

689
00:34:34,159 --> 00:34:40,159
few graphs in this talk but allow me a

690
00:34:36,469 --> 00:34:42,678
couple this is telling you the planets

691
00:34:40,159 --> 00:34:44,838
that have been discovered at the bottom

692
00:34:42,679 --> 00:34:46,639
is their separation from That star so

693
00:34:44,838 --> 00:34:48,858
how far away they are they are from

694
00:34:46,639 --> 00:34:51,409
their star and up the side is the size

695
00:34:48,858 --> 00:34:54,019
of those planets the mass of them now to

696
00:34:51,409 --> 00:34:56,599
put this in context a dump the solar

697
00:34:54,019 --> 00:34:58,250
system on top of it for you so we've got

698
00:34:56,599 --> 00:34:59,059
Jupiter up there and amongst those blue

699
00:34:58,250 --> 00:35:01,670
triangles

700
00:34:59,059 --> 00:35:03,619
we've got Saturn Uranus and Neptune out

701
00:35:01,670 --> 00:35:05,630
there there's nothing really that we've

702
00:35:03,619 --> 00:35:08,200
discovered in that that's space in the

703
00:35:05,630 --> 00:35:10,608
diagram and we've got earth down here

704
00:35:08,199 --> 00:35:13,039
now the reason why we haven't discovered

705
00:35:10,608 --> 00:35:14,808
anything in these portions is purely to

706
00:35:13,039 --> 00:35:17,239
do the techniques that we use and the

707
00:35:14,809 --> 00:35:19,309
ability of our instruments it's not that

708
00:35:17,239 --> 00:35:21,679
they're not there it's that it's really

709
00:35:19,309 --> 00:35:22,790
difficult to find them and that's a

710
00:35:21,679 --> 00:35:25,519
little bit of a problem that we're

711
00:35:22,789 --> 00:35:27,558
trying to work out but what you're

712
00:35:25,519 --> 00:35:28,880
seeing here in red are these transits

713

00:35:27,559 --> 00:35:32,809
and if you've heard about the Kepler

714
00:35:28,880 --> 00:35:34,460
mission Kepler was a beauty it was so

715
00:35:32,809 --> 00:35:35,930
prolific at finding these planets we're

716
00:35:34,460 --> 00:35:37,900
still trying to work out if some of them

717
00:35:35,929 --> 00:35:40,669
were real it hasn't it's catalogue

718
00:35:37,900 --> 00:35:42,318
thousands more candidate worlds that

719
00:35:40,670 --> 00:35:44,450
people on the ground are doing

720
00:35:42,318 --> 00:35:47,269
observations of right now trying to work

721
00:35:44,449 --> 00:35:47,929
out if those are real planets orbiting

722
00:35:47,269 --> 00:35:50,088
other stars

723
00:35:47,929 --> 00:35:51,679
so this numbers just gonna keep going up

724
00:35:50,088 --> 00:35:54,710
this isn't steady this isn't everything

725
00:35:51,679 --> 00:35:57,889
this is just a tiny fraction of what is

726
00:35:54,710 --> 00:36:00,318
out there but what I want you to focus

727
00:35:57,889 --> 00:36:02,929

on is this corner up here away from

728

00:36:00,318 --> 00:36:06,079

Jupiter in a very strange parameter

729

00:36:02,929 --> 00:36:09,828

space in this corner of the diagram we

730

00:36:06,079 --> 00:36:11,990

are so close to the star that we are

731

00:36:09,829 --> 00:36:14,809

twenty times closer than the office of

732

00:36:11,989 --> 00:36:17,568

the Sun that's even eight times closer

733

00:36:14,809 --> 00:36:20,750

to their stars than mercury is to our

734

00:36:17,568 --> 00:36:24,079

Sun and we just said that the Sun is

735

00:36:20,750 --> 00:36:27,159

bombarding Mercury's surface with huge

736

00:36:24,079 --> 00:36:30,400

amounts of radiation and particles

737

00:36:27,159 --> 00:36:33,710

mercury sits inside the sun's atmosphere

738

00:36:30,400 --> 00:36:35,690

these are eight times closer to their

739

00:36:33,710 --> 00:36:38,478

star than mercury is

740

00:36:35,690 --> 00:36:42,088

but also the ones at the top here

741

00:36:38,478 --> 00:36:44,068

they're as big as Jupiter take Jupiter

742
00:36:42,088 --> 00:36:46,528
that 11 times the size of the earth

743
00:36:44,068 --> 00:36:49,380
planet and stick it right next to the

744
00:36:46,528 --> 00:36:51,150
Sun that's what we're seeing here in

745
00:36:49,380 --> 00:36:53,249
this top corner this is showing us that

746
00:36:51,150 --> 00:36:56,579
there are these giant Jupiter sized

747
00:36:53,248 --> 00:36:59,068
worlds now to put that in context in

748
00:36:56,579 --> 00:37:01,339
something that you can go home and you

749
00:36:59,068 --> 00:37:03,630
can visualize and try and understand I

750
00:37:01,338 --> 00:37:08,400
want you to imagine that the earth was

751
00:37:03,630 --> 00:37:11,400
the size of a pea now on this scale if

752
00:37:08,400 --> 00:37:13,559
we had our nice Jupiter eleven times

753
00:37:11,400 --> 00:37:18,269
that size it would be about the size of

754
00:37:13,559 --> 00:37:20,519
an orange some of these are bigger than

755
00:37:18,268 --> 00:37:25,288
Jupiter you can see that they go all the

756
00:37:20,518 --> 00:37:28,998
way up here on average these planets

757
00:37:25,289 --> 00:37:32,220
here are the size of a large watermelon

758
00:37:28,998 --> 00:37:33,959
they're huge compared to what we have in

759
00:37:32,219 --> 00:37:35,578
our solar system now you'll be

760
00:37:33,960 --> 00:37:38,130
hard-pressed to find such a beautifully

761
00:37:35,579 --> 00:37:42,829
spherical watermelon but if you could

762
00:37:38,130 --> 00:37:45,390
imagine that it's a little bit crazy I

763
00:37:42,829 --> 00:37:48,420
find this is a very helpful I call it my

764
00:37:45,389 --> 00:37:50,038
fruit basket of planets the the Neptune

765
00:37:48,420 --> 00:37:52,170
ones if you wanted to look for something

766
00:37:50,039 --> 00:37:55,769
this size there'd be about the size of a

767
00:37:52,170 --> 00:37:58,829
plum nice purple world and those are

768
00:37:55,768 --> 00:38:00,209
actually if you look here most of the

769
00:37:58,829 --> 00:38:02,849
planets that have been discovered

770

00:38:00,210 --> 00:38:04,679
are these Neptune size worlds Neptune is

771
00:38:02,849 --> 00:38:06,298
four times the size of the earth and

772
00:38:04,679 --> 00:38:09,028
most of the planets that have been

773
00:38:06,298 --> 00:38:11,038
discovered are neptune-sized worlds or

774
00:38:09,028 --> 00:38:12,298
something that is slightly smaller and

775
00:38:11,039 --> 00:38:14,339
something we don't have in our solar

776
00:38:12,298 --> 00:38:15,630
system to compare to so there's a lot

777
00:38:14,338 --> 00:38:20,608
out there that we really don't

778
00:38:15,630 --> 00:38:22,079
understand yet but how do we take this

779
00:38:20,608 --> 00:38:23,130
further this is just telling us numbers

780
00:38:22,079 --> 00:38:25,798
this is just telling us that there are

781
00:38:23,130 --> 00:38:27,210
other planets out there we want to look

782
00:38:25,798 --> 00:38:29,699
a little bit closer we want to try and

783
00:38:27,210 --> 00:38:32,670
understand those worlds now what I'm

784
00:38:29,699 --> 00:38:35,939

showing you here is how we do that we

785

00:38:32,670 --> 00:38:39,028
look for the light that has come

786

00:38:35,940 --> 00:38:40,798
directly from that planet so we're

787

00:38:39,028 --> 00:38:44,728
seeing the emission from that planet

788

00:38:40,798 --> 00:38:47,400
itself ignoring the star or we're

789

00:38:44,728 --> 00:38:48,149
looking at the Starlight that has shone

790

00:38:47,400 --> 00:38:50,068
through that

791

00:38:48,150 --> 00:38:52,769
atmosphere before reaching us and we get

792

00:38:50,068 --> 00:38:54,538
an absorption spectrum so if that star

793

00:38:52,769 --> 00:38:56,579
light is shining through that planetary

794

00:38:54,539 --> 00:38:59,579
atmosphere anything in that atmosphere

795

00:38:56,579 --> 00:39:01,339
is going to block that light and every

796

00:38:59,579 --> 00:39:03,450
single molecule has its own little

797

00:39:01,338 --> 00:39:06,269
absorption spectrum its own little

798

00:39:03,449 --> 00:39:07,500
pattern and we can look for those it's

799
00:39:06,269 --> 00:39:09,239
the same in a mission they've got their

800
00:39:07,500 --> 00:39:12,329
own little patterns that we can look for

801
00:39:09,239 --> 00:39:14,308
but the amount of light that is put out

802
00:39:12,329 --> 00:39:16,710
by the planet alone is very small so

803
00:39:14,309 --> 00:39:19,109
that's very difficult to do this on the

804
00:39:16,710 --> 00:39:20,760
other hand if those that planet is

805
00:39:19,108 --> 00:39:24,058
passing directly in front of That star

806
00:39:20,760 --> 00:39:25,170
we can do this and we can do this by

807
00:39:24,059 --> 00:39:28,650
something called transmission

808
00:39:25,170 --> 00:39:30,809
spectroscopy so take absorption spectrum

809
00:39:28,650 --> 00:39:33,420
we are then shining the light for the

810
00:39:30,809 --> 00:39:34,740
atmosphere it absorbs and transmits the

811
00:39:33,420 --> 00:39:36,990
rest of it which is why it's called a

812
00:39:34,739 --> 00:39:39,419
transmission spectrum rather than the

813
00:39:36,989 --> 00:39:43,108
absorption spectrum just to confuse

814
00:39:39,420 --> 00:39:45,450
everyone it confuses everyone that isn't

815
00:39:43,108 --> 00:39:49,920
an exoplanet scientist I think we did it

816
00:39:45,449 --> 00:39:51,598
on purpose so what we're doing is we're

817
00:39:49,920 --> 00:39:53,818
looking at that planet as it passes in

818
00:39:51,599 --> 00:39:55,380
front of its star as it as it does it

819
00:39:53,818 --> 00:39:58,380
blocks out a very small amount of that

820
00:39:55,380 --> 00:40:00,000
light if we look at that in lots of

821
00:39:58,380 --> 00:40:03,630
different wavelengths if we build up our

822
00:40:00,000 --> 00:40:07,230
colors we look at it in say I don't know

823
00:40:03,630 --> 00:40:09,000
red or blue we get a different amount of

824
00:40:07,230 --> 00:40:11,068
absorption because the atmosphere is

825
00:40:09,000 --> 00:40:14,219
going to be absorbing some of that light

826
00:40:11,068 --> 00:40:16,230
and then we build up our colors we get

827

00:40:14,219 --> 00:40:18,750
our picture and we start putting it

828
00:40:16,230 --> 00:40:20,429
together and we get the change in the

829
00:40:18,750 --> 00:40:22,469
amount of light blocked by that planet

830
00:40:20,429 --> 00:40:25,469
over different wavelengths over

831
00:40:22,469 --> 00:40:26,669
different colors and then we can start

832
00:40:25,469 --> 00:40:28,980
using some of the physics that we

833
00:40:26,670 --> 00:40:31,440
understand we can use these spectra each

834
00:40:28,980 --> 00:40:33,659
elements each molecule has unique

835
00:40:31,440 --> 00:40:35,970
fingerprint if we piece that together

836
00:40:33,659 --> 00:40:37,348
and try to understand it we can put a

837
00:40:35,969 --> 00:40:39,419
model to that and try and work out

838
00:40:37,349 --> 00:40:41,160
what's in the atmosphere in this case

839
00:40:39,420 --> 00:40:44,190
what it's showing you is some sodium and

840
00:40:41,159 --> 00:40:45,960
potassium there what you're seeing over

841
00:40:44,190 --> 00:40:47,548

here is something that I recently did

842

00:40:45,960 --> 00:40:49,619

with the Hubble Space Telescope and

843

00:40:47,548 --> 00:40:51,329

you're seeing this slope here from

844

00:40:49,619 --> 00:40:53,490

hydrogen and helium in the atmosphere

845

00:40:51,329 --> 00:40:55,318

these are big gassy world's mostly

846

00:40:53,489 --> 00:40:57,419

hydrogen and helium you're seeing this

847

00:40:55,318 --> 00:41:00,690

sodium absorption this potassium

848

00:40:57,420 --> 00:41:01,470

absorption and most importantly huge

849

00:41:00,690 --> 00:41:04,650

amounts of

850

00:41:01,469 --> 00:41:06,779

- vapor in the atmosphere they're so

851

00:41:04,650 --> 00:41:12,720

close to their star they're incredibly

852

00:41:06,780 --> 00:41:14,820

hot they're about 1500 Kelvin they're

853

00:41:12,719 --> 00:41:17,009

very very hot everything's in the gas

854

00:41:14,820 --> 00:41:19,260

phase so what we found was there's lots

855

00:41:17,010 --> 00:41:21,869

of water none of its liquid it's all

856
00:41:19,260 --> 00:41:26,630
happily floating around in the gas these

857
00:41:21,869 --> 00:41:31,590
are these are boiling pots of material

858
00:41:26,630 --> 00:41:34,740
so that's how we we do that another way

859
00:41:31,590 --> 00:41:37,200
of showing this showing this change in

860
00:41:34,739 --> 00:41:39,899
depth is showing you how the planet

861
00:41:37,199 --> 00:41:42,118
appears to us what it's doing is it's

862
00:41:39,900 --> 00:41:43,740
changing its relative size it's changing

863
00:41:42,119 --> 00:41:45,358
the amount of light it's blocking out so

864
00:41:43,739 --> 00:41:46,919
if you've got our model and we watch

865
00:41:45,358 --> 00:41:48,900
this the planet looks like it gets

866
00:41:46,920 --> 00:41:51,960
bigger and smaller they're going smaller

867
00:41:48,900 --> 00:41:53,430
as it's absorbing that light and that's

868
00:41:51,960 --> 00:41:56,490
what we're doing we're looking for this

869
00:41:53,429 --> 00:41:59,579
change in the size of that planet as you

870
00:41:56,489 --> 00:42:01,589
go through all of those colors I find

871
00:41:59,579 --> 00:42:03,119
that's a very helpful visualization I

872
00:42:01,590 --> 00:42:05,780
even have to go back to it every now and

873
00:42:03,119 --> 00:42:09,150
again to remember what it is we're doing

874
00:42:05,780 --> 00:42:11,849
so taking all of that the techniques

875
00:42:09,150 --> 00:42:13,530
that we use how do we do that I've

876
00:42:11,849 --> 00:42:16,530
already hinted at this but we need our

877
00:42:13,530 --> 00:42:19,349
eye on that storm we need to be looking

878
00:42:16,530 --> 00:42:22,410
for this how are we doing that my

879
00:42:19,349 --> 00:42:24,570
favorite workhorse in astronomy the

880
00:42:22,409 --> 00:42:27,449
Hubble Space Telescope it gave me my PhD

881
00:42:24,570 --> 00:42:29,039
so I'm quite happy with it right now the

882
00:42:27,449 --> 00:42:31,799
Hubble Space Telescope has been an

883
00:42:29,039 --> 00:42:35,070
amazing tour de force of looking at

884

00:42:31,800 --> 00:42:38,460
these exoplanet atmospheres and this is

885
00:42:35,070 --> 00:42:40,500
showing you 10 different planets and you

886
00:42:38,460 --> 00:42:43,139
can see them happily rotating there

887
00:42:40,500 --> 00:42:44,010
these are 10 different planets that we

888
00:42:43,139 --> 00:42:45,960
looked at with the Hubble Space

889
00:42:44,010 --> 00:42:47,339
Telescope and we got that spectrum we

890
00:42:45,960 --> 00:42:50,369
got those fingerprints from those

891
00:42:47,338 --> 00:42:53,759
molecules but what we found was that

892
00:42:50,369 --> 00:42:57,210
these jupiter-sized planets all of them

893
00:42:53,760 --> 00:42:58,890
bigger than Jupiter all of them about 20

894
00:42:57,210 --> 00:43:01,139
times close to their star then we out of

895
00:42:58,889 --> 00:43:03,449
the Sun so we would expect them all to

896
00:43:01,139 --> 00:43:04,980
be roughly the same they're all

897
00:43:03,449 --> 00:43:09,118
different of course they are why

898
00:43:04,980 --> 00:43:13,079

wouldn't they be nature's of pain we

899

00:43:09,119 --> 00:43:15,000

have no clue they are all different and

900

00:43:13,079 --> 00:43:15,449

what we're seeing here is that they go

901

00:43:15,000 --> 00:43:17,789

from

902

00:43:15,449 --> 00:43:19,769

very clear atmospheres so what we would

903

00:43:17,789 --> 00:43:21,900

expect to be finding all gas-phase

904

00:43:19,769 --> 00:43:24,599

everything's a gas it's so hot it should

905

00:43:21,900 --> 00:43:27,960

be a gas down to these ones which

906

00:43:24,599 --> 00:43:29,460

display really flat spectra we don't

907

00:43:27,960 --> 00:43:31,889

know there's something blocking that

908

00:43:29,460 --> 00:43:35,130

what is blocking that down to these ones

909

00:43:31,889 --> 00:43:37,170

which show these huge slants which shows

910

00:43:35,130 --> 00:43:41,840

that things are scattering in the blue

911

00:43:37,170 --> 00:43:44,700

end and then in the red end they're not

912

00:43:41,840 --> 00:43:46,559

what is happening here what I love about

913
00:43:44,699 --> 00:43:48,569
this little animation is that if you

914
00:43:46,559 --> 00:43:50,099
watch it carefully you can see that

915
00:43:48,570 --> 00:43:53,670
they're all rotating at a different

916
00:43:50,099 --> 00:43:56,039
speed and that's because they have

917
00:43:53,670 --> 00:44:00,059
different orbital periods and their

918
00:43:56,039 --> 00:44:03,599
orbital period matches their their

919
00:44:00,059 --> 00:44:06,690
rotation speed we have that phenomenon

920
00:44:03,599 --> 00:44:09,000
here the moon the orbital period of the

921
00:44:06,690 --> 00:44:10,800
Moon matches the rotation period of the

922
00:44:09,000 --> 00:44:13,230
Moon a year on the moon is the same

923
00:44:10,800 --> 00:44:15,570
length as a day on the moon these are

924
00:44:13,230 --> 00:44:17,969
what is called tidally locked to their

925
00:44:15,570 --> 00:44:20,280
star they have a permanent day side

926
00:44:17,969 --> 00:44:22,409
which is always facing the star and a

927
00:44:20,280 --> 00:44:25,470
permanent night side which is always

928
00:44:22,409 --> 00:44:28,829
facing away you have heat from the star

929
00:44:25,469 --> 00:44:30,719
bombarding one side and no light at all

930
00:44:28,829 --> 00:44:33,630
getting to the other side of that planet

931
00:44:30,719 --> 00:44:35,909
so that does some very strange things to

932
00:44:33,630 --> 00:44:39,210
a planetary atmosphere and I'm gonna

933
00:44:35,909 --> 00:44:41,009
take you through some of those later but

934
00:44:39,210 --> 00:44:43,170
it's not just these ten planets that

935
00:44:41,010 --> 00:44:44,580
we've looked at this is just a

936
00:44:43,170 --> 00:44:47,730
smattering of some of the work that I've

937
00:44:44,579 --> 00:44:49,799
been doing I've got more now where all

938
00:44:47,730 --> 00:44:51,840
of those gaps are so I've got some work

939
00:44:49,800 --> 00:44:55,080
ahead of me but what we're finding is

940
00:44:51,840 --> 00:44:57,000
that these giant planets 80% of them

941

00:44:55,079 --> 00:44:59,369
show evidence that there is water vapour

942
00:44:57,000 --> 00:45:01,710
in their atmosphere we're seeing this

943
00:44:59,369 --> 00:45:04,199
fingerprint of water gas in the

944
00:45:01,710 --> 00:45:07,470
atmosphere of these giant planets water

945
00:45:04,199 --> 00:45:08,730
is the third most abundant molecule in

946
00:45:07,469 --> 00:45:11,549
the entire universe

947
00:45:08,730 --> 00:45:13,260
it's absolutely everywhere we look and

948
00:45:11,550 --> 00:45:15,480
we need to really understand the balance

949
00:45:13,260 --> 00:45:18,660
of water in these atmospheres to work

950
00:45:15,480 --> 00:45:21,659
out where and how they formed but

951
00:45:18,659 --> 00:45:22,139
unfortunately we can't quite get there

952
00:45:21,659 --> 00:45:25,049
yet

953
00:45:22,139 --> 00:45:27,869
because we can't constrain it a lot of

954
00:45:25,050 --> 00:45:29,220
these have very large uncertainties on

955
00:45:27,869 --> 00:45:32,039

them that

956

00:45:29,219 --> 00:45:34,079

means that we can't precisely measure

957

00:45:32,039 --> 00:45:37,559

how much water there is

958

00:45:34,079 --> 00:45:39,900

and only roughly 5% of them have this

959

00:45:37,559 --> 00:45:42,179

nice precise measurement so that we can

960

00:45:39,900 --> 00:45:45,840

work out perhaps where that planet

961

00:45:42,179 --> 00:45:48,239

formed enter the James Webb Space

962

00:45:45,840 --> 00:45:49,950

Telescope and for those of you who were

963

00:45:48,239 --> 00:45:51,358

here at the last one we had a really

964

00:45:49,949 --> 00:45:53,519

nice presentation on the James Webb

965

00:45:51,358 --> 00:45:56,848

Space Telescope it's going to be

966

00:45:53,519 --> 00:46:00,269

launching in spring of next year and it

967

00:45:56,849 --> 00:46:01,950

is going to be a lot larger than Hubble

968

00:46:00,269 --> 00:46:03,840

it's going to be a lot further away from

969

00:46:01,949 --> 00:46:05,689

the earth so we're not going to have the

970
00:46:03,840 --> 00:46:08,369
Earth's light getting in the way and

971
00:46:05,690 --> 00:46:11,280
it's going to be looking in the infrared

972
00:46:08,369 --> 00:46:13,260
in a different wavelength and what that

973
00:46:11,280 --> 00:46:15,359
allows us to do is look for different

974
00:46:13,260 --> 00:46:17,640
molecules instead of just looking at the

975
00:46:15,358 --> 00:46:20,519
water that we can see here we're also

976
00:46:17,639 --> 00:46:23,039
looking for this carbon dioxide in the

977
00:46:20,519 --> 00:46:24,929
atmosphere and that's really important

978
00:46:23,039 --> 00:46:27,869
for us to understand the balance between

979
00:46:24,929 --> 00:46:29,730
oxygen and carbon this is just a

980
00:46:27,869 --> 00:46:32,369
simulation that was done by one of my

981
00:46:29,730 --> 00:46:33,929
colleagues Natasha Battaglia and this is

982
00:46:32,369 --> 00:46:35,460
simulating the atmosphere of one of

983
00:46:33,929 --> 00:46:38,399
those those planets that I showed you

984
00:46:35,460 --> 00:46:41,639
before we're going to get absolutely

985
00:46:38,400 --> 00:46:43,500
beautiful precision data on these so

986
00:46:41,639 --> 00:46:45,929
that we can understand this planet's

987
00:46:43,500 --> 00:46:49,980
atmosphere where did it come from how

988
00:46:45,929 --> 00:46:52,319
did it get there what is it made of now

989
00:46:49,980 --> 00:46:53,490
that's not the only one there's loads of

990
00:46:52,320 --> 00:46:56,309
them that we're going to be looking at

991
00:46:53,489 --> 00:46:58,469
this is just one from a DD director's

992
00:46:56,309 --> 00:47:00,509
discretionary early release science time

993
00:46:58,469 --> 00:47:02,519
that has been awarded to the exoplanet

994
00:47:00,510 --> 00:47:04,920
transiting community and we're going to

995
00:47:02,519 --> 00:47:08,449
be getting observations of this giant

996
00:47:04,920 --> 00:47:12,150
planet called wasp 79 be great name

997
00:47:08,449 --> 00:47:13,409
whilst 79 be from our observations with

998

00:47:12,150 --> 00:47:15,930
Hubble which are in grey in the

999
00:47:13,409 --> 00:47:18,000
background there this is what we predict

1000
00:47:15,929 --> 00:47:20,879
we're going to be observing with the

1001
00:47:18,000 --> 00:47:24,289
James Webb Space Telescope amazing

1002
00:47:20,880 --> 00:47:27,240
precision there on this CO and CO₂

1003
00:47:24,289 --> 00:47:29,550
features and the water and what you can

1004
00:47:27,239 --> 00:47:31,739
see here in red is what we understand

1005
00:47:29,550 --> 00:47:34,470
based on Hubble data alone and then in

1006
00:47:31,739 --> 00:47:36,659
blue how much better we would understand

1007
00:47:34,469 --> 00:47:38,549
this planet's atmosphere just from

1008
00:47:36,659 --> 00:47:41,338
adding these observations with the James

1009
00:47:38,550 --> 00:47:42,560
Webb Space Telescope so we have a huge

1010
00:47:41,338 --> 00:47:44,929
amount

1011
00:47:42,559 --> 00:47:45,949
learn about these exoplanets and it's

1012
00:47:44,929 --> 00:47:48,349

all going to be coming in the next

1013

00:47:45,949 --> 00:47:51,739

decade we're going to know so much more

1014

00:47:48,349 --> 00:47:54,309

about how planetary systems form and how

1015

00:47:51,739 --> 00:47:58,519

a planetary system like our own formed

1016

00:47:54,309 --> 00:48:00,710

so that's all to look forward to but

1017

00:47:58,519 --> 00:48:02,199

let's delve into the atmospheres of some

1018

00:48:00,710 --> 00:48:07,070

of these planets a little bit more

1019

00:48:02,199 --> 00:48:09,859

explore some alien worlds with me I want

1020

00:48:07,070 --> 00:48:17,410

you to watch this video I want you to

1021

00:48:09,860 --> 00:48:25,309

tell me what you think this is sunrise

1022

00:48:17,409 --> 00:48:29,179

beautiful sunrise but that's the sunrise

1023

00:48:25,309 --> 00:48:33,409

of this planet here and that's the

1024

00:48:29,179 --> 00:48:35,419

sunrise of the earth to scale what

1025

00:48:33,409 --> 00:48:38,359

you'll notice is the colors are

1026

00:48:35,420 --> 00:48:41,000

remarkably similar what I think is

1027
00:48:38,360 --> 00:48:42,980
immediately apparent is that it's a bit

1028
00:48:41,000 --> 00:48:47,119
larger than what we're seeing here on

1029
00:48:42,980 --> 00:48:49,429
the earth that is an actual size scale

1030
00:48:47,119 --> 00:48:51,380
image compared to the earth of what the

1031
00:48:49,429 --> 00:48:52,789
sunrise would look like if you were in

1032
00:48:51,380 --> 00:48:54,470
the atmosphere or a planet called

1033
00:48:52,789 --> 00:48:59,690
haich-d one eight nine seven three

1034
00:48:54,469 --> 00:49:01,369
freebie telephone numbers a lot of this

1035
00:48:59,690 --> 00:49:03,980
audience will remember having to

1036
00:49:01,369 --> 00:49:06,679
memorize telephone numbers that's what

1037
00:49:03,980 --> 00:49:09,650
we're doing still HD one eight nine

1038
00:49:06,679 --> 00:49:12,169
seven three freebie much like the

1039
00:49:09,650 --> 00:49:15,440
Earth's atmosphere scatters all of its

1040
00:49:12,170 --> 00:49:18,079
light in the blue end of the spectrum it

1041
00:49:15,440 --> 00:49:19,700
scatters that light away and if you were

1042
00:49:18,079 --> 00:49:21,980
sitting looking through the atmosphere

1043
00:49:19,699 --> 00:49:26,960
at its star you would see this gorgeous

1044
00:49:21,980 --> 00:49:29,840
red hue across the star much like the

1045
00:49:26,960 --> 00:49:31,880
earth sunset you of course on this

1046
00:49:29,840 --> 00:49:34,130
planet would be twenty times closer so

1047
00:49:31,880 --> 00:49:37,849
the star in the sky would look a lot

1048
00:49:34,130 --> 00:49:39,740
bigger and also because you're so much

1049
00:49:37,849 --> 00:49:42,170
closer to the star you'd see all of the

1050
00:49:39,739 --> 00:49:43,879
arrays of the colors of a sunset all at

1051
00:49:42,170 --> 00:49:47,690
once so it would be a beautiful

1052
00:49:43,880 --> 00:49:51,170
spectacle now of course another caveat

1053
00:49:47,690 --> 00:49:52,789
to this is that you'd be sitting in an

1054
00:49:51,170 --> 00:49:56,260
atmosphere that it was at the

1055

00:49:52,789 --> 00:50:01,369
temperature of 1200 degrees

1056
00:49:56,260 --> 00:50:04,010
so you wouldn't be very happy you would

1057
00:50:01,369 --> 00:50:07,700
also be sitting in an atmosphere where

1058
00:50:04,010 --> 00:50:09,339
it's tidally locked so the only way you

1059
00:50:07,699 --> 00:50:11,929
can see the sunset is to be sitting

1060
00:50:09,338 --> 00:50:13,730
specifically at a point on the edge of

1061
00:50:11,929 --> 00:50:17,329
that atmosphere between the day and the

1062
00:50:13,730 --> 00:50:20,719
night the boundary between the bright

1063
00:50:17,329 --> 00:50:23,269
Sun bombarded day side and the cold

1064
00:50:20,719 --> 00:50:25,338
frigid lightless night side of this

1065
00:50:23,269 --> 00:50:30,619
planet you'd be looking out at that star

1066
00:50:25,338 --> 00:50:32,119
and you'd see this gorgeous sunset but

1067
00:50:30,619 --> 00:50:35,510
that's kind of like the earth it

1068
00:50:32,119 --> 00:50:36,789
scatters it's a bit boring sunset we've

1069
00:50:35,510 --> 00:50:41,390

seen that one before

1070

00:50:36,789 --> 00:50:43,699

what about this one this is a simulation

1071

00:50:41,389 --> 00:50:49,519

of a sunset on a different planet called

1072

00:50:43,699 --> 00:50:52,969

HD 209 4 5 8 b HD 209 4 5 8 b has sodium

1073

00:50:49,519 --> 00:50:54,829

in its atmosphere and it doesn't scatter

1074

00:50:52,969 --> 00:50:56,929

light like the Earth's atmosphere

1075

00:50:54,829 --> 00:51:01,519

it doesn't scatter all of this blue

1076

00:50:56,929 --> 00:51:04,338

light it's relatively flat but then it's

1077

00:51:01,519 --> 00:51:06,619

got sodium absorbing that light now

1078

00:51:04,338 --> 00:51:09,049

sodium is a nice yellow color street

1079

00:51:06,619 --> 00:51:13,010

lamps are sodium lamps they shine a nice

1080

00:51:09,050 --> 00:51:15,349

orange but if it's orange that's shining

1081

00:51:13,010 --> 00:51:17,839

that means that orange is taken out of

1082

00:51:15,349 --> 00:51:19,640

your spectrum so it's being absorbed

1083

00:51:17,838 --> 00:51:22,608

you're not seeing that for your sunset

1084
00:51:19,639 --> 00:51:24,500
so take out that orange and then see

1085
00:51:22,608 --> 00:51:27,889
what the Sun would look like and it

1086
00:51:24,500 --> 00:51:30,530
would look a nice alien green blue this

1087
00:51:27,889 --> 00:51:33,319
is what the Sun would look like or the

1088
00:51:30,530 --> 00:51:37,010
star but HD well I'm gonna say it wrong

1089
00:51:33,320 --> 00:51:40,250
HD Turin i45 8 is the star the planet is

1090
00:51:37,010 --> 00:51:42,500
the B so this is what HD 209 4 5 8 would

1091
00:51:40,250 --> 00:51:45,349
look like from the atmosphere of the

1092
00:51:42,500 --> 00:51:48,849
planet alien green and that's because

1093
00:51:45,349 --> 00:51:52,220
there's sodium in the atmosphere

1094
00:51:48,849 --> 00:51:54,588
absolutely brilliant but I want to take

1095
00:51:52,219 --> 00:51:56,269
you back to this boring mundane sunset

1096
00:51:54,588 --> 00:51:58,929
right now because this planet is more

1097
00:51:56,269 --> 00:52:04,099
interesting than it lets it out to be

1098
00:51:58,929 --> 00:52:09,649
this planet has shards in the wind it is

1099
00:52:04,099 --> 00:52:13,940
as I said 1200 degrees 1000

1100
00:52:09,650 --> 00:52:16,670
200 degrees it is also being bombarded

1101
00:52:13,940 --> 00:52:19,220
by an active star what you're gonna see

1102
00:52:16,670 --> 00:52:22,690
here in this video is a flare go off on

1103
00:52:19,219 --> 00:52:27,199
that star and a reaction from the planet

1104
00:52:22,690 --> 00:52:30,139
and this is a simulation that is done

1105
00:52:27,199 --> 00:52:32,239
based on the data down here this is

1106
00:52:30,139 --> 00:52:33,769
showing us that when a flare goes off

1107
00:52:32,239 --> 00:52:35,838
and this was measured with an x-ray

1108
00:52:33,769 --> 00:52:37,909
telescope the flare from the star was

1109
00:52:35,838 --> 00:52:41,389
measured and then the planet was looked

1110
00:52:37,909 --> 00:52:43,969
at during this time using a UV telescope

1111
00:52:41,389 --> 00:52:45,798
and what it saw was a really big spike

1112

00:52:43,969 --> 00:52:48,068
in the lyman-alpha and that's looking

1113
00:52:45,798 --> 00:52:52,278
for hydrogen lyman-alpha lines are

1114
00:52:48,068 --> 00:52:55,460
created by hydrogen and what we saw was

1115
00:52:52,278 --> 00:52:57,889
this humongous tail of material that had

1116
00:52:55,460 --> 00:53:01,480
been blasted off of this planet's

1117
00:52:57,889 --> 00:53:06,588
atmosphere by this flare from the star

1118
00:53:01,480 --> 00:53:08,269
that's a violent place to be not only is

1119
00:53:06,588 --> 00:53:11,420
it a violent place to be because of the

1120
00:53:08,269 --> 00:53:15,619
star but the winds on this planet

1121
00:53:11,420 --> 00:53:18,858
remember I said Neptune's winds 1,200

1122
00:53:15,619 --> 00:53:22,849
miles per hour the winds on this planet

1123
00:53:18,858 --> 00:53:26,900
have been measured to be 5,400 miles per

1124
00:53:22,849 --> 00:53:32,170
hour whipping around that planets

1125
00:53:26,900 --> 00:53:34,940
equator in a huge band speeds that are

1126
00:53:32,170 --> 00:53:38,059

absolutely insane you physically cannot

1127

00:53:34,940 --> 00:53:39,769

imagine them but because of the

1128

00:53:38,059 --> 00:53:42,680

temperature of this planet's atmosphere

1129

00:53:39,769 --> 00:53:45,889

there's another issue it's really a

1130

00:53:42,679 --> 00:53:47,808

horrible place the other issue is that

1131

00:53:45,889 --> 00:53:50,389

there are clouds in this planet's

1132

00:53:47,809 --> 00:53:51,289

atmosphere now the clouds here on earth

1133

00:53:50,389 --> 00:53:53,929

are made of water

1134

00:53:51,289 --> 00:53:56,510

we like water it's a bit painful when

1135

00:53:53,929 --> 00:54:00,078

it's hitting you and it's hail or it's a

1136

00:53:56,510 --> 00:54:03,079

bit cold when it's snow these clouds are

1137

00:54:00,079 --> 00:54:07,190

made of magnesium silicates they're made

1138

00:54:03,079 --> 00:54:09,980

of sand but they're not made of nice

1139

00:54:07,190 --> 00:54:12,380

beach sand that kind of hurts when it

1140

00:54:09,980 --> 00:54:17,088

blows off the beach these are made of

1141
00:54:12,380 --> 00:54:21,048
molten glass and that is flying into you

1142
00:54:17,088 --> 00:54:22,849
at 5,400 miles per hour

1143
00:54:21,048 --> 00:54:26,019
horizontal winds

1144
00:54:22,849 --> 00:54:29,029
of molten glass over a thousand degrees

1145
00:54:26,019 --> 00:54:31,659
and then every now and again you'll get

1146
00:54:29,030 --> 00:54:37,160
blasted by radiation from the star I

1147
00:54:31,659 --> 00:54:40,309
think that counts as wild weather that's

1148
00:54:37,159 --> 00:54:41,809
just the start of the craziness this

1149
00:54:40,309 --> 00:54:43,460
planet has been studied the most out of

1150
00:54:41,809 --> 00:54:45,110
almost all of the exoplanets that we've

1151
00:54:43,460 --> 00:54:47,570
been observing so we know quite a lot

1152
00:54:45,110 --> 00:54:49,849
about it but there are other really

1153
00:54:47,570 --> 00:54:53,480
wacky worlds out there that we're

1154
00:54:49,849 --> 00:54:59,779
learning about one of them is HD 80606 b

1155
00:54:53,480 --> 00:55:03,949
and HD 80606 b is essentially a Jupiter

1156
00:54:59,780 --> 00:55:07,340
sized comet this is its orbit compared

1157
00:55:03,949 --> 00:55:11,119
to our solar system it comes in from up

1158
00:55:07,340 --> 00:55:14,510
here close to where the earth orbits so

1159
00:55:11,119 --> 00:55:17,420
it's fairly decent quite nice out there

1160
00:55:14,510 --> 00:55:21,650
and then it whips right down close to

1161
00:55:17,420 --> 00:55:26,150
its star this actually goes much much

1162
00:55:21,650 --> 00:55:29,030
closer and then it slingshots out again

1163
00:55:26,150 --> 00:55:31,280
and then it comes back down and then

1164
00:55:29,030 --> 00:55:34,490
it's slingshots out again this is a

1165
00:55:31,280 --> 00:55:36,700
commentary Jupiter sized world can you

1166
00:55:34,489 --> 00:55:39,739
imagine what that does to an atmosphere

1167
00:55:36,699 --> 00:55:41,809
we call this an engineering problem more

1168
00:55:39,739 --> 00:55:43,250
than anything in engineering you hit

1169

00:55:41,809 --> 00:55:44,630
something with a hammer and you wait to

1170
00:55:43,250 --> 00:55:48,230
see how long it takes to go back to

1171
00:55:44,630 --> 00:55:50,539
normal the every time this planet orbits

1172
00:55:48,230 --> 00:55:52,400
gets hit by a hammer and we have to wait

1173
00:55:50,539 --> 00:55:54,019
to see how long goes back to normal and

1174
00:55:52,400 --> 00:55:57,079
naturally we've been making those

1175
00:55:54,019 --> 00:56:00,409
observations with the telescopes and we

1176
00:55:57,079 --> 00:56:02,449
can do that measurement by looking at

1177
00:56:00,409 --> 00:56:05,359
the planet over the course of this orbit

1178
00:56:02,449 --> 00:56:08,389
and looking at how that atmosphere is

1179
00:56:05,360 --> 00:56:10,039
reacting by measuring the heat now I

1180
00:56:08,389 --> 00:56:15,219
don't know if this video is playing or

1181
00:56:10,039 --> 00:56:17,989
not I think it is now and this is a

1182
00:56:15,219 --> 00:56:20,119
actual this is a model of what happens

1183
00:56:17,989 --> 00:56:22,969

to this planet's atmosphere as it comes

1184

00:56:20,119 --> 00:56:26,179

close to the star it starts to heat up

1185

00:56:22,969 --> 00:56:28,639

it gets smacked in the face and then

1186

00:56:26,179 --> 00:56:31,069

over time it settles back down again and

1187

00:56:28,639 --> 00:56:33,710

if you look towards the end there you

1188

00:56:31,070 --> 00:56:35,568

can see this bow shock coming around

1189

00:56:33,710 --> 00:56:37,728

here just shockwave

1190

00:56:35,568 --> 00:56:40,489

going around and around the planet as it

1191

00:56:37,728 --> 00:56:42,288

tries to calm down and get back to

1192

00:56:40,489 --> 00:56:44,150

normal the adrenaline rush is kind of

1193

00:56:42,289 --> 00:56:46,420

coming down we're sitting nice and

1194

00:56:44,150 --> 00:56:48,739

halfway back out here and then

1195

00:56:46,420 --> 00:56:51,019

rollercoaster ride and getting here

1196

00:56:48,739 --> 00:56:53,630

again this atmosphere goes through

1197

00:56:51,018 --> 00:56:56,348

extreme growing pains every time it

1198
00:56:53,630 --> 00:57:00,559
comes close to the star and it's on a

1199
00:56:56,349 --> 00:57:04,449
111 day orbit so it happens quite often

1200
00:57:00,559 --> 00:57:06,589
for it and it's a great kind of

1201
00:57:04,449 --> 00:57:08,930
test-tube for us understanding the

1202
00:57:06,588 --> 00:57:14,449
engineering of a planetary atmosphere

1203
00:57:08,929 --> 00:57:16,669
it's fluid dynamics in action crazy

1204
00:57:14,449 --> 00:57:18,680
planet now the next one is one of my

1205
00:57:16,670 --> 00:57:24,019
favorites and I think you'll find out

1206
00:57:18,679 --> 00:57:29,268
why what's 12 B not only is it easier to

1207
00:57:24,018 --> 00:57:31,848
remember bonus but what we saw when we

1208
00:57:29,268 --> 00:57:33,919
measured this atmosphere was this kind

1209
00:57:31,849 --> 00:57:36,019
of slope again like I showed you if that

1210
00:57:33,920 --> 00:57:38,028
HD one eight nine seven three free we

1211
00:57:36,018 --> 00:57:41,419
saw this scattering from the blue end

1212
00:57:38,028 --> 00:57:43,518
all the way down into the infrared now

1213
00:57:41,420 --> 00:57:47,869
the reason why this sunsets a little

1214
00:57:43,518 --> 00:57:49,458
duller than we see in 189 is because

1215
00:57:47,869 --> 00:57:52,430
it's scattering uniformly at all

1216
00:57:49,458 --> 00:57:55,608
wavelengths just scattering all that

1217
00:57:52,429 --> 00:57:58,009
light and it's a very film-noir kind of

1218
00:57:55,608 --> 00:57:59,679
sunset on this one it's all very kind of

1219
00:57:58,009 --> 00:58:03,858
mysterious

1220
00:57:59,679 --> 00:58:08,748
but this planets even hotter than HD 189

1221
00:58:03,858 --> 00:58:11,778
this planet is 2500 degrees on its day

1222
00:58:08,748 --> 00:58:13,248
side 2500 degrees that's hotter than

1223
00:58:11,778 --> 00:58:15,259
sitting under that Falcon nine as it was

1224
00:58:13,248 --> 00:58:16,639
taking off sitting right underneath that

1225
00:58:15,259 --> 00:58:20,958
that planet is sitting in that

1226

00:58:16,639 --> 00:58:22,818
temperature all the time now what this

1227
00:58:20,958 --> 00:58:24,048
scattering tells us is that there's

1228
00:58:22,818 --> 00:58:26,599
something in the atmosphere there's

1229
00:58:24,048 --> 00:58:28,579
liquid droplets in this atmosphere it's

1230
00:58:26,599 --> 00:58:31,400
not all gas at that temperature

1231
00:58:28,579 --> 00:58:33,589
everything we know of should be in the

1232
00:58:31,400 --> 00:58:36,880
gas phase there should not be any liquid

1233
00:58:33,588 --> 00:58:39,978
droplets of anything in this atmosphere

1234
00:58:36,880 --> 00:58:42,469
so what this is telling us is that the

1235
00:58:39,978 --> 00:58:47,028
temperature changed from that day side

1236
00:58:42,469 --> 00:58:49,780
about 2500 degrees to the night side

1237
00:58:47,028 --> 00:58:52,130
where we're looking at this planet is he

1238
00:58:49,780 --> 00:58:56,030
the night side where we're observing

1239
00:58:52,130 --> 00:58:58,250
this has to be around eighteen nineteen

1240
00:58:56,030 --> 00:59:01,700

hundred degrees there is a temperature

1241

00:58:58,250 --> 00:59:03,679

change of over five hundred degrees from

1242

00:59:01,699 --> 00:59:07,039

the day side to the night side of this

1243

00:59:03,679 --> 00:59:11,059

planet that causes huge amounts of winds

1244

00:59:07,039 --> 00:59:12,590

around the planet's atmosphere but that

1245

00:59:11,059 --> 00:59:14,000

also tells us a little bit about what

1246

00:59:12,590 --> 00:59:16,430

these clouds might be made of and

1247

00:59:14,000 --> 00:59:18,559

there's only really one option left in

1248

00:59:16,429 --> 00:59:20,869

this temperature range for what these

1249

00:59:18,559 --> 00:59:24,590

clouds can be formed off and it's a

1250

00:59:20,869 --> 00:59:29,179

little thing called corundum or more

1251

00:59:24,590 --> 00:59:32,090

commonly known sapphires and rubies the

1252

00:59:29,179 --> 00:59:36,819

clouds in this atmosphere are gems and

1253

00:59:32,090 --> 00:59:39,590

they are raining down in this atmosphere

1254

00:59:36,820 --> 00:59:41,600

absolutely beautiful and the reason why

1255
00:59:39,590 --> 00:59:43,820
it's all of these colors and the reason

1256
00:59:41,599 --> 00:59:46,029
why rubies and sapphires are different

1257
00:59:43,820 --> 00:59:47,690
colors is because this corundum this

1258
00:59:46,030 --> 00:59:50,180
al2o3

1259
00:59:47,690 --> 00:59:53,059
nice small combination of elements if

1260
00:59:50,179 --> 00:59:54,639
you stick a random metal from a

1261
00:59:53,059 --> 00:59:57,230
different element it changes the color

1262
00:59:54,639 --> 00:59:59,389
so if you stick a different element in

1263
00:59:57,230 --> 01:00:02,150
it could be green or yellow and we find

1264
00:59:59,389 --> 01:00:03,699
all of the spectrum of colors in this

1265
01:00:02,150 --> 01:00:06,470
Quraan dome here on the earth as

1266
01:00:03,699 --> 01:00:10,609
beautiful gems rubies and sapphires

1267
01:00:06,469 --> 01:00:13,899
being the easiest and nicest to make so

1268
01:00:10,610 --> 01:00:16,480
the atmosphere will be a rainbow of gems

1269
01:00:13,900 --> 01:00:21,860
that's why it's my favorite it's just

1270
01:00:16,480 --> 01:00:24,260
I'll take it I'll have all of them so

1271
01:00:21,860 --> 01:00:25,519
we've found some really strange worlds

1272
01:00:24,260 --> 01:00:27,050
and we've been able to look at them with

1273
01:00:25,519 --> 01:00:28,670
this technique and it's only going to

1274
01:00:27,050 --> 01:00:30,860
get better in the future and so the

1275
01:00:28,670 --> 01:00:32,869
telescope's get bigger our understanding

1276
01:00:30,860 --> 01:00:34,670
gets better and more planets are found

1277
01:00:32,869 --> 01:00:36,980
that we can do these observations of

1278
01:00:34,670 --> 01:00:38,990
it's really exciting for me because I

1279
01:00:36,980 --> 01:00:40,699
get to just play around with all of this

1280
01:00:38,989 --> 01:00:43,219
stuff and try and understand it and try

1281
01:00:40,699 --> 01:00:46,039
and communicate to everybody here just

1282
01:00:43,219 --> 01:00:48,259
how amazing nature's imagination truly

1283

01:00:46,039 --> 01:00:51,469
is so we want to go on an exploration

1284
01:00:48,260 --> 01:00:53,840
beyond our own solar system and we're

1285
01:00:51,469 --> 01:00:56,989
moving outwards we're moving past our

1286
01:00:53,840 --> 01:00:59,600
planets we're moving to another bit of

1287
01:00:56,989 --> 01:01:03,419
our galaxy we've only explored a tiny

1288
01:00:59,599 --> 01:01:05,940
portion of where we are this is just

1289
01:01:03,420 --> 01:01:09,750
gonna take you through every bit that

1290
01:01:05,940 --> 01:01:14,068
we've been exploring out from the Sun as

1291
01:01:09,750 --> 01:01:17,849
it becomes a small dot out to our

1292
01:01:14,068 --> 01:01:20,190
nearest stars and every single one of

1293
01:01:17,849 --> 01:01:21,869
the lines on here shows you a line to

1294
01:01:20,190 --> 01:01:27,389
the direction of an exoplanet that's

1295
01:01:21,869 --> 01:01:31,950
been discovered as we move out to our

1296
01:01:27,389 --> 01:01:34,679
galaxy every single day more exoplanets

1297
01:01:31,949 --> 01:01:36,808

are being discovered every single day

1298

01:01:34,679 --> 01:01:39,419

we're learning more and more about these

1299

01:01:36,809 --> 01:01:42,839

alien worlds and in turn learning more

1300

01:01:39,420 --> 01:01:45,119

about our own solar system it's not the

1301

01:01:42,838 --> 01:01:48,328

end there's going to be more it's never

1302

01:01:45,119 --> 01:01:50,160

the end this is just the current look

1303

01:01:48,329 --> 01:01:52,400

again so this is the size of the planet

1304

01:01:50,159 --> 01:01:55,078

versus the temperature of that planet

1305

01:01:52,400 --> 01:01:57,809

this is what we currently have thanks to

1306

01:01:55,079 --> 01:02:00,930

Kepler and everything else that was not

1307

01:01:57,809 --> 01:02:02,819

Kepler in the future so towards the end

1308

01:02:00,929 --> 01:02:04,679

of this year a satellite called Tess is

1309

01:02:02,818 --> 01:02:08,548

gonna be launched and Tesla's gonna find

1310

01:02:04,679 --> 01:02:10,828

planets all down in this range down in

1311

01:02:08,548 --> 01:02:13,829

these smaller worlds much more similar

1312
01:02:10,829 --> 01:02:15,660
to the earth down here so we're going to

1313
01:02:13,829 --> 01:02:16,890
be moving towards these smaller planets

1314
01:02:15,659 --> 01:02:18,690
and trying to understand what a smaller

1315
01:02:16,889 --> 01:02:20,608
planet may be not a Jupiter actually

1316
01:02:18,690 --> 01:02:22,829
looks like what its atmosphere is like

1317
01:02:20,608 --> 01:02:24,779
and we're gonna be finding colder

1318
01:02:22,829 --> 01:02:25,798
planets colder planets are important

1319
01:02:24,780 --> 01:02:27,510
their atmosphere is going to be very

1320
01:02:25,798 --> 01:02:28,858
different from the ones that I've shown

1321
01:02:27,510 --> 01:02:30,890
you today they're going to have

1322
01:02:28,858 --> 01:02:33,469
atmospheres that are filled with

1323
01:02:30,889 --> 01:02:36,509
hydrocarbons like Titan's atmosphere

1324
01:02:33,469 --> 01:02:38,338
filled with suits that are a bit of a

1325
01:02:36,510 --> 01:02:40,730
pain that are really interesting to

1326
01:02:38,338 --> 01:02:43,650
study in the labs they're going to be

1327
01:02:40,730 --> 01:02:46,170
something we don't have in our solar

1328
01:02:43,650 --> 01:02:48,660
system and that makes it really exciting

1329
01:02:46,170 --> 01:02:51,389
because we don't have a test-tube here

1330
01:02:48,659 --> 01:02:53,250
or we can throw something at it we have

1331
01:02:51,389 --> 01:02:57,568
to learn remotely we have to collect

1332
01:02:53,250 --> 01:02:59,130
every photon we can so I'm really

1333
01:02:57,568 --> 01:03:01,529
looking forward to the future of

1334
01:02:59,130 --> 01:03:03,480
exoplanets and I hope you all keep an

1335
01:03:01,530 --> 01:03:04,769
eye out for some of the most exciting

1336
01:03:03,480 --> 01:03:06,030
discoveries that are coming because

1337
01:03:04,769 --> 01:03:07,949
we're going to be learning so much more

1338
01:03:06,030 --> 01:03:11,940
and there's going to be a lot more

1339
01:03:07,949 --> 01:03:15,779
surprises along the way if you enjoyed

1340

01:03:11,940 --> 01:03:16,740
hearing me talk I talked for about an

1341
01:03:15,780 --> 01:03:17,310
hour

1342
01:03:16,739 --> 01:03:20,159
once everyone

1343
01:03:17,309 --> 01:03:23,130
with some of my friends as was mentioned

1344
01:03:20,159 --> 01:03:25,649
before I do a podcast called XA cast I

1345
01:03:23,130 --> 01:03:27,900
have a colleague called Hugh as one who

1346
01:03:25,650 --> 01:03:29,130
does detections I do the classification

1347
01:03:27,900 --> 01:03:30,660
so I'm actually looking at what these

1348
01:03:29,130 --> 01:03:32,910
atmospheres might be like he's finding

1349
01:03:30,659 --> 01:03:36,420
the planets and then my other colleague

1350
01:03:32,909 --> 01:03:39,029
Andrew rush B who does astrobiology what

1351
01:03:36,420 --> 01:03:41,430
is life out there in the universe

1352
01:03:39,030 --> 01:03:42,900
how can we find it so the combination of

1353
01:03:41,429 --> 01:03:45,599
us arguing if you think that'll be

1354
01:03:42,900 --> 01:03:47,970

entertaining is good I do warn you we're

1355

01:03:45,599 --> 01:03:50,670

all British so the accents might be a

1356

01:03:47,969 --> 01:03:51,869

bit of a pain but we also will be

1357

01:03:50,670 --> 01:03:55,800

getting transcripts of all those

1358

01:03:51,869 --> 01:03:57,989

episodes but I just want to leave you

1359

01:03:55,800 --> 01:03:59,370

with that predicted number of planets

1360

01:03:57,989 --> 01:04:01,919

that we're going to be discovering and

1361

01:03:59,369 --> 01:04:02,599

just the thought that anything is

1362

01:04:01,920 --> 01:04:04,180

possible

1363

01:04:02,599 --> 01:04:18,598

thank you

1364

01:04:04,179 --> 01:04:18,598

[Applause]

1365

01:04:19,349 --> 01:04:31,358

okay we have some questions for our

1366

01:04:22,150 --> 01:04:33,070

speaker down front here all right so

1367

01:04:31,358 --> 01:04:35,679

they're cut I have to repeat the

1368

01:04:33,070 --> 01:04:37,470

question for the online audience does as

1369
01:04:35,679 --> 01:04:39,819
Neptune tightly locked or doesn't rotate

1370
01:04:37,469 --> 01:05:00,250
so all of the planets in our solar

1371
01:04:39,820 --> 01:05:01,720
system rotates so variations I want to

1372
01:05:00,250 --> 01:05:05,309
actually add to that a question from the

1373
01:05:01,719 --> 01:05:09,549
online audience so what causes those

1374
01:05:05,309 --> 01:05:10,150
1309 on Neptune and from the online

1375
01:05:09,550 --> 01:05:12,490
audience

1376
01:05:10,150 --> 01:05:14,170
how are those what winds measured on

1377
01:05:12,489 --> 01:05:18,099
Neptune what is your reference point

1378
01:05:14,170 --> 01:05:19,869
since there's no hard surface so the

1379
01:05:18,099 --> 01:05:22,358
answer is going to be unsatisfying I'm

1380
01:05:19,869 --> 01:05:23,079
not entirely certain I imagine it's

1381
01:05:22,358 --> 01:05:25,269
something to do with temperature

1382
01:05:23,079 --> 01:05:27,039
differences Neptune has internal heating

1383
01:05:25,269 --> 01:05:30,190
that's going to be causing some

1384
01:05:27,039 --> 01:05:33,400
differences that causes differences in

1385
01:05:30,190 --> 01:05:35,650
the vertical uplift of material so if

1386
01:05:33,400 --> 01:05:37,539
your uplifting material its cooling its

1387
01:05:35,650 --> 01:05:40,090
condensing and then that's going to be

1388
01:05:37,539 --> 01:05:42,279
driving the fluid dynamics of the

1389
01:05:40,090 --> 01:05:44,320
atmosphere in terms of a reference point

1390
01:05:42,280 --> 01:05:46,119
those clouds are very very helpful if

1391
01:05:44,320 --> 01:05:48,190
Voyager is not the only image we have of

1392
01:05:46,119 --> 01:05:50,410
Neptune the Hubble Space Telescope has

1393
01:05:48,190 --> 01:05:52,119
taken some amazing images of Neptune and

1394
01:05:50,409 --> 01:05:53,679
some of the ground-based telescopes also

1395
01:05:52,119 --> 01:05:55,119
in lots of different wavelengths have

1396
01:05:53,679 --> 01:05:57,429
been looking at Neptune's atmosphere

1397

01:05:55,119 --> 01:05:59,470
trying to understand it one of the

1398
01:05:57,429 --> 01:06:01,299
really impressive things on Neptune is

1399
01:05:59,469 --> 01:06:03,368
this dark spot I showed you the one on

1400
01:06:01,300 --> 01:06:05,700
Jupiter which is bright red spot on

1401
01:06:03,369 --> 01:06:08,350
Neptune there's this big dark cloud

1402
01:06:05,699 --> 01:06:11,169
region which is kind of confined to a

1403
01:06:08,349 --> 01:06:13,179
spot and looking at that rotation we

1404
01:06:11,170 --> 01:06:14,409
know the rotation of Neptune and we can

1405
01:06:13,179 --> 01:06:16,149
see the rotation of these cloud

1406
01:06:14,409 --> 01:06:18,429
structures and it's different so we can

1407
01:06:16,150 --> 01:06:21,070
get this different choice is what it is

1408
01:06:18,429 --> 01:06:23,679
between the rotation period of Neptune

1409
01:06:21,070 --> 01:06:25,130
and the the material that we're seeing

1410
01:06:23,679 --> 01:06:30,980
able to detect in

1411
01:06:25,130 --> 01:06:33,650

atmosphere okay over there these we're

1412

01:06:30,980 --> 01:06:36,650

not think of storms earthwise to think

1413

01:06:33,650 --> 01:06:41,480

of a precipitation does these actually

1414

01:06:36,650 --> 01:06:44,088

these storms in the precipitate so on

1415

01:06:41,480 --> 01:06:45,769

these crazy weather that you're having

1416

01:06:44,088 --> 01:06:48,858

is it actual real precipitation falling

1417

01:06:45,768 --> 01:06:51,409

down through the atmosphere so that's a

1418

01:06:48,858 --> 01:06:53,719

really good question from the models

1419

01:06:51,409 --> 01:06:55,639

that we have these 3d GCMs they're all

1420

01:06:53,719 --> 01:06:57,558

based on earth GCMs which have them be

1421

01:06:55,639 --> 01:06:58,969

expanded and applied to these giant

1422

01:06:57,559 --> 01:07:01,430

planets and to the planets in our solar

1423

01:06:58,969 --> 01:07:04,308

system and what they're showing us is

1424

01:07:01,429 --> 01:07:06,259

that you get these big this heat from

1425

01:07:04,309 --> 01:07:08,750

the dayside causes these very huge

1426
01:07:06,259 --> 01:07:10,670
upwellings and then on the night side of

1427
01:07:08,750 --> 01:07:12,768
the planet at this kind of Terminator

1428
01:07:10,670 --> 01:07:14,809
region you get these updrafts and

1429
01:07:12,768 --> 01:07:15,768
downdrafts these upwellings and down

1430
01:07:14,809 --> 01:07:18,170
Wellings where you're getting this

1431
01:07:15,768 --> 01:07:20,508
precipitation and it's not only those

1432
01:07:18,170 --> 01:07:22,519
vertical motions that are doing it but

1433
01:07:20,509 --> 01:07:25,278
this temperature contrast from the the

1434
01:07:22,518 --> 01:07:27,229
boiling dayside around the night side

1435
01:07:25,278 --> 01:07:29,539
means that you could have something that

1436
01:07:27,230 --> 01:07:31,548
is heated to a high temperature becomes

1437
01:07:29,539 --> 01:07:33,829
a vapor on the day side and then as it

1438
01:07:31,548 --> 01:07:37,088
cools down as it goes around the planet

1439
01:07:33,829 --> 01:07:40,068
it cools it condenses it rains out

1440
01:07:37,088 --> 01:07:41,989
sometimes it might even become a ice of

1441
01:07:40,068 --> 01:07:44,239
some kind it could be snowing or rubies

1442
01:07:41,989 --> 01:07:46,459
on one of these planets and then as it

1443
01:07:44,239 --> 01:07:49,219
goes round as these winds carry it round

1444
01:07:46,460 --> 01:07:51,619
as these dynamics push it around into

1445
01:07:49,219 --> 01:07:53,239
the dayside heat again it heats up and

1446
01:07:51,619 --> 01:07:55,759
it's being pushed up in the atmosphere

1447
01:07:53,239 --> 01:07:57,528
as a gas and then you get this cycle

1448
01:07:55,759 --> 01:07:59,210
again so you see these big upwellings

1449
01:07:57,528 --> 01:08:01,068
and down Wellings in the planetary

1450
01:07:59,210 --> 01:08:06,159
atmosphere where this material is just

1451
01:08:01,068 --> 01:08:08,659
constantly being transported around okay

1452
01:08:06,159 --> 01:08:10,699
other questions I thought there was one

1453
01:08:08,659 --> 01:08:12,348
over here there's one why is the moon

1454

01:08:10,699 --> 01:08:14,659
gravitationally locked with the earth

1455
01:08:12,349 --> 01:08:16,429
why is the moon gravitationally locked

1456
01:08:14,659 --> 01:08:20,358
to the earth so the gravitational

1457
01:08:16,429 --> 01:08:22,609
locking comes from just conservation of

1458
01:08:20,359 --> 01:08:24,798
the angular momentum and when we're

1459
01:08:22,609 --> 01:08:26,060
looking at these hot Jupiters what would

1460
01:08:24,798 --> 01:08:28,908
have happened they couldn't have formed

1461
01:08:26,060 --> 01:08:31,159
there so as after they formed and

1462
01:08:28,908 --> 01:08:34,759
they're spinning around the disk of the

1463
01:08:31,158 --> 01:08:36,888
star as they move inwards as you spiral

1464
01:08:34,759 --> 01:08:37,770
inwards you've got to lose some of that

1465
01:08:36,889 --> 01:08:39,750
energy

1466
01:08:37,770 --> 01:08:41,970
how and as you lose that energy you

1467
01:08:39,750 --> 01:08:44,189
reach this very stable state where your

1468
01:08:41,970 --> 01:08:44,670

orbital period matches your rotation

1469

01:08:44,189 --> 01:08:46,649
period

1470

01:08:44,670 --> 01:08:49,710
it's an incredibly stable position to be

1471

01:08:46,649 --> 01:08:50,729
in so the the earth the earth immune

1472

01:08:49,710 --> 01:08:53,039
systems a little different cuz the

1473

01:08:50,729 --> 01:08:56,309
Earth's the the moon started as the

1474

01:08:53,039 --> 01:08:58,470
earth got bombarded broken off formed in

1475

01:08:56,310 --> 01:09:00,480
this spiral ring structure and the most

1476

01:08:58,470 --> 01:09:02,640
energy efficient way is to be tidally

1477

01:09:00,479 --> 01:09:04,829
locked of the moon's moving further and

1478

01:09:02,640 --> 01:09:06,480
further away from us every single year

1479

01:09:04,829 --> 01:09:08,399
so there might be a point in the moon's

1480

01:09:06,479 --> 01:09:10,829
future where it is no longer tidally

1481

01:09:08,399 --> 01:09:15,509
locked to the earth I won't be around

1482

01:09:10,829 --> 01:09:19,130
them all right over here

1483
01:09:15,510 --> 01:09:22,020
question you know these Jupiter and

1484
01:09:19,130 --> 01:09:25,319
larger size plane that's very close to a

1485
01:09:22,020 --> 01:09:27,750
star if they're a core it's holding them

1486
01:09:25,319 --> 01:09:31,410
together or they just the aggregations

1487
01:09:27,750 --> 01:09:33,689
of gas that have accumulated provides

1488
01:09:31,409 --> 01:09:37,559
the stability because it seems like the

1489
01:09:33,689 --> 01:09:39,568
energy being that close to the star I'm

1490
01:09:37,560 --> 01:09:41,940
gonna summarize that in terms of you got

1491
01:09:39,569 --> 01:09:44,100
these hot Jupiters these gas giant

1492
01:09:41,939 --> 01:09:45,778
planets in so close to the star why

1493
01:09:44,100 --> 01:09:48,450
don't they evaporate away what's keeping

1494
01:09:45,779 --> 01:09:51,299
together that's a good question it's

1495
01:09:48,449 --> 01:09:52,920
mainly the mass there are actually some

1496
01:09:51,298 --> 01:09:54,840
planets that have been discovered where

1497
01:09:52,920 --> 01:09:57,119
we think they used to be these giant

1498
01:09:54,840 --> 01:09:59,250
gassy worlds but all of their atmosphere

1499
01:09:57,119 --> 01:10:02,510
has got blown away we see evidence of

1500
01:09:59,250 --> 01:10:04,500
these very condensed rocky cores of

1501
01:10:02,510 --> 01:10:06,750
planets where they don't have an

1502
01:10:04,500 --> 01:10:08,550
atmosphere and they really should so we

1503
01:10:06,750 --> 01:10:10,979
see evidence that some of them have lost

1504
01:10:08,550 --> 01:10:12,720
their atmosphere entirely but as I said

1505
01:10:10,979 --> 01:10:15,029
before these planets did not form there

1506
01:10:12,720 --> 01:10:17,400
you cannot form a giant planet that

1507
01:10:15,029 --> 01:10:20,939
close to a star it had to have moved in

1508
01:10:17,399 --> 01:10:22,589
from earlier in the Sitz system earlier

1509
01:10:20,939 --> 01:10:24,750
in the disk it had to have moved in from

1510
01:10:22,590 --> 01:10:26,310
further out now there's a number of

1511

01:10:24,750 --> 01:10:27,869
theories of planet formation but first

1512
01:10:26,310 --> 01:10:29,820
you need to stick together a load of

1513
01:10:27,869 --> 01:10:31,529
particles and as you stick together

1514
01:10:29,819 --> 01:10:33,449
those particles you accumulate gas

1515
01:10:31,529 --> 01:10:35,819
around you from the disk and it's this

1516
01:10:33,449 --> 01:10:37,979
runaway accumulation of that gas which

1517
01:10:35,819 --> 01:10:41,460
causes you to create a planet like

1518
01:10:37,979 --> 01:10:45,119
Jupiter now if that have been moved in

1519
01:10:41,460 --> 01:10:47,520
towards its star in these positions

1520
01:10:45,119 --> 01:10:49,949
where they are we've seen evidence that

1521
01:10:47,520 --> 01:10:50,790
the the atmosphere gets blown off but we

1522
01:10:49,949 --> 01:10:53,099
can measure how

1523
01:10:50,789 --> 01:10:55,260
and it's very very little it's the

1524
01:10:53,100 --> 01:10:57,300
equivalent ratio of a CME coming off of

1525
01:10:55,260 --> 01:11:00,720

our Sun it's losing a very small amount

1526

01:10:57,300 --> 01:11:02,010

of its mass in any one time so it's not

1527

01:11:00,720 --> 01:11:03,960

something that's going to completely

1528

01:11:02,010 --> 01:11:06,510

wipe out a chi one eight nine seven four

1529

01:11:03,960 --> 01:11:08,730

three B's atmosphere based on the

1530

01:11:06,510 --> 01:11:11,159

measurements that we have so it's really

1531

01:11:08,729 --> 01:11:13,079

the mass that's holding this atmosphere

1532

01:11:11,159 --> 01:11:14,639

on it's clinging to it and every planet

1533

01:11:13,079 --> 01:11:16,649

even our own planet has something called

1534

01:11:14,640 --> 01:11:18,210

a Roche lobe which is a gravitational

1535

01:11:16,649 --> 01:11:19,229

distance away from that planet

1536

01:11:18,210 --> 01:11:21,539

where something is no longer

1537

01:11:19,229 --> 01:11:24,149

gravitationally bound if the gas was

1538

01:11:21,539 --> 01:11:26,069

energy energized enough so that it got

1539

01:11:24,149 --> 01:11:27,659

outside of this Roche lobe it would

1540
01:11:26,069 --> 01:11:29,789
escape forever it wouldn't ever come

1541
01:11:27,659 --> 01:11:32,099
back if it was energised such as it kind

1542
01:11:29,789 --> 01:11:34,289
of escaped and then it fell back inside

1543
01:11:32,100 --> 01:11:36,810
this Roche lobe then you wouldn't ever

1544
01:11:34,289 --> 01:11:38,519
lose that bit of the atmosphere so

1545
01:11:36,810 --> 01:11:41,850
there's there's a number of things there

1546
01:11:38,520 --> 01:11:43,470
that are kind of keeping it in all right

1547
01:11:41,850 --> 01:11:52,230
all the way in the far side of the room

1548
01:11:43,470 --> 01:11:54,240
there have we found exoplanets in binary

1549
01:11:52,229 --> 01:11:56,179
star star systems and how does the

1550
01:11:54,239 --> 01:11:59,309
presence of the binary affect the planet

1551
01:11:56,180 --> 01:12:01,950
found planets and binary stars and

1552
01:11:59,310 --> 01:12:05,760
triple stars and in quadruple star

1553
01:12:01,949 --> 01:12:10,380
systems so binary stars are the most

1554
01:12:05,760 --> 01:12:11,489
common in our galaxy and there's quite a

1555
01:12:10,380 --> 01:12:14,460
few planets that have been discovered

1556
01:12:11,489 --> 01:12:15,630
around binary systems what's 12 be the

1557
01:12:14,460 --> 01:12:18,239
one that I showed you at the end is in a

1558
01:12:15,630 --> 01:12:20,609
triple star system whilst twelve only

1559
01:12:18,239 --> 01:12:23,099
orbits one of those stars but also

1560
01:12:20,609 --> 01:12:25,199
orbiting that one star is two tiny

1561
01:12:23,100 --> 01:12:27,450
little stars M stars that orbit each

1562
01:12:25,199 --> 01:12:29,429
other and orbit that star so it's in a

1563
01:12:27,449 --> 01:12:31,649
triple star system it's pretty brilliant

1564
01:12:29,430 --> 01:12:32,940
well that's also a pain when you're

1565
01:12:31,649 --> 01:12:35,519
trying to do data analysis because

1566
01:12:32,939 --> 01:12:38,369
there's two other stars right there but

1567
01:12:35,520 --> 01:12:43,200
yes we found planets and multi-planet

1568

01:12:38,369 --> 01:12:47,130
systems around stars and that really

1569
01:12:43,199 --> 01:12:49,619
tells us about our own solar system and

1570
01:12:47,130 --> 01:12:51,930
how possible that is and some of these

1571
01:12:49,619 --> 01:12:53,519
have interactions and some of them don't

1572
01:12:51,930 --> 01:12:55,140
and that's really important for us to

1573
01:12:53,520 --> 01:13:00,590
try and understand it's an area that

1574
01:12:55,140 --> 01:13:04,730
we're really pushing into okay down here

1575
01:13:00,590 --> 01:13:07,170
day and night years on some of these

1576
01:13:04,729 --> 01:13:08,849
all right so what is the range of day

1577
01:13:07,170 --> 01:13:11,760
and night temperatures on these really

1578
01:13:08,850 --> 01:13:15,870
hot planets so that really depends on

1579
01:13:11,760 --> 01:13:18,180
your Bayside temperature the orbital

1580
01:13:15,869 --> 01:13:20,039
period of your planet because the

1581
01:13:18,180 --> 01:13:22,079
orbital period of your planet defines

1582
01:13:20,039 --> 01:13:24,000

your rotation period of your planet and

1583

01:13:22,079 --> 01:13:26,039

the rotation period of your planet

1584

01:13:24,000 --> 01:13:28,470

defines how dynamic the atmosphere is

1585

01:13:26,039 --> 01:13:32,189

going to be because that's a good driver

1586

01:13:28,470 --> 01:13:35,190

of an atmosphere so on some of the

1587

01:13:32,189 --> 01:13:37,769

hottest ones we we expect that day/night

1588

01:13:35,189 --> 01:13:41,579

contrast in temperatures to be in the

1589

01:13:37,770 --> 01:13:43,560

range of 500 plus degrees but on some of

1590

01:13:41,579 --> 01:13:45,960

the cooler ones and I say cooler because

1591

01:13:43,560 --> 01:13:48,270

my temperature scale is completely wacky

1592

01:13:45,960 --> 01:13:51,359

HD one eight nine is a nice cool planet

1593

01:13:48,270 --> 01:13:53,340

at 1200 degrees and on that nice cool

1594

01:13:51,359 --> 01:13:54,599

planet the temperature difference

1595

01:13:53,340 --> 01:13:58,079

between the day and the night is only

1596

01:13:54,600 --> 01:14:00,600

about 50 to 200 degrees

1597
01:13:58,079 --> 01:14:02,640
so it ranges based on the orbital period

1598
01:14:00,600 --> 01:14:05,310
of that planet and the heat from the

1599
01:14:02,640 --> 01:14:07,230
star so a bigger star a hotter star will

1600
01:14:05,310 --> 01:14:09,330
also be putting out way more heat and

1601
01:14:07,229 --> 01:14:16,819
therefore you get a bigger contrast

1602
01:14:09,329 --> 01:14:22,829
there and others temperature yes okay so

1603
01:14:16,819 --> 01:14:24,779
centigrade degrees yes astronomers

1604
01:14:22,829 --> 01:14:27,149
that's always my question too because I

1605
01:14:24,779 --> 01:14:36,710
know astronomers always working Kelvin

1606
01:14:27,149 --> 01:14:43,889
and such question their time scale

1607
01:14:36,710 --> 01:14:47,010
variations roughly the same for billions

1608
01:14:43,890 --> 01:14:49,320
of years and how can you tell anything

1609
01:14:47,010 --> 01:14:52,619
about many of the planets

1610
01:14:49,319 --> 01:14:56,099
how long will there at mister your last

1611
01:14:52,619 --> 01:14:58,800
well the temperature stays the same so

1612
01:14:56,100 --> 01:15:01,800
really he's asking how research

1613
01:14:58,800 --> 01:15:03,570
questions yeah can we tell how long the

1614
01:15:01,800 --> 01:15:05,520
atmospheres will last on these planets

1615
01:15:03,569 --> 01:15:07,559
and other characteristics like that so

1616
01:15:05,520 --> 01:15:08,880
these planets are fairly old they've

1617
01:15:07,560 --> 01:15:10,950
been like this for a really long time

1618
01:15:08,880 --> 01:15:13,619
and as I said they're not losing a huge

1619
01:15:10,949 --> 01:15:15,869
amount of mass from their atmosphere the

1620
01:15:13,619 --> 01:15:17,309
planets that we've observed where they

1621
01:15:15,869 --> 01:15:17,640
appear like they've lost all of their

1622
01:15:17,310 --> 01:15:19,140
atoms

1623
01:15:17,640 --> 01:15:21,329
there that clearly happened very early

1624
01:15:19,140 --> 01:15:23,100
on and very quickly so it's not expected

1625

01:15:21,329 --> 01:15:25,019
that these giant planets will lose a

1626
01:15:23,100 --> 01:15:27,210
humongous amount of their atmosphere at

1627
01:15:25,020 --> 01:15:29,670
all in the lifetime of us looking at

1628
01:15:27,210 --> 01:15:32,750
them the way that we are in terms of

1629
01:15:29,670 --> 01:15:35,579
intrinsic variations weather patterns

1630
01:15:32,750 --> 01:15:36,689
that's a lot harder to do one of the

1631
01:15:35,579 --> 01:15:38,579
reasons we look at those really

1632
01:15:36,689 --> 01:15:42,359
eccentric planets that I showed you

1633
01:15:38,579 --> 01:15:44,399
before that comet planet HD 80606 b is

1634
01:15:42,359 --> 01:15:47,099
because we can look at this variation

1635
01:15:44,399 --> 01:15:49,079
over time of what an atmosphere does at

1636
01:15:47,100 --> 01:15:51,329
different distances from a star just

1637
01:15:49,079 --> 01:15:54,000
from having one system these are fairly

1638
01:15:51,329 --> 01:15:55,890
consistent from what we have the other

1639
01:15:54,000 --> 01:15:57,659

problem with that is your measurement

1640

01:15:55,890 --> 01:16:00,450
has to be so precise

1641

01:15:57,659 --> 01:16:02,639
every time you measure it so if I

1642

01:16:00,449 --> 01:16:04,229
measured it this year and I got a really

1643

01:16:02,640 --> 01:16:05,880
nice measurement and they measured it

1644

01:16:04,229 --> 01:16:07,289
next year and it was different and then

1645

01:16:05,880 --> 01:16:09,449
I measured it the year after and it was

1646

01:16:07,289 --> 01:16:11,369
different again I need to know that it's

1647

01:16:09,449 --> 01:16:12,689
not the way that I'm doing my data

1648

01:16:11,369 --> 01:16:14,099
analysis I need to know that it's not

1649

01:16:12,689 --> 01:16:16,589
something in the telescope I need to

1650

01:16:14,100 --> 01:16:17,970
know that it is actually something in

1651

01:16:16,590 --> 01:16:19,860
that planet's atmosphere that's causing

1652

01:16:17,970 --> 01:16:21,480
that rather than something that we as

1653

01:16:19,859 --> 01:16:24,149
scientists have done to look at that

1654
01:16:21,479 --> 01:16:27,119
data so it's really hard to say whether

1655
01:16:24,149 --> 01:16:29,219
we've got any kind of small weather

1656
01:16:27,119 --> 01:16:31,079
patterns one of the really good examples

1657
01:16:29,220 --> 01:16:33,539
of of looking for these kinds of weather

1658
01:16:31,079 --> 01:16:36,500
patterns is brown dwarfs now brown

1659
01:16:33,539 --> 01:16:41,189
dwarfs are much Trevor off this diagram

1660
01:16:36,500 --> 01:16:43,470
they are roughly the size of Jupiter but

1661
01:16:41,189 --> 01:16:46,409
they're much much more massive they're

1662
01:16:43,470 --> 01:16:50,610
over 15 times the mass of Jupiter and

1663
01:16:46,409 --> 01:16:52,079
that is Ola these brown dwarfs aren't

1664
01:16:50,609 --> 01:16:53,699
quite stars but they're not quite

1665
01:16:52,079 --> 01:16:57,210
planets they're actually burning at

1666
01:16:53,699 --> 01:16:59,130
their core deuterium and in these brown

1667
01:16:57,210 --> 01:17:01,109
dwarfs there's this transition between

1668
01:16:59,130 --> 01:17:03,090
different masses and ages of brown

1669
01:17:01,109 --> 01:17:06,359
dwarfs where we see these patchy clouds

1670
01:17:03,090 --> 01:17:09,150
in the atmosphere and the rotation of

1671
01:17:06,359 --> 01:17:11,939
those clouds so you can see and measure

1672
01:17:09,149 --> 01:17:13,649
this weather pattern in a brown dwarfs

1673
01:17:11,939 --> 01:17:15,089
atmosphere because you're doing the

1674
01:17:13,649 --> 01:17:16,500
opposite of what I was explaining the

1675
01:17:15,090 --> 01:17:18,690
beginning you're doing the emission

1676
01:17:16,500 --> 01:17:20,609
spectrum directly from the the brown

1677
01:17:18,689 --> 01:17:22,799
dwarf rather than the absorption

1678
01:17:20,609 --> 01:17:24,210
spectrum through the atmosphere so it's

1679
01:17:22,800 --> 01:17:25,529
the different techniques which allow you

1680
01:17:24,210 --> 01:17:27,680
to kind of look at these different

1681
01:17:25,529 --> 01:17:27,679
systems

1682

01:17:28,250 --> 01:17:35,189
okay we had one question online that

1683
01:17:31,529 --> 01:17:37,050
wanted to know what is the force

1684
01:17:35,189 --> 01:17:39,689
responsible for producing that beautiful

1685
01:17:37,050 --> 01:17:41,610
hexagon pattern on Saturn they were

1686
01:17:39,689 --> 01:17:44,219
speculating that it was the moons and I

1687
01:17:41,609 --> 01:17:45,988
was like no no it's not the moons is do

1688
01:17:44,219 --> 01:17:48,980
we know the hydrodynamic forces that

1689
01:17:45,988 --> 01:17:52,319
produce that beautiful hexagon pattern

1690
01:17:48,979 --> 01:17:54,799
we see that hexagon pattern appear in

1691
01:17:52,319 --> 01:17:58,049
multiple places on the earth that

1692
01:17:54,800 --> 01:18:00,210
hexagon pattern appears for a number of

1693
01:17:58,050 --> 01:18:03,270
different reasons it's a very stable

1694
01:18:00,210 --> 01:18:05,399
pattern it's a very strong pattern the

1695
01:18:03,270 --> 01:18:07,590
way in which fluid dynamics works we

1696
01:18:05,399 --> 01:18:09,420

really we really don't know specifically

1697

01:18:07,590 --> 01:18:11,639

for certain what those driving forces

1698

01:18:09,420 --> 01:18:14,250

are but we see that pattern here on the

1699

01:18:11,639 --> 01:18:16,079

earth mathematically it comes out of a

1700

01:18:14,250 --> 01:18:17,969

lot of solutions I don't know if anyone

1701

01:18:16,079 --> 01:18:21,118

knows the The Devil's causeway in

1702

01:18:17,969 --> 01:18:22,948

Ireland it's the columns of basalt for

1703

01:18:21,118 --> 01:18:25,319

the volcanic material form these

1704

01:18:22,948 --> 01:18:27,899

hexagons and they form hexagons because

1705

01:18:25,319 --> 01:18:30,238

when you're cooling a material down that

1706

01:18:27,899 --> 01:18:32,849

is the most stable II struck at the

1707

01:18:30,238 --> 01:18:34,559

structurally stable shape that something

1708

01:18:32,850 --> 01:18:36,090

comes into it because of the structure

1709

01:18:34,560 --> 01:18:37,440

of the materials it's made out of so

1710

01:18:36,090 --> 01:18:39,329

there's a huge number of things that

1711
01:18:37,439 --> 01:18:41,250
make this hexagon pattern we're still

1712
01:18:39,329 --> 01:18:43,050
trying to work out exactly what's going

1713
01:18:41,250 --> 01:18:45,359
on because that is that is on a scale

1714
01:18:43,050 --> 01:18:48,029
that we can't produce here on earth

1715
01:18:45,359 --> 01:18:50,279
right yeah and I'd seen a laboratory

1716
01:18:48,029 --> 01:18:52,920
experiment that produced hexagonal

1717
01:18:50,279 --> 01:18:55,618
pattern from residences but it wasn't

1718
01:18:52,920 --> 01:18:56,908
really a proper analog for it so yeah so

1719
01:18:55,618 --> 01:18:58,170
you have to when you're doing these

1720
01:18:56,908 --> 01:18:59,519
analog you need to get the pressures

1721
01:18:58,170 --> 01:19:00,600
right you need to get the temperatures

1722
01:18:59,520 --> 01:19:03,090
right you need to get the materials

1723
01:19:00,600 --> 01:19:08,250
right the problem with Saturn is it is

1724
01:19:03,090 --> 01:19:12,239
hydrogen helium atmosphere at high and

1725
01:19:08,250 --> 01:19:14,189
low pressures and you are not allowed or

1726
01:19:12,238 --> 01:19:18,299
you will not be funded to have a lab

1727
01:19:14,189 --> 01:19:19,799
that will almost certainly explode so

1728
01:19:18,300 --> 01:19:21,060
it's a little bit hard for us to

1729
01:19:19,800 --> 01:19:22,590
simulate so that's why we do it in

1730
01:19:21,060 --> 01:19:24,600
computers and that's the way we kind of

1731
01:19:22,590 --> 01:19:25,409
really explore these worlds all right so

1732
01:19:24,600 --> 01:19:27,810
I think there was one more question

1733
01:19:25,408 --> 01:19:29,908
right there okay last question for the

1734
01:19:27,810 --> 01:19:32,219
evening in systems where there's

1735
01:19:29,908 --> 01:19:34,859
multiple stars is there any are there

1736
01:19:32,219 --> 01:19:36,750
any planets that would orbit one star

1737
01:19:34,859 --> 01:19:39,089
for a while and then switch over to the

1738
01:19:36,750 --> 01:19:40,890
orbit of another star so the question is

1739

01:19:39,090 --> 01:19:43,529
in multiple star systems

1740
01:19:40,890 --> 01:19:50,039
planets switch from orbiting one star to

1741
01:19:43,529 --> 01:19:52,949
the other star there are three types of

1742
01:19:50,039 --> 01:19:56,670
binary systems that I can explain to you

1743
01:19:52,949 --> 01:19:58,289
there is imagine your two stars here you

1744
01:19:56,670 --> 01:19:59,940
can have a binary system where you've

1745
01:19:58,289 --> 01:20:02,579
got a planet orbiting just one of those

1746
01:19:59,939 --> 01:20:05,639
stars you can have a planet orbiting

1747
01:20:02,579 --> 01:20:08,279
both of those stars and you can have

1748
01:20:05,640 --> 01:20:10,260
technically we haven't found one yet

1749
01:20:08,279 --> 01:20:13,469
technically a stable orbit where it does

1750
01:20:10,260 --> 01:20:15,329
this so you get the smiley face you can

1751
01:20:13,470 --> 01:20:17,220
have it here you can have it here you

1752
01:20:15,329 --> 01:20:20,090
can have it here or you can have it here

1753
01:20:17,220 --> 01:20:23,270

the smiley face of binary systems I

1754

01:20:20,090 --> 01:20:26,039

don't know about this one

1755

01:20:23,270 --> 01:20:28,290

you'd have to play that what's that game

1756

01:20:26,039 --> 01:20:30,479

called that simulator for gravity

1757

01:20:28,289 --> 01:20:32,970

simulator that would be fun but it just

1758

01:20:30,479 --> 01:20:36,419

it really strikes me that the dynamics

1759

01:20:32,970 --> 01:20:41,010

really you go chaotic and it wouldn't be

1760

01:20:36,420 --> 01:20:43,380

safe early in like the history of these

1761

01:20:41,010 --> 01:20:45,570

binary systems and different planetary

1762

01:20:43,380 --> 01:20:46,920

systems we know that stars kind of come

1763

01:20:45,569 --> 01:20:49,109

by we know we have evidence of that

1764

01:20:46,920 --> 01:20:51,779

stars of the past our solar system

1765

01:20:49,109 --> 01:20:53,939

pretty close the stars are pretty evil

1766

01:20:51,779 --> 01:20:56,519

they will grab your planetary children

1767

01:20:53,939 --> 01:20:58,379

and take them with them so we have

1768
01:20:56,520 --> 01:21:00,450
evidence that some of these planets that

1769
01:20:58,380 --> 01:21:01,260
we're looking at have been grabbed from

1770
01:21:00,449 --> 01:21:02,760
somewhere else

1771
01:21:01,260 --> 01:21:06,930
they've been they've been nicked from

1772
01:21:02,760 --> 01:21:08,250
their parent star so there's lots of

1773
01:21:06,930 --> 01:21:09,840
different ways in which you can get

1774
01:21:08,250 --> 01:21:12,300
these configurations but we know that

1775
01:21:09,840 --> 01:21:13,650
the formation of planets we know that

1776
01:21:12,300 --> 01:21:16,020
the formation of stars we know that the

1777
01:21:13,649 --> 01:21:18,269
dynamics of our galaxy is very very

1778
01:21:16,020 --> 01:21:21,420
kicking dynamic so there's a lot of

1779
01:21:18,270 --> 01:21:24,120
things like all right so lesson for you

1780
01:21:21,420 --> 01:21:28,109
hold on to your planets okay all right

1781
01:21:24,119 --> 01:21:29,640
so next month on March 6th Mia Bobo will

1782

01:21:28,109 --> 01:21:31,619

be talking about mapping the United

1783

01:21:29,640 --> 01:21:34,110

Federation of Planets and astronomers

1784

01:21:31,619 --> 01:21:37,279

guide to the galaxy and let us give

1785

01:21:34,109 --> 01:21:37,279

Hannah one more big