PUBLIC LECTURE SERIES

The Wildest Weather in the Universe

Featuring Guest Speaker:
Hannah Wakeford

1
00:00:00,000 --> 00:00:03,750
oh

2
00:00:08,070 --> 00:00:05,430
good evening ladies and gentlemen and

3
00:00:10,709 --> 00:00:08,080
welcome to the space telescope public

4
00:00:12,709 --> 00:00:10,719
lecture series it is my joy and pleasure

5
00:00:15,110 --> 00:00:12,719
to be your host i'm dr frank summers of

6
00:00:17,750 --> 00:00:15,120
the office of public outreach

7
00:00:20,710 --> 00:00:17,760
on your way in you could have grabbed a

8
00:00:23,150 --> 00:00:20,720
lithograph tonight's lithograph is the

9
00:00:26,310 --> 00:00:23,160
interacting galaxy's

10
00:00:27,990 --> 00:00:26,320
arp147 there are a lot of interacting

11
00:00:28,950 --> 00:00:28,000
galaxies that have these arp names

12
00:00:31,830 --> 00:00:28,960
because

13
00:00:33,750 --> 00:00:31,840

arp created the catalog okay if you want

14
00:00:35,510 --> 00:00:33,760
to learn more about interacting galaxies

15
00:00:36,470 --> 00:00:35,520
you can turn over on the back and read

16
00:00:38,310 --> 00:00:36,480
about them

17
00:00:40,310 --> 00:00:38,320
if you did not get one on your way in

18
00:00:43,510 --> 00:00:40,320
they are down here on both sides grab

19
00:00:44,549 --> 00:00:43,520
one on your way out

20
00:00:45,910 --> 00:00:44,559
tonight

21
00:00:48,549 --> 00:00:45,920
i guess my

22
00:00:51,670 --> 00:00:48,559
pointer's gone uh tonight we have the

23
00:00:53,750 --> 00:00:51,680
wildest weather in the universe a very

24
00:00:55,590 --> 00:00:53,760
catchy title which i think is partly

25
00:00:59,189 --> 00:00:55,600
responsible for so many of you showing

26
00:01:01,830 --> 00:00:59,199
up today um by hannah wakeford

27
00:01:02,790 --> 00:01:01,840
next month we have another very catchy

28
00:01:05,750 --> 00:01:02,800
title

29
00:01:07,990 --> 00:01:05,760
mapping the united federation of planets

30
00:01:10,550 --> 00:01:08,000
an astronomer's guide to the galaxy and

31
00:01:14,230 --> 00:01:10,560
yes that is a star trek reference and

32
00:01:17,030 --> 00:01:14,240
yes star trek will be part of the talk

33
00:01:19,429 --> 00:01:17,040
next month although it will be used in a

34
00:01:20,630 --> 00:01:19,439
scientific context for mapping the

35
00:01:23,190 --> 00:01:20,640
galaxy

36
00:01:25,270 --> 00:01:23,200
um in april oh

37
00:01:27,670 --> 00:01:25,280
we do not actually have a title so i

38
00:01:30,469 --> 00:01:27,680

gave it the title lovely plumage on

39
00:01:32,390 --> 00:01:30,479
europa um susanna and i chatted on the

40
00:01:34,870 --> 00:01:32,400
phone today she said i'll talk about the

41
00:01:37,190 --> 00:01:34,880
uh the plumes on europa and i said oh

42
00:01:38,550 --> 00:01:37,200
the lovely plumage story and so i wrote

43
00:01:41,830 --> 00:01:38,560
that as a placeholder and she was

44
00:01:45,190 --> 00:01:41,840
supposed to email me um an actual title

45
00:01:46,230 --> 00:01:45,200
and i forgot to i i i don't know if she

46
00:01:48,550 --> 00:01:46,240
actually did

47
00:01:51,030 --> 00:01:48,560
um because i forgot to check so that

48
00:01:53,030 --> 00:01:51,040
it's about the plumes on the europa okay

49
00:01:56,310 --> 00:01:53,040
uh it'll be a cool talk susanna's a very

50
00:01:58,630 --> 00:01:56,320
good speaker all right and in may a talk

51
00:02:01,069 --> 00:01:58,640
that i've been trying to get for a while

52
00:02:04,149 --> 00:02:01,079
andy fructor has agreed to talk about

53
00:02:05,590 --> 00:02:04,159
gravitational wave astronomy

54
00:02:07,830 --> 00:02:05,600
the new

55
00:02:10,550 --> 00:02:07,840
new of way we're going to view the

56
00:02:12,470 --> 00:02:10,560
universe with gravitational waves

57
00:02:15,750 --> 00:02:12,480
so you can find all about all our

58
00:02:17,430 --> 00:02:15,760
upcoming talks on our website um that

59
00:02:20,229 --> 00:02:17,440
has on the right the list of the

60
00:02:21,510 --> 00:02:20,239
upcoming talks on the left we have links

61
00:02:24,229 --> 00:02:21,520
to our

62
00:02:25,430 --> 00:02:24,239
webcasting and our recordings of them on

63
00:02:27,270 --> 00:02:25,440

youtube

64
00:02:29,030 --> 00:02:27,280
when we are live you can click those and

65
00:02:31,750 --> 00:02:29,040
go directly to those

66
00:02:33,670 --> 00:02:31,760
you can also sign up for email if you

67
00:02:35,750 --> 00:02:33,680
just go to your favorite

68
00:02:37,910 --> 00:02:35,760
search engine and type in hubble public

69
00:02:41,030 --> 00:02:37,920
talks or space telescope public talks

70
00:02:43,910 --> 00:02:41,040
you will find this web page

71
00:02:45,670 --> 00:02:43,920
if you would like uh email announcements

72
00:02:47,509 --> 00:02:45,680
actually you don't

73
00:02:50,150 --> 00:02:47,519
you sign up at the website i mentioned

74
00:02:53,190 --> 00:02:50,160
that that down the lower left is our

75
00:02:55,990 --> 00:02:53,200
email uh server listserv so you can

76
00:02:57,110 --> 00:02:56,000
subscribe or unsubscribe there

77
00:02:58,550 --> 00:02:57,120
um

78
00:03:00,070 --> 00:02:58,560
if you have comments or questions you

79
00:03:04,229 --> 00:03:00,080
can send it to the email address public

80
00:03:10,149 --> 00:03:07,670
uh uh social media last month i said i'd

81
00:03:12,470 --> 00:03:10,159
start including the web telescope uh

82
00:03:14,470 --> 00:03:12,480
accounts and here they are for you uh we

83
00:03:17,190 --> 00:03:14,480
have facebook twitter youtube instagram

84
00:03:18,949 --> 00:03:17,200
and and probably more for both hubble

85
00:03:21,270 --> 00:03:18,959
and webb and some for the space

86
00:03:24,309 --> 00:03:21,280
telescope science institute as well

87
00:03:26,869 --> 00:03:24,319
i do a tiny bit of social media on a

88
00:03:28,710 --> 00:03:26,879

blog and facebook and google and twitter

89
00:03:30,149 --> 00:03:28,720
so if you want to hear more from me you

90
00:03:32,949 --> 00:03:30,159
can do that

91
00:03:35,430 --> 00:03:32,959
the observatory the question is whether

92
00:03:36,869 --> 00:03:35,440
or not the weather is permitting um did

93
00:03:39,270 --> 00:03:36,879
somebody notice whether their clouds

94
00:03:41,110 --> 00:03:39,280
were up when they came in oh somebody's

95
00:03:45,430 --> 00:03:41,120
giving me the thumbs down

96
00:03:47,110 --> 00:03:45,440
okay it was a questionable and irini um

97
00:03:48,630 --> 00:03:47,120
may have may have emailed me her

98
00:03:50,789 --> 00:03:48,640
decision by now

99
00:03:54,149 --> 00:03:50,799
but the audience gives us a thumbs down

100
00:03:57,270 --> 00:03:54,159
so it probably will not happen okay

101
00:04:00,110 --> 00:03:57,280
but uh they do do an open house on

102
00:04:02,309 --> 00:04:00,120
friday evenings if you go to

103
00:04:04,550 --> 00:04:02,319
md.spacegrant.org you'll find that web

104
00:04:05,990 --> 00:04:04,560
page over there on the right

105
00:04:09,270 --> 00:04:06,000
and in that box where it says

106
00:04:12,390 --> 00:04:09,280
observatory status each friday by like 5

107
00:04:13,670 --> 00:04:12,400
or 6 p.m they update it with weather

108
00:04:15,750 --> 00:04:13,680
the information as to whether they're

109
00:04:16,789 --> 00:04:15,760
going to be open that friday evening

110
00:04:19,270 --> 00:04:16,799
okay

111
00:04:20,629 --> 00:04:19,280
so check that out i'm sorry that we

112
00:04:21,909 --> 00:04:20,639
probably won't be able to get that in

113
00:04:23,030 --> 00:04:21,919

tonight

114
00:04:27,590 --> 00:04:23,040
and now

115
00:04:30,390 --> 00:04:27,600
news from the universe for february 2018

116
00:04:33,350 --> 00:04:30,400
in which we answer that amazingly

117
00:04:37,270 --> 00:04:33,360
scientifically detailed question

118
00:04:40,310 --> 00:04:38,550
now

119
00:04:42,870 --> 00:04:40,320
massive galaxies

120
00:04:45,110 --> 00:04:42,880
are known to have supermassive black

121
00:04:47,990 --> 00:04:45,120
holes at their very core

122
00:04:51,030 --> 00:04:48,000
this is a massive galaxy and there is a

123
00:04:52,629 --> 00:04:51,040
super massive black hole at its core

124
00:04:54,629 --> 00:04:52,639
but of course you can't see it because

125
00:04:56,390 --> 00:04:54,639
the supermassive black hole is tiny

126
00:04:58,870 --> 00:04:56,400
compared to the galaxy

127
00:04:59,830 --> 00:04:58,880
but these supermassive black holes can

128
00:05:01,830 --> 00:04:59,840
cause

129
00:05:04,390 --> 00:05:01,840
huge emission

130
00:05:06,870 --> 00:05:04,400
this one is called hercules a

131
00:05:08,830 --> 00:05:06,880
and when viewed in radio light it looks

132
00:05:12,469 --> 00:05:08,840
like

133
00:05:15,510 --> 00:05:12,479
that from that tiny supermassive black

134
00:05:17,909 --> 00:05:15,520
hole in the core are emitted huge jets

135
00:05:20,390 --> 00:05:17,919
of emission that spew out across the

136
00:05:22,870 --> 00:05:20,400
galaxy and beyond the galaxy to form

137
00:05:26,469 --> 00:05:22,880
these giant radial lobes

138
00:05:28,870 --> 00:05:26,479

now not every supermassive black hole is

139
00:05:30,710 --> 00:05:28,880
in this phase when when there's giant

140
00:05:33,110 --> 00:05:30,720
jets of emission coming from them

141
00:05:35,350 --> 00:05:33,120
sometimes it's a little harder to find

142
00:05:36,390 --> 00:05:35,360
they're not always in this emission

143
00:05:39,189 --> 00:05:36,400
phase

144
00:05:41,749 --> 00:05:39,199
and what we want to know when we look at

145
00:05:44,629 --> 00:05:41,759
the cosmological history of these uh

146
00:05:46,950 --> 00:05:44,639
supermassive black holes is how often

147
00:05:49,270 --> 00:05:46,960
are they on when they're when there's

148
00:05:51,830 --> 00:05:49,280
material falling in and stuff that's

149
00:05:53,749 --> 00:05:51,840
being emitted back out and how often are

150
00:05:55,430 --> 00:05:53,759
they quiescent how often are they quiet

151
00:05:56,629 --> 00:05:55,440
and they're not really emitting that's

152
00:05:58,710 --> 00:05:56,639
one of the things that we that the

153
00:06:01,110 --> 00:05:58,720
cosmologists really want to understand

154
00:06:05,029 --> 00:06:01,120
about these black holes over time

155
00:06:08,029 --> 00:06:05,039
so here is a hubble image of a galaxy

156
00:06:11,510 --> 00:06:08,039
sdss

157
00:06:13,830 --> 00:06:11,520
j1354 okay uh that's just its catalog

158
00:06:15,510 --> 00:06:13,840
number in the sloan digital sky survey

159
00:06:17,189 --> 00:06:15,520
and this is the hubble image of the

160
00:06:19,590 --> 00:06:17,199
galaxy and the galaxy we're interested

161
00:06:21,990 --> 00:06:19,600
is not the one at the top but it's

162
00:06:24,070 --> 00:06:22,000
actually the one at the bottom okay the

163
00:06:26,790 --> 00:06:24,080

one at the bottom

164
00:06:27,830 --> 00:06:26,800
it has a supermassive black hole that's

165
00:06:29,909 --> 00:06:27,840
active

166
00:06:31,510 --> 00:06:29,919
now what you'll notice between the top

167
00:06:33,670 --> 00:06:31,520
and the bottom is that there's sort of a

168
00:06:35,990 --> 00:06:33,680
striation material that seems to be

169
00:06:38,230 --> 00:06:36,000
flowing down from the one at the top

170
00:06:40,790 --> 00:06:38,240
these two galaxies are believed to be in

171
00:06:42,710 --> 00:06:40,800
our acting okay and when galaxies

172
00:06:44,469 --> 00:06:42,720
interact sometimes material from one

173
00:06:47,510 --> 00:06:44,479
galaxy can

174
00:06:48,469 --> 00:06:47,520
accrete onto the other galaxy

175
00:06:50,309 --> 00:06:48,479
and so

176
00:06:53,909 --> 00:06:50,319
what we wanted to know what what we

177
00:06:54,710 --> 00:06:53,919
found out when looking in x-rays is that

178
00:06:57,350 --> 00:06:54,720
the

179
00:07:00,469 --> 00:06:57,360
galaxy

180
00:07:02,870 --> 00:07:00,479
is turned on it is in an emissive phase

181
00:07:04,870 --> 00:07:02,880
because here is the spitz the the

182
00:07:07,909 --> 00:07:04,880
chandra x-ray observatory now you gotta

183
00:07:10,469 --> 00:07:07,919
look carefully all right there's hubble

184
00:07:12,950 --> 00:07:10,479
there's hubble and chandra okay you can

185
00:07:15,830 --> 00:07:12,960
see that purple x-ray emission that

186
00:07:19,029 --> 00:07:15,840
identifies what's coming from that super

187
00:07:20,550 --> 00:07:19,039
massive black hole so let's magnify that

188
00:07:21,909 --> 00:07:20,560

and give you a little bit of context

189
00:07:25,670 --> 00:07:21,919
here

190
00:07:28,309 --> 00:07:25,680
is that the x-ray

191
00:07:31,350 --> 00:07:28,319
material is coming from it and that

192
00:07:34,230 --> 00:07:31,360
white burst above it

193
00:07:36,870 --> 00:07:34,240
appears to be material spewed out of the

194
00:07:39,029 --> 00:07:36,880
supermassive black hole matter of fact

195
00:07:40,469 --> 00:07:39,039
what they tell me and it's kind of hard

196
00:07:43,189 --> 00:07:40,479
i can't i couldn't really see it in the

197
00:07:44,870 --> 00:07:43,199
image is that there are two

198
00:07:47,029 --> 00:07:44,880
periods of emission

199
00:07:48,629 --> 00:07:47,039
and given the speed that this material

200
00:07:49,670 --> 00:07:48,639
is traveling away

201
00:07:51,830 --> 00:07:49,680
they had

202
00:07:54,390 --> 00:07:51,840
that it was in emission and then a

203
00:07:57,189 --> 00:07:54,400
hundred thousand years of being quiet

204
00:08:00,150 --> 00:07:57,199
and then another emission

205
00:08:03,749 --> 00:08:00,160
the hypothesis the best explanation for

206
00:08:06,790 --> 00:08:03,759
it is that these two galaxies interacted

207
00:08:08,390 --> 00:08:06,800
material flowed in

208
00:08:10,390 --> 00:08:08,400
all right and started to spiral in on

209
00:08:13,110 --> 00:08:10,400
the supermassive black hole some was

210
00:08:16,150 --> 00:08:13,120
spewed out and then it went quiet for a

211
00:08:19,670 --> 00:08:16,160
while and then some more was spewed out

212
00:08:22,230 --> 00:08:19,680
right and in the press release they call

213
00:08:23,270 --> 00:08:22,240

these burps from a supermassive black

214
00:08:25,270 --> 00:08:23,280
hole

215
00:08:28,309 --> 00:08:25,280
i kid you not in the actual press

216
00:08:30,309 --> 00:08:28,319
release they use the word burp but is it

217
00:08:32,469 --> 00:08:30,319
really a burp

218
00:08:34,709 --> 00:08:32,479
and i would say no

219
00:08:37,990 --> 00:08:34,719
because when you or i burp it comes from

220
00:08:41,350 --> 00:08:38,000
inside us and spews out right

221
00:08:43,909 --> 00:08:41,360
but material doesn't come out of a black

222
00:08:45,590 --> 00:08:43,919
hole right even light can't escape from

223
00:08:47,509 --> 00:08:45,600
a black hole

224
00:08:50,470 --> 00:08:47,519
it's not the supermassive black hole

225
00:08:52,790 --> 00:08:50,480
that is burping but rather the material

226
00:08:54,470 --> 00:08:52,800
is falling onto the super onto an

227
00:08:55,590 --> 00:08:54,480
accretion disk around the supermassive

228
00:08:57,269 --> 00:08:55,600
black hole

229
00:08:58,389 --> 00:08:57,279
some of that material goes into the

230
00:09:00,630 --> 00:08:58,399
black hole

231
00:09:04,310 --> 00:09:00,640
some of the material gets flung back out

232
00:09:06,470 --> 00:09:04,320
from the accretion disk okay so i would

233
00:09:09,190 --> 00:09:06,480
say just to be a little technical that

234
00:09:12,470 --> 00:09:09,200
it's the accretion disk that is burping

235
00:09:16,070 --> 00:09:12,480
and not the supermassive black hole

236
00:09:19,190 --> 00:09:16,080
so that's my answer to that question

237
00:09:21,350 --> 00:09:19,200
our second story tonight the launch of a

238
00:09:24,230 --> 00:09:21,360

new era

239
00:09:27,509 --> 00:09:24,240
way back in the 60s in the apollo era we

240
00:09:30,310 --> 00:09:27,519
had the saturn v rocket the most

241
00:09:32,870 --> 00:09:30,320
powerful launch vehicle that america has

242
00:09:36,790 --> 00:09:32,880
ever had and this actually is the launch

243
00:09:40,710 --> 00:09:36,800
of apollo 11 from kennedy and the saturn

244
00:09:43,509 --> 00:09:40,720
v rocket was retired back in 1973.

245
00:09:45,509 --> 00:09:43,519
it was followed by the space shuttle

246
00:09:47,350 --> 00:09:45,519
this by the way is the launch that

247
00:09:49,910 --> 00:09:47,360
carried the hubble space telescope into

248
00:09:51,990 --> 00:09:49,920
orbit and you can see the space of the

249
00:09:55,430 --> 00:09:52,000
launch on the right but also you can see

250
00:09:56,949 --> 00:09:55,440
another um sts um actually actually

251
00:09:59,590 --> 00:09:56,959
testing on another launch pad at the

252
00:10:01,190 --> 00:09:59,600
same time okay and this was also

253
00:10:04,310 --> 00:10:01,200
incredibly powerful

254
00:10:06,470 --> 00:10:04,320
but it had to carry the space shuttle up

255
00:10:09,350 --> 00:10:06,480
so the payload that could be inside the

256
00:10:11,509 --> 00:10:09,360
space shuttle was considerably smaller

257
00:10:13,670 --> 00:10:11,519
and so what people have been looking for

258
00:10:15,509 --> 00:10:13,680
is a really big

259
00:10:19,110 --> 00:10:15,519
boost to get into space

260
00:10:21,750 --> 00:10:19,120
and so nasa has plans for a wonderful

261
00:10:24,550 --> 00:10:21,760
system coming up but in the meantime we

262
00:10:25,829 --> 00:10:24,560
have developed commercial companies such

263
00:10:29,350 --> 00:10:25,839

as

264
00:10:33,990 --> 00:10:29,360
spacex elon musk's company spacex and

265
00:10:36,230 --> 00:10:34,000
this is their workhorse the falcon 9

266
00:10:38,949 --> 00:10:36,240
launch a booster

267
00:10:40,630 --> 00:10:38,959
so called 9 because there are 9 engines

268
00:10:42,550 --> 00:10:40,640
in this booster okay

269
00:10:44,230 --> 00:10:42,560
and they have been launching these for

270
00:10:45,990 --> 00:10:44,240
several years

271
00:10:49,990 --> 00:10:46,000
and putting satellites into orbit with

272
00:10:51,509 --> 00:10:50,000
it but it wasn't powerful enough

273
00:10:54,230 --> 00:10:51,519
so what

274
00:10:56,230 --> 00:10:54,240
elon musk is a little bit ambitious and

275
00:10:57,829 --> 00:10:56,240
what does he want to do he wants to take

276
00:11:01,509 --> 00:10:57,839
he wants to make the world's most

277
00:11:02,630 --> 00:11:01,519
powerful rocket this one is the falcon

278
00:11:04,470 --> 00:11:02,640
heavy

279
00:11:07,110 --> 00:11:04,480
and you will notice it looks very much

280
00:11:10,389 --> 00:11:07,120
like the falcon 9

281
00:11:13,190 --> 00:11:10,399
except it has outboard motors on it

282
00:11:16,389 --> 00:11:13,200
which are in fact two other boosters

283
00:11:19,269 --> 00:11:16,399
identical boosters so there are 27

284
00:11:21,110 --> 00:11:19,279
engines on this three-pronged rocket

285
00:11:23,269 --> 00:11:21,120
all right and they did a test firing a

286
00:11:24,550 --> 00:11:23,279
week or so ago um and they didn't

287
00:11:25,910 --> 00:11:24,560
actually launch anything they didn't

288
00:11:29,110 --> 00:11:25,920

actually go offline they did a test

289
00:11:31,350 --> 00:11:29,120
firing show they could launch all 27

290
00:11:33,030 --> 00:11:31,360
they could fire all 27 engines together

291
00:11:34,069 --> 00:11:33,040
and today

292
00:11:36,470 --> 00:11:34,079
they did

293
00:11:38,790 --> 00:11:36,480
the test launch

294
00:11:41,670 --> 00:11:38,800
what was the payload

295
00:11:45,509 --> 00:11:41,680
the payload was from elon musk's other

296
00:11:49,190 --> 00:11:45,519
company the tesla cars and it was a

297
00:11:50,230 --> 00:11:49,200
tesla roadster a cherry red tesla

298
00:11:53,269 --> 00:11:50,240
roadster

299
00:11:56,069 --> 00:11:53,279
with a dummy in a one of the spacex

300
00:11:59,269 --> 00:11:56,079
space suits in the driver's seat okay

301
00:12:01,030 --> 00:11:59,279
this is the actual roadster that was on

302
00:12:03,110 --> 00:12:01,040
the payload today okay

303
00:12:06,389 --> 00:12:03,120
and did it work

304
00:12:08,829 --> 00:12:06,399
oh yeah yes it did

305
00:12:11,430 --> 00:12:08,839
here is the footage released by

306
00:12:14,310 --> 00:12:11,440
spacex showing the

307
00:12:17,590 --> 00:12:14,320
falcon heavy launching from the space

308
00:12:22,550 --> 00:12:19,509
and once it got up

309
00:12:24,550 --> 00:12:22,560
the two side boosters uh separated all

310
00:12:26,230 --> 00:12:24,560
right and they

311
00:12:28,949 --> 00:12:26,240
came back

312
00:12:31,030 --> 00:12:28,959
and landed vertically

313
00:12:33,190 --> 00:12:31,040

i never get tired of seeing that okay

314
00:12:35,030 --> 00:12:33,200
you know falcon

315
00:12:37,190 --> 00:12:35,040
spacex has been doing this for a while i

316
00:12:39,509 --> 00:12:37,200
never get tired of watching this

317
00:12:42,150 --> 00:12:39,519
now the center booster was supposed to

318
00:12:43,910 --> 00:12:42,160
land on a platform out at sea which uh

319
00:12:46,710 --> 00:12:43,920
spacex has done before

320
00:12:48,790 --> 00:12:46,720
but there are no confirmation from

321
00:12:51,190 --> 00:12:48,800
spacex that it landed safely

322
00:12:53,509 --> 00:12:51,200
there was a disruption in the video feed

323
00:12:56,550 --> 00:12:53,519
that makes people a lot of speculate

324
00:12:58,230 --> 00:12:56,560
that it did not land successfully

325
00:13:01,590 --> 00:12:58,240
but there has been no confirmation as

326
00:13:02,870 --> 00:13:01,600
far as i've heard from spacex okay

327
00:13:05,350 --> 00:13:02,880
and then

328
00:13:09,430 --> 00:13:05,360
then they had the payload deployment so

329
00:13:12,230 --> 00:13:09,440
this is footage of the tesla roadster

330
00:13:18,710 --> 00:13:12,240
being deployed into space okay when then

331
00:13:23,030 --> 00:13:20,870
all right and this is my favorite shot

332
00:13:26,550 --> 00:13:23,040
this is a shot over

333
00:13:29,269 --> 00:13:26,560
the shoulder of a thing

334
00:13:31,910 --> 00:13:29,279
of the tesla roadster in orbit around

335
00:13:34,230 --> 00:13:31,920
earth right now um and you'll notice it

336
00:13:36,550 --> 00:13:34,240
says on the dashboard don't panic which

337
00:13:39,910 --> 00:13:36,560
is an homage to hitchhiker's guide to

338
00:13:42,389 --> 00:13:39,920

the galaxy and elon musk says yes there

339
00:13:44,949 --> 00:13:42,399
is a towel in the glove box for those

340
00:13:48,790 --> 00:13:47,910
while this is a lot of fun it actually

341
00:13:50,949 --> 00:13:48,800
makes

342
00:13:52,389 --> 00:13:50,959
for a really interesting point in our

343
00:13:54,470 --> 00:13:52,399
history of space

344
00:13:57,350 --> 00:13:54,480
because right now

345
00:13:58,550 --> 00:13:57,360
the most powerful launch vehicle on the

346
00:14:01,670 --> 00:13:58,560
planet

347
00:14:04,949 --> 00:14:01,680
is not from a nationalized space agency

348
00:14:06,629 --> 00:14:04,959
but it's from a commercial space company

349
00:14:09,430 --> 00:14:06,639
and that's

350
00:14:11,670 --> 00:14:09,440
that's a new era in in space flight all

351
00:14:13,990 --> 00:14:11,680
right now of course you know uh nasa has

352
00:14:15,189 --> 00:14:14,000
planned the sls which will be more

353
00:14:17,350 --> 00:14:15,199
powerful in the falcon heavy when it

354
00:14:19,910 --> 00:14:17,360
when it goes but

355
00:14:21,189 --> 00:14:19,920
for now spacex has the most powerful

356
00:14:22,470 --> 00:14:21,199
launch vehicle

357
00:14:24,629 --> 00:14:22,480
and if you want to get something heavy

358
00:14:26,470 --> 00:14:24,639
into space they're the people to go to

359
00:14:28,949 --> 00:14:26,480
so this um

360
00:14:30,949 --> 00:14:28,959
i love the audacity of elon musk and i

361
00:14:34,230 --> 00:14:30,959
love that he has a sense of humor so

362
00:14:37,990 --> 00:14:36,389
all right so yeah i'm not exactly sure

363
00:14:39,750 --> 00:14:38,000

the timing of it it's got to get out

364
00:14:41,910 --> 00:14:39,760
past the van allen belts and then the

365
00:14:43,590 --> 00:14:41,920
second stage will fire

366
00:14:46,629 --> 00:14:43,600
and try to put it into orbit around the

367
00:14:49,750 --> 00:14:46,639
sun that goes out to the orbit of mars

368
00:14:52,069 --> 00:14:49,760
so we'll have a tesla roadster orbiting

369
00:14:55,030 --> 00:14:52,079
uh driving around the solar system you

370
00:14:58,470 --> 00:14:55,040
know sort of like interplanetary nascar

371
00:15:00,470 --> 00:14:58,480
um but it's only a one-vehicle race

372
00:15:02,150 --> 00:15:00,480
and actually it it's it'll it'll a

373
00:15:04,150 --> 00:15:02,160
little trial it'll have quite some some

374
00:15:09,829 --> 00:15:04,160
frequent flyer miles um but it's still

375
00:15:09,839 --> 00:15:14,150
you want to go back where here

376
00:15:18,150 --> 00:15:15,030
that

377
00:15:23,030 --> 00:15:18,160
it's available on the internet because

378
00:15:26,870 --> 00:15:24,310
okay

379
00:15:28,710 --> 00:15:26,880
our final story for tonight

380
00:15:31,269 --> 00:15:28,720
um you have to imagine that the falcon

381
00:15:33,590 --> 00:15:31,279
heavy could not only go interplanetary

382
00:15:35,110 --> 00:15:33,600
but could go interstellar

383
00:15:38,790 --> 00:15:35,120
all right and could

384
00:15:41,750 --> 00:15:38,800
shift wavelengths all right um our um

385
00:15:43,829 --> 00:15:41,760
outreach program uh is now called the

386
00:15:46,389 --> 00:15:43,839
universe of learning nasa's universe of

387
00:15:48,389 --> 00:15:46,399
learning we used to be funded as the

388
00:15:50,230 --> 00:15:48,399

hubble outreach program or the james

389
00:15:52,550 --> 00:15:50,240
webb spa outreach program the spitzer

390
00:15:53,910 --> 00:15:52,560
outreach program or the chandra x-ray

391
00:15:56,310 --> 00:15:53,920
observatory outreach program they were

392
00:15:59,110 --> 00:15:56,320
associated with emissions well nasa

393
00:16:02,230 --> 00:15:59,120
refunded things in a

394
00:16:04,710 --> 00:16:02,240
multi-mission way where our outreach is

395
00:16:07,030 --> 00:16:04,720
about the astronomy and it covers all

396
00:16:08,470 --> 00:16:07,040
the various wavelengths and so for

397
00:16:10,550 --> 00:16:08,480
example one of the things we've been

398
00:16:11,990 --> 00:16:10,560
doing for years um and actually the

399
00:16:14,949 --> 00:16:12,000
spitzer folks have been doing a lot of

400
00:16:16,550 --> 00:16:14,959
too is doing sort of a slider here where

401
00:16:18,629 --> 00:16:16,560
you can slide from the

402
00:16:20,389 --> 00:16:18,639
visible light view on the left to the

403
00:16:22,470 --> 00:16:20,399
infrared view on the right and as you

404
00:16:25,110 --> 00:16:22,480
move that slider across the screen it

405
00:16:26,710 --> 00:16:25,120
goes it shows you how how the universe

406
00:16:29,110 --> 00:16:26,720
looks invisible and infrared and we

407
00:16:31,829 --> 00:16:29,120
found this to be a very powerful thing

408
00:16:33,189 --> 00:16:31,839
to do all right but you know that's

409
00:16:35,269 --> 00:16:33,199
doing it in

410
00:16:37,110 --> 00:16:35,279
two dimensions

411
00:16:40,230 --> 00:16:37,120
we wanted to take

412
00:16:41,590 --> 00:16:40,240
these two images of the orion nebula

413
00:16:43,670 --> 00:16:41,600

on the left from the hubble space

414
00:16:46,470 --> 00:16:43,680
telescope and on the right from the

415
00:16:48,550 --> 00:16:46,480
spitzer space telescope and we wanted to

416
00:16:50,629 --> 00:16:48,560
do that same thing

417
00:16:52,870 --> 00:16:50,639
in 3d

418
00:16:55,110 --> 00:16:52,880
so one thing you notice automatically is

419
00:16:57,749 --> 00:16:55,120
that the spitzer image covers a much

420
00:17:00,230 --> 00:16:57,759
larger area it's infrared radiation

421
00:17:02,230 --> 00:17:00,240
which comes from cooler gas which is

422
00:17:03,910 --> 00:17:02,240
spreads out further in the nebula you

423
00:17:06,230 --> 00:17:03,920
can actually see the whole bowl of the

424
00:17:09,350 --> 00:17:06,240
orion nebula over there

425
00:17:11,110 --> 00:17:09,360
there's also more stars in the infrared

426
00:17:12,309 --> 00:17:11,120
because you're seeing the fainter cooler

427
00:17:15,510 --> 00:17:12,319
stars

428
00:17:17,189 --> 00:17:15,520
that only shine mostly in the infrared

429
00:17:19,750 --> 00:17:17,199
but when you get down into the detail

430
00:17:21,429 --> 00:17:19,760
hubble has higher resolution and you can

431
00:17:24,069 --> 00:17:21,439
see those bow shocks and those

432
00:17:24,949 --> 00:17:24,079
protoplanetary disks and all sorts of

433
00:17:27,029 --> 00:17:24,959
cool

434
00:17:28,069 --> 00:17:27,039
fine-grained structures and hubble of

435
00:17:29,590 --> 00:17:28,079
course you can't see it at this

436
00:17:31,190 --> 00:17:29,600
resolution

437
00:17:33,830 --> 00:17:31,200
but you'll see it in a second

438
00:17:36,470 --> 00:17:33,840

that you can't see in spitzer so what we

439
00:17:38,950 --> 00:17:36,480
did is we built a model of the orion

440
00:17:40,630 --> 00:17:38,960
nebula for the imax film hubble 3d

441
00:17:43,190 --> 00:17:40,640
using visible light

442
00:17:46,150 --> 00:17:43,200
then we rebuilt the model using the

443
00:17:47,430 --> 00:17:46,160
spitzer data in infrared

444
00:17:49,510 --> 00:17:47,440
and then

445
00:17:50,950 --> 00:17:49,520
we're going to fly you into it so uh

446
00:17:52,470 --> 00:17:50,960
thomas can we take the lights down a

447
00:17:58,220 --> 00:17:52,480
little bit

448
00:19:30,950 --> 00:19:18,200
[Music]

449
00:19:30,960 --> 00:19:55,030
so

450
00:20:29,990 --> 00:20:09,840
[Music]

451
00:20:40,210 --> 00:20:30,000
[Applause]

452
00:20:41,620 --> 00:20:40,220
[Music]

453
00:20:41,840 --> 00:20:41,630
[Applause]

454
00:20:58,220 --> 00:20:41,850
[Music]

455
00:21:05,029 --> 00:20:58,230
laughs

456
00:21:10,310 --> 00:21:07,029
so we thought that was a considerable

457
00:21:12,710 --> 00:21:10,320
success being able to show you in 3d

458
00:21:14,390 --> 00:21:12,720
that what it looks like from the hubble

459
00:21:16,710 --> 00:21:14,400
visible light image what it looks like

460
00:21:18,789 --> 00:21:16,720
in the this the spitzer infrared image

461
00:21:21,270 --> 00:21:18,799
and you get a real feel for the

462
00:21:24,230 --> 00:21:21,280
different structures that we see and

463
00:21:25,830 --> 00:21:24,240

inherently the value of multi-wavelength

464
00:21:28,630 --> 00:21:25,840
astronomy

465
00:21:30,390 --> 00:21:28,640
all right so now we go to our featured

466
00:21:32,390 --> 00:21:30,400
speaker tonight

467
00:21:35,990 --> 00:21:32,400
and our featured speaker is hannah

468
00:21:38,310 --> 00:21:36,000
wakeford um she got her let's see let me

469
00:21:41,110 --> 00:21:38,320
just find things all right she got her

470
00:21:42,950 --> 00:21:41,120
phd in physics from the university of

471
00:21:43,990 --> 00:21:42,960
exeter

472
00:21:46,950 --> 00:21:44,000
previous to that you were at the

473
00:21:48,870 --> 00:21:46,960
university of wales in some city that

474
00:21:50,950 --> 00:21:48,880
i'm not sure i can pronounce so you'll

475
00:21:52,950 --> 00:21:50,960
switch yeah you'll have to you'll have

476
00:21:53,750 --> 00:21:52,960
to pronounce it yourself okay

477
00:21:56,390 --> 00:21:53,760
um

478
00:22:00,390 --> 00:21:56,400
and she also worked at the university

479
00:22:03,270 --> 00:22:00,400
center in svalbard in the arctic at 78

480
00:22:04,950 --> 00:22:03,280
degrees north latitude

481
00:22:07,350 --> 00:22:04,960
yeah that's further north than i'm sure

482
00:22:09,190 --> 00:22:07,360
most ever anybody of us have ever been

483
00:22:12,230 --> 00:22:09,200
she can tell you about that if you

484
00:22:14,390 --> 00:22:12,240
thought it was cold here last week no

485
00:22:17,510 --> 00:22:14,400
you don't know cold

486
00:22:20,630 --> 00:22:17,520
she has worked at the nasa goddard space

487
00:22:23,190 --> 00:22:20,640
flight center as a nasa post doctoral

488
00:22:27,510 --> 00:22:23,200

fellow after getting her phd and she

489
00:22:30,789 --> 00:22:27,520
came here as the 2017 giacone fellow

490
00:22:32,950 --> 00:22:30,799
um here and one of the most important

491
00:22:35,830 --> 00:22:32,960
things is that she has extensive

492
00:22:38,710 --> 00:22:35,840
experience in public outreach uh working

493
00:22:41,270 --> 00:22:38,720
on a podcast called exocast about

494
00:22:45,110 --> 00:22:41,280
exoplanets as you might guess

495
00:22:47,750 --> 00:22:45,120
as well as writing a blog called

496
00:22:49,990 --> 00:22:47,760
stellar planet all right

497
00:22:51,830 --> 00:22:50,000
and she can tell you more about that but

498
00:22:53,029 --> 00:22:51,840
i'm looking forward to seeing how she

499
00:22:54,390 --> 00:22:53,039
performs

500
00:23:03,750 --> 00:22:54,400
the hearing aid tonight

501
00:23:07,350 --> 00:23:05,350
let me just switch this over for

502
00:23:13,750 --> 00:23:07,360
everybody and you can watch me type in

503
00:23:18,149 --> 00:23:16,230
okay

504
00:23:21,990 --> 00:23:18,159
well all right then

505
00:23:24,070 --> 00:23:22,000
hello everybody this is a great crowd

506
00:23:25,909 --> 00:23:24,080
brilliant loving it

507
00:23:27,190 --> 00:23:25,919
so i'm going to take you on a little bit

508
00:23:28,310 --> 00:23:27,200
of a journey

509
00:23:29,750 --> 00:23:28,320
across

510
00:23:31,669 --> 00:23:29,760
our galaxy

511
00:23:35,029 --> 00:23:31,679
through different worlds and looking at

512
00:23:37,110 --> 00:23:35,039
some of the wildest weather that we have

513
00:23:40,549 --> 00:23:37,120

actually been able to

514
00:23:42,070 --> 00:23:40,559
look at and understand

515
00:23:44,149 --> 00:23:42,080
i'm going to start our journey a little

516
00:23:46,149 --> 00:23:44,159
bit closer to home

517
00:23:48,390 --> 00:23:46,159
this is our wonderful solar system to

518
00:23:52,310 --> 00:23:48,400
scale and i love this picture because it

519
00:23:55,029 --> 00:23:52,320
really puts a good perspective on our

520
00:23:56,710 --> 00:23:55,039
planets and ourself

521
00:23:58,310 --> 00:23:56,720
right down here

522
00:24:02,630 --> 00:23:58,320
tiny little dot

523
00:24:04,390 --> 00:24:02,640
poor pluto and the plutoids out there

524
00:24:07,590 --> 00:24:04,400
this really kind of this is our solar

525
00:24:09,190 --> 00:24:07,600
system encapsulated in a single image

526
00:24:11,350 --> 00:24:09,200
and i'm going to take you through what

527
00:24:13,350 --> 00:24:11,360
makes up these planets what's really

528
00:24:15,029 --> 00:24:13,360
interesting about these planets

529
00:24:17,190 --> 00:24:15,039
and

530
00:24:19,110 --> 00:24:17,200
where weather comes from

531
00:24:21,510 --> 00:24:19,120
now you can't have weather without a

532
00:24:25,190 --> 00:24:21,520
little bit of gas

533
00:24:27,990 --> 00:24:25,200
mercury has really only got a little bit

534
00:24:31,029 --> 00:24:28,000
of gas mercury's weather comes from when

535
00:24:33,110 --> 00:24:31,039
the sun bombards it with particles

536
00:24:35,510 --> 00:24:33,120
the sun's uh

537
00:24:37,830 --> 00:24:35,520
particles come out in the solar wind and

538
00:24:39,669 --> 00:24:37,840

they hit the surface of mercury there's

539
00:24:41,669 --> 00:24:39,679
nothing getting in the way of that just

540
00:24:43,190 --> 00:24:41,679
slams into the surface

541
00:24:45,430 --> 00:24:43,200
that actually then causes other

542
00:24:48,310 --> 00:24:45,440
particles to be lifted up from the rock

543
00:24:50,470 --> 00:24:48,320
and that forms mercury's atmosphere it's

544
00:24:53,669 --> 00:24:50,480
not permanent it's very intermittent it

545
00:24:55,669 --> 00:24:53,679
only happens it only has this gas around

546
00:24:57,750 --> 00:24:55,679
mercury at very specific points where

547
00:25:00,789 --> 00:24:57,760
the solar wind has hit it

548
00:25:02,149 --> 00:25:00,799
we don't really call that an atmosphere

549
00:25:03,669 --> 00:25:02,159
so it doesn't

550
00:25:06,070 --> 00:25:03,679
really have weather

551
00:25:10,149 --> 00:25:06,080
what mercury has is the sun's weather

552
00:25:12,710 --> 00:25:10,159
and it lives inside the sun's atmosphere

553
00:25:15,590 --> 00:25:12,720
venus on the other hand has something

554
00:25:19,190 --> 00:25:15,600
very very different

555
00:25:21,590 --> 00:25:19,200
venus has an atmosphere which contains

556
00:25:23,590 --> 00:25:21,600
lots of different materials

557
00:25:25,590 --> 00:25:23,600
but it's one of the smallest percentages

558
00:25:29,190 --> 00:25:25,600
of these materials

559
00:25:32,230 --> 00:25:29,200
this so2 sulfuric acid

560
00:25:35,669 --> 00:25:32,240
that causes the most trouble for venus

561
00:25:38,789 --> 00:25:35,679
this is a gorgeous image of venus from

562
00:25:40,470 --> 00:25:38,799
the jaxa the japanese space agency

563
00:25:42,789 --> 00:25:40,480

satellite which is an orbit around it

564
00:25:45,510 --> 00:25:42,799
now called atkasuki

565
00:25:48,310 --> 00:25:45,520
and if i just take a next look at that

566
00:25:49,990 --> 00:25:48,320
we can zoom in on these cloud structures

567
00:25:52,470 --> 00:25:50,000
that you have in the atmosphere this

568
00:25:55,029 --> 00:25:52,480
image is taken in the infrared and what

569
00:25:59,029 --> 00:25:55,039
you're seeing from those dark bits there

570
00:26:00,950 --> 00:25:59,039
is this sulfuric acid in the atmosphere

571
00:26:04,070 --> 00:26:00,960
it extends

572
00:26:05,710 --> 00:26:04,080
for hundreds of kilometers

573
00:26:07,909 --> 00:26:05,720
it makes up

574
00:26:10,950 --> 00:26:07,919
.015 percent

575
00:26:13,669 --> 00:26:10,960
of the material in the atmosphere

576
00:26:15,510 --> 00:26:13,679
but if we were sitting in the atmosphere

577
00:26:17,190 --> 00:26:15,520
of venus at the same pressure as we're

578
00:26:19,110 --> 00:26:17,200
all feeling right now

579
00:26:21,510 --> 00:26:19,120
a centimeter per square inch

580
00:26:22,830 --> 00:26:21,520
we'd be sitting right in the clouds and

581
00:26:26,630 --> 00:26:22,840
we would have melted

582
00:26:28,870 --> 00:26:26,640
away this stuff is horrible

583
00:26:31,029 --> 00:26:28,880
it would melt through your skin in less

584
00:26:33,750 --> 00:26:31,039
than a minute it would get down to the

585
00:26:35,750 --> 00:26:33,760
bone in two minutes

586
00:26:37,350 --> 00:26:35,760
and there wouldn't be much left of us so

587
00:26:39,350 --> 00:26:37,360
it's incredibly difficult for us to

588
00:26:42,470 --> 00:26:39,360

understand and study venus because it's

589
00:26:43,990 --> 00:26:42,480
such a horrid harsh environment

590
00:26:45,350 --> 00:26:44,000
when you get down to the surface of

591
00:26:47,750 --> 00:26:45,360
venus

592
00:26:49,110 --> 00:26:47,760
it's 90 times the pressure that we feel

593
00:26:50,710 --> 00:26:49,120
here

594
00:26:53,029 --> 00:26:50,720
90 times

595
00:26:54,789 --> 00:26:53,039
that's going down very deep into the

596
00:26:57,590 --> 00:26:54,799
ocean now

597
00:26:58,710 --> 00:26:57,600
humans have scuba dives that deep so the

598
00:26:59,830 --> 00:26:58,720
pressure's not the thing that's going to

599
00:27:02,310 --> 00:26:59,840
kill you and you've got to get through

600
00:27:08,230 --> 00:27:02,320
the sulphuric acid first but it's also

601
00:27:13,510 --> 00:27:11,510
ugly little sister right there

602
00:27:15,909 --> 00:27:13,520
it's not a nice place and that's some

603
00:27:18,149 --> 00:27:15,919
very strange weather

604
00:27:20,470 --> 00:27:18,159
but it's not the strangest in our solar

605
00:27:22,710 --> 00:27:20,480
system some of the strangest phenomenon

606
00:27:24,870 --> 00:27:22,720
that we have aren't permanent like

607
00:27:26,149 --> 00:27:24,880
venus's sulfuric haze that extends

608
00:27:27,830 --> 00:27:26,159
throughout the atmosphere but they're

609
00:27:29,990 --> 00:27:27,840
intermittent they only happen every now

610
00:27:30,870 --> 00:27:30,000
and again and one of these we actually

611
00:27:33,269 --> 00:27:30,880
see

612
00:27:35,110 --> 00:27:33,279
on our neighbor mars

613
00:27:37,909 --> 00:27:35,120

what happens on mars every now and again

614
00:27:40,149 --> 00:27:37,919
is a global dust storm what you're

615
00:27:41,750 --> 00:27:40,159
looking at is two images that were taken

616
00:27:43,669 --> 00:27:41,760
just months apart

617
00:27:45,350 --> 00:27:43,679
one which is nicely labeled for us we

618
00:27:46,789 --> 00:27:45,360
can see all of these different features

619
00:27:48,390 --> 00:27:46,799
on mars

620
00:27:50,950 --> 00:27:48,400
and the next one

621
00:27:53,190 --> 00:27:50,960
just a couple of months later

622
00:27:54,710 --> 00:27:53,200
everything is wiped out you can just see

623
00:27:58,630 --> 00:27:54,720
the shadow

624
00:28:02,070 --> 00:27:58,640
of the edge of this eden region

625
00:28:04,310 --> 00:28:02,080
a global dust storm can encompass mars

626
00:28:06,149 --> 00:28:04,320
in just a week

627
00:28:08,789 --> 00:28:06,159
and we're actually expecting another one

628
00:28:11,350 --> 00:28:08,799
quite soon so i don't know how curiosity

629
00:28:13,269 --> 00:28:11,360
is going to be feeling about that one

630
00:28:15,430 --> 00:28:13,279
but these storms are intermittent and

631
00:28:17,350 --> 00:28:15,440
they go away so

632
00:28:20,230 --> 00:28:17,360
it's a very strange phenomenon that we

633
00:28:21,430 --> 00:28:20,240
don't actually understand it's we think

634
00:28:23,430 --> 00:28:21,440
it's got something to do with the

635
00:28:25,029 --> 00:28:23,440
gravity

636
00:28:26,630 --> 00:28:25,039
but people are still trying to work that

637
00:28:27,830 --> 00:28:26,640
out and it's really great that we've got

638
00:28:29,190 --> 00:28:27,840

these different missions that are going

639
00:28:30,710 --> 00:28:29,200
into orbit around mars and we've got

640
00:28:33,510 --> 00:28:30,720
missions on the surface that can monitor

641
00:28:35,510 --> 00:28:33,520
these long time uh the for a long time

642
00:28:37,830 --> 00:28:35,520
so we can see these

643
00:28:39,990 --> 00:28:37,840
chance occurrences

644
00:28:41,510 --> 00:28:40,000
so that's just another strange thing

645
00:28:43,110 --> 00:28:41,520
those are our terrestrial planets these

646
00:28:45,510 --> 00:28:43,120
are small rocky worlds what happens when

647
00:28:49,110 --> 00:28:45,520
we stick a load of gas on top of that

648
00:28:51,669 --> 00:28:49,120
well you get something like jupiter

649
00:28:53,510 --> 00:28:51,679
isn't that gorgeous i want pictures like

650
00:28:56,070 --> 00:28:53,520
this of everything

651
00:28:58,789 --> 00:28:56,080
this is a beautiful image that was taken

652
00:28:59,750 --> 00:28:58,799
with juno which is currently in orbit

653
00:29:01,029 --> 00:28:59,760
around

654
00:29:02,549 --> 00:29:01,039
jupiter

655
00:29:04,070 --> 00:29:02,559
and you could fit

656
00:29:05,430 --> 00:29:04,080
free earths

657
00:29:08,310 --> 00:29:05,440
in the side

658
00:29:11,029 --> 00:29:08,320
of that storm that is a hurricane the

659
00:29:13,029 --> 00:29:11,039
size of free earth that's hard to

660
00:29:15,269 --> 00:29:13,039
imagine it's not something you can

661
00:29:17,830 --> 00:29:15,279
really put a scale to

662
00:29:19,430 --> 00:29:17,840
to try and help out this is jupiter

663
00:29:21,990 --> 00:29:19,440

looking down at its pole where you can

664
00:29:24,149 --> 00:29:22,000
see these gorgeous vortices this is just

665
00:29:27,909 --> 00:29:24,159
dynamics in action this is fluid

666
00:29:32,149 --> 00:29:27,919
dynamics and it's at its core

667
00:29:34,149 --> 00:29:32,159
and you can fit 11 earths across that

668
00:29:36,230 --> 00:29:34,159
so the storm

669
00:29:38,149 --> 00:29:36,240
around near the equator just south of

670
00:29:39,510 --> 00:29:38,159
the equator on jupiter is three times

671
00:29:41,669 --> 00:29:39,520
the size of the earth

672
00:29:44,870 --> 00:29:41,679
jupiter itself is 11 times the size of

673
00:29:47,029 --> 00:29:44,880
the earth that is a humongous storm you

674
00:29:49,669 --> 00:29:47,039
do not want to be caught in there

675
00:29:51,110 --> 00:29:49,679
not only is it a huge storm but actually

676
00:29:53,029 --> 00:29:51,120
some of the scientific evidence has

677
00:29:55,990 --> 00:29:53,039
shown that it's heating up the

678
00:29:58,230 --> 00:29:56,000
atmosphere above it so the storm itself

679
00:29:59,750 --> 00:29:58,240
is colder than the air that it's

680
00:30:01,350 --> 00:29:59,760
generating above

681
00:30:04,070 --> 00:30:01,360
and that's really interesting for us to

682
00:30:07,430 --> 00:30:04,080
try and understand that this massive

683
00:30:08,389 --> 00:30:07,440
hurricane is generating heat high up in

684
00:30:10,389 --> 00:30:08,399
the atmosphere

685
00:30:12,070 --> 00:30:10,399
how is it transferring that heat and

686
00:30:13,990 --> 00:30:12,080
where's it going afterwards is that

687
00:30:15,669 --> 00:30:14,000
what's sustaining the fact that the

688
00:30:18,070 --> 00:30:15,679

storm is still there

689
00:30:20,310 --> 00:30:18,080
now hubble space telescope images have

690
00:30:23,029 --> 00:30:20,320
shown that this storm is changing size

691
00:30:25,990 --> 00:30:23,039
it's kind of fluctuating but that's over

692
00:30:27,590 --> 00:30:26,000
many years time scale it gets bigger and

693
00:30:29,510 --> 00:30:27,600
smaller and we're like oh it's going

694
00:30:31,110 --> 00:30:29,520
away it's going away and then it comes

695
00:30:34,230 --> 00:30:31,120
back full force and you get a picture

696
00:30:37,110 --> 00:30:34,240
like this which was taken just last year

697
00:30:40,149 --> 00:30:37,120
so it's a truly amazing phenomenon in

698
00:30:45,830 --> 00:30:42,070
but you can see the pole here and i want

699
00:30:48,389 --> 00:30:45,840
you to really focus on that pole

700
00:30:50,389 --> 00:30:48,399
look at all of these gorgeous vortices

701
00:30:53,029 --> 00:30:50,399
look how small some of them are

702
00:30:55,830 --> 00:30:53,039
look at them spiraling down this is the

703
00:30:57,909 --> 00:30:55,840
pole of jupiter if we go to the next

704
00:31:00,149 --> 00:30:57,919
planet saturn

705
00:31:01,750 --> 00:31:00,159
the pole looks very different

706
00:31:03,590 --> 00:31:01,760
there's a strange

707
00:31:05,510 --> 00:31:03,600
giant feature

708
00:31:08,310 --> 00:31:05,520
and if we zoom in

709
00:31:11,029 --> 00:31:08,320
take a look at that

710
00:31:14,230 --> 00:31:11,039
it's formed a beehive shape

711
00:31:16,830 --> 00:31:14,240
nature does this very naturally and it's

712
00:31:18,549 --> 00:31:16,840
all about the way material cools and

713
00:31:20,389 --> 00:31:18,559

expands

714
00:31:22,870 --> 00:31:20,399
but if we zoom in even further we can

715
00:31:24,870 --> 00:31:22,880
see that there's this hurricane right at

716
00:31:26,710 --> 00:31:24,880
the center we didn't see that on jupiter

717
00:31:29,669 --> 00:31:26,720
there wasn't this central

718
00:31:31,909 --> 00:31:29,679
storm this vortex in the center of the

719
00:31:33,269 --> 00:31:31,919
pole like we would expect everything

720
00:31:35,269 --> 00:31:33,279
spinning around there was lots of them

721
00:31:38,149 --> 00:31:35,279
lots of little bowls

722
00:31:41,750 --> 00:31:38,159
here we've got this ginormous storm

723
00:31:43,269 --> 00:31:41,760
right at the pole of saturn inside this

724
00:31:44,630 --> 00:31:43,279
weird

725
00:31:47,029 --> 00:31:44,640
shape

726
00:31:48,389 --> 00:31:47,039
and that really threw people for a while

727
00:31:51,269 --> 00:31:48,399
we're trying to still work on

728
00:31:53,029 --> 00:31:51,279
simulations to see why this is forming

729
00:31:55,669 --> 00:31:53,039
what temperature the material would have

730
00:31:57,430 --> 00:31:55,679
to be what would it be made of to form

731
00:31:58,789 --> 00:31:57,440
this perfect shape

732
00:32:01,430 --> 00:31:58,799
and this came from the cassini

733
00:32:03,509 --> 00:32:01,440
spacecraft

734
00:32:06,549 --> 00:32:03,519
these are modified colors so this is

735
00:32:08,470 --> 00:32:06,559
infrared image this is an optical image

736
00:32:10,870 --> 00:32:08,480
and this is very much modified the blue

737
00:32:12,950 --> 00:32:10,880
that you see there actually is the rings

738
00:32:14,549 --> 00:32:12,960

so we're looking at a slant edge there

739
00:32:16,789 --> 00:32:14,559
and you're seeing the rings in the

740
00:32:19,909 --> 00:32:16,799
distance in this image so these are all

741
00:32:21,750 --> 00:32:19,919
enhanced color images of saturn

742
00:32:25,830 --> 00:32:21,760
this one's a little bit closer to the

743
00:32:28,070 --> 00:32:26,710
but

744
00:32:31,110 --> 00:32:28,080
that's not the coolest place in our

745
00:32:31,990 --> 00:32:31,120
solar system i'm biased but the coolest

746
00:32:34,230 --> 00:32:32,000
place

747
00:32:35,590 --> 00:32:34,240
is neptune

748
00:32:39,350 --> 00:32:35,600
neptune

749
00:32:43,750 --> 00:32:39,360
has winds that reach up to 13

750
00:32:48,070 --> 00:32:43,760
well 1300 miles per hour

751
00:32:49,590 --> 00:32:48,080
1 300 miles per hour and that's what

752
00:32:52,630 --> 00:32:49,600
you're seeing here this image was taken

753
00:32:54,870 --> 00:32:52,640
by voyager 2 when it went past and it

754
00:32:56,870 --> 00:32:54,880
took this image i'm

755
00:32:57,990 --> 00:32:56,880
not ashamed to say just two months after

756
00:32:59,750 --> 00:32:58,000
i was born

757
00:33:02,549 --> 00:32:59,760
um

758
00:33:05,509 --> 00:33:02,559
i'm as old as this images

759
00:33:09,590 --> 00:33:05,519
and it's a fantastic picture of our most

760
00:33:10,870 --> 00:33:09,600
distant giant neptune is an ice giant

761
00:33:13,110 --> 00:33:10,880
and these

762
00:33:15,750 --> 00:33:13,120
this cloud that we're seeing here that

763
00:33:18,789 --> 00:33:15,760

is solid ammonia particles in the

764
00:33:21,509 --> 00:33:18,799
atmosphere it's so cold out there almost

765
00:33:24,870 --> 00:33:21,519
everything freezes and these storms are

766
00:33:27,430 --> 00:33:24,880
whipping around the planet at whopping

767
00:33:29,750 --> 00:33:27,440
speeds those are the fastest winds in

768
00:33:31,830 --> 00:33:29,760
the solar system can't get faster than

769
00:33:32,789 --> 00:33:31,840
that

770
00:33:34,950 --> 00:33:32,799
but

771
00:33:37,430 --> 00:33:34,960
that's just our solar system that's a

772
00:33:39,509 --> 00:33:37,440
statistic of one

773
00:33:41,669 --> 00:33:39,519
we can't deal with that in astronomy we

774
00:33:43,590 --> 00:33:41,679
want lots of things we need to start

775
00:33:45,750 --> 00:33:43,600
looking at all of the other stars what

776
00:33:49,110 --> 00:33:45,760
else is out there what other kind of

777
00:33:50,870 --> 00:33:49,120
phenomena have we not discovered yet

778
00:33:53,350 --> 00:33:50,880
so

779
00:33:56,149 --> 00:33:53,360
how about that

780
00:33:57,350 --> 00:33:56,159
that's just a artist's impression of

781
00:33:59,430 --> 00:33:57,360
just a

782
00:34:02,389 --> 00:33:59,440
handful of the planets that have been

783
00:34:06,070 --> 00:34:02,399
discovered in the last two decades

784
00:34:07,830 --> 00:34:06,080
there are now over 4 000 planets that

785
00:34:10,550 --> 00:34:07,840
have been discovered outside of our

786
00:34:12,470 --> 00:34:10,560
solar system orbiting other stars if you

787
00:34:15,669 --> 00:34:12,480
look up in the night sky

788
00:34:18,149 --> 00:34:15,679

over 50 of them will have planets

789
00:34:20,869 --> 00:34:18,159
and those are just the ones we can see

790
00:34:24,230 --> 00:34:20,879
the stars that we can't see have planets

791
00:34:26,470 --> 00:34:24,240
that number in the billions more planets

792
00:34:27,990 --> 00:34:26,480
than there are stars and we're just

793
00:34:29,349 --> 00:34:28,000
trying to look for them and trying to

794
00:34:31,109 --> 00:34:29,359
understand them

795
00:34:33,349 --> 00:34:31,119
that really helps us try and understand

796
00:34:35,349 --> 00:34:33,359
our own solar system

797
00:34:37,589 --> 00:34:35,359
now there's very few graphs in this talk

798
00:34:39,510 --> 00:34:37,599
but allow me a couple

799
00:34:41,909 --> 00:34:39,520
this is telling you

800
00:34:43,829 --> 00:34:41,919
the planets that have been discovered

801
00:34:46,230 --> 00:34:43,839
at the bottom is their separation from

802
00:34:48,389 --> 00:34:46,240
their star so how far away they are they

803
00:34:50,149 --> 00:34:48,399
are from their star and up the side is

804
00:34:51,109 --> 00:34:50,159
the size of those planets the mass of

805
00:34:53,589 --> 00:34:51,119
them

806
00:34:55,909 --> 00:34:53,599
now to put this in context i dump the

807
00:34:57,430 --> 00:34:55,919
solar system on top of it for you

808
00:34:59,430 --> 00:34:57,440
so we've got jupiter up there and

809
00:35:01,589 --> 00:34:59,440
amongst those blue triangles

810
00:35:03,510 --> 00:35:01,599
we've got saturn uranus and neptune out

811
00:35:05,510 --> 00:35:03,520
there there's nothing really that we've

812
00:35:08,950 --> 00:35:05,520
discovered in that that space in the

813
00:35:10,630 --> 00:35:08,960

diagram and we've got earth down here

814
00:35:12,870 --> 00:35:10,640
now the reason why we haven't discovered

815
00:35:14,550 --> 00:35:12,880
anything in these portions is purely to

816
00:35:16,950 --> 00:35:14,560
do with the techniques that we use and

817
00:35:18,790 --> 00:35:16,960
the ability of our instruments it's not

818
00:35:21,109 --> 00:35:18,800
that they're not there it's that it's

819
00:35:22,390 --> 00:35:21,119
really difficult to find them

820
00:35:24,870 --> 00:35:22,400
and that's a little bit of a problem

821
00:35:26,630 --> 00:35:24,880
that we're trying to work out

822
00:35:28,230 --> 00:35:26,640
but what you're seeing here in red are

823
00:35:31,109 --> 00:35:28,240
these transits and if you've heard about

824
00:35:33,670 --> 00:35:31,119
the kepler mission kepler was

825
00:35:35,109 --> 00:35:33,680
a beauty it was so prolific at finding

826
00:35:37,030 --> 00:35:35,119
these planets we're still trying to work

827
00:35:39,910 --> 00:35:37,040
out if some of them were real it has in

828
00:35:41,990 --> 00:35:39,920
its catalogue thousands more candidate

829
00:35:44,069 --> 00:35:42,000
worlds that people on the ground are

830
00:35:46,710 --> 00:35:44,079
doing observations of right now trying

831
00:35:48,950 --> 00:35:46,720
to work out if those are real planets

832
00:35:50,630 --> 00:35:48,960
orbiting other stars so this number is

833
00:35:52,230 --> 00:35:50,640
just going to keep going up this isn't

834
00:35:54,870 --> 00:35:52,240
steady this isn't everything this is

835
00:35:56,470 --> 00:35:54,880
just a tiny fraction of what is out

836
00:35:58,550 --> 00:35:56,480
there

837
00:36:01,349 --> 00:35:58,560
but what i want you to focus on is this

838
00:36:04,230 --> 00:36:01,359

corner up here away from jupiter in a

839
00:36:06,870 --> 00:36:04,240
very strange parameter space

840
00:36:07,829 --> 00:36:06,880
in this corner of the diagram we are so

841
00:36:12,950 --> 00:36:07,839
close

842
00:36:15,349 --> 00:36:12,960
than the earth is to the sun

843
00:36:19,109 --> 00:36:15,359
that's even eight times closer to their

844
00:36:20,710 --> 00:36:19,119
stars than mercury is to our sun

845
00:36:24,230 --> 00:36:20,720
and we just said that the sun is

846
00:36:27,589 --> 00:36:24,240
bombarding mercury's surface with huge

847
00:36:31,109 --> 00:36:27,599
amounts of radiation and particles

848
00:36:33,589 --> 00:36:31,119
mercury sits inside the sun's atmosphere

849
00:36:36,390 --> 00:36:33,599
these are eight times closer to their

850
00:36:39,190 --> 00:36:36,400
star than mercury is

851
00:36:41,270 --> 00:36:39,200
but also the ones at the top here

852
00:36:43,670 --> 00:36:41,280
they're as big as jupiter

853
00:36:46,230 --> 00:36:43,680
take jupiter that 11 times the size of

854
00:36:47,510 --> 00:36:46,240
the earth planet and stick it right next

855
00:36:49,670 --> 00:36:47,520
to the sun

856
00:36:51,430 --> 00:36:49,680
that's what we're seeing here in this

857
00:36:54,870 --> 00:36:51,440
top corner this is showing us that there

858
00:36:56,870 --> 00:36:54,880
are these giant jupiter-sized worlds

859
00:36:57,829 --> 00:36:56,880
now to put that in context in something

860
00:36:59,829 --> 00:36:57,839
that

861
00:37:01,910 --> 00:36:59,839
you can go home and you can visualize

862
00:37:03,589 --> 00:37:01,920
and try and understand

863
00:37:06,870 --> 00:37:03,599

i want you to imagine that the earth was

864
00:37:11,670 --> 00:37:08,390
now on this scale

865
00:37:13,670 --> 00:37:11,680
if we had our nice jupiter 11 times that

866
00:37:16,470 --> 00:37:13,680
size it would be about the size of an

867
00:37:20,790 --> 00:37:18,630
some of these are bigger than jupiter

868
00:37:23,430 --> 00:37:20,800
you can see that they go all the way up

869
00:37:29,670 --> 00:37:23,440
here

870
00:37:32,150 --> 00:37:29,680
are the size of a large watermelon

871
00:37:33,910 --> 00:37:32,160
they're huge compared to what we have in

872
00:37:35,430 --> 00:37:33,920
our solar system now you'll be

873
00:37:38,069 --> 00:37:35,440
hard-pressed to find such a beautifully

874
00:37:41,030 --> 00:37:38,079
spherical watermelon but if you could

875
00:37:45,190 --> 00:37:43,270
it's a little bit crazy

876
00:37:47,270 --> 00:37:45,200
i find this is a very helpful i call it

877
00:37:49,430 --> 00:37:47,280
my fruit basket of planets

878
00:37:51,109 --> 00:37:49,440
the the neptune ones if you wanted to

879
00:37:53,750 --> 00:37:51,119
look for something this size that'd be

880
00:37:55,030 --> 00:37:53,760
about the size of a plum nice purple

881
00:37:58,150 --> 00:37:55,040
world

882
00:37:59,510 --> 00:37:58,160
and those are actually if you look here

883
00:38:01,510 --> 00:37:59,520
most of the planets that have been

884
00:38:03,910 --> 00:38:01,520
discovered are these neptune-sized

885
00:38:05,990 --> 00:38:03,920
worlds neptune is four times the size of

886
00:38:08,390 --> 00:38:06,000
the earth and most of the planets that

887
00:38:10,390 --> 00:38:08,400
have been discovered are neptune-sized

888
00:38:11,829 --> 00:38:10,400

worlds or something that is slightly

889
00:38:13,750 --> 00:38:11,839
smaller and something we don't have in

890
00:38:15,349 --> 00:38:13,760
our solar system to compare to so

891
00:38:18,630 --> 00:38:15,359
there's a lot out there that we really

892
00:38:19,670 --> 00:38:18,640
don't understand yet

893
00:38:21,190 --> 00:38:19,680
but

894
00:38:22,550 --> 00:38:21,200
how do we take this further this is just

895
00:38:25,109 --> 00:38:22,560
telling us numbers this is just telling

896
00:38:26,630 --> 00:38:25,119
us there are other planets out there

897
00:38:29,030 --> 00:38:26,640
we want to look a little bit closer we

898
00:38:31,030 --> 00:38:29,040
want to try and understand those worlds

899
00:38:32,390 --> 00:38:31,040
now what i'm showing you here is how we

900
00:38:34,550 --> 00:38:32,400
do that

901
00:38:38,470 --> 00:38:34,560
we look for the light

902
00:38:40,390 --> 00:38:38,480
that has come directly from that planet

903
00:38:41,990 --> 00:38:40,400
so we're seeing the emission from that

904
00:38:43,750 --> 00:38:42,000
planet itself

905
00:38:46,470 --> 00:38:43,760
ignoring the star

906
00:38:48,630 --> 00:38:46,480
or we're looking at the starlight

907
00:38:50,069 --> 00:38:48,640
that has shone through that atmosphere

908
00:38:51,829 --> 00:38:50,079
before reaching us and we get an

909
00:38:53,829 --> 00:38:51,839
absorption spectrum

910
00:38:55,750 --> 00:38:53,839
so if that starlight is shining through

911
00:38:57,910 --> 00:38:55,760
that planetary atmosphere anything in

912
00:38:58,710 --> 00:38:57,920
that atmosphere is going to block that

913
00:39:00,950 --> 00:38:58,720

light

914
00:39:03,190 --> 00:39:00,960
and every single molecule has its own

915
00:39:05,990 --> 00:39:03,200
little absorption spectrum its own

916
00:39:07,270 --> 00:39:06,000
little pattern and we can look for those

917
00:39:08,710 --> 00:39:07,280
it's the same in a mission they've got

918
00:39:09,910 --> 00:39:08,720
their own little patterns that we can

919
00:39:12,310 --> 00:39:09,920
look for

920
00:39:14,150 --> 00:39:12,320
but the amount of light that is put out

921
00:39:16,150 --> 00:39:14,160
by the planet alone is very small so

922
00:39:17,750 --> 00:39:16,160
that's very difficult to do

923
00:39:19,910 --> 00:39:17,760
this on the other hand

924
00:39:22,790 --> 00:39:19,920
if those that planet is passing directly

925
00:39:24,550 --> 00:39:22,800
in front of that star we can do this

926
00:39:27,349 --> 00:39:24,560
and we can do this by something called

927
00:39:30,069 --> 00:39:27,359
transmission spectroscopy so take

928
00:39:31,510 --> 00:39:30,079
absorption spectrum we are then shining

929
00:39:33,750 --> 00:39:31,520
the light through the atmosphere it

930
00:39:35,589 --> 00:39:33,760
absorbs and transmits the rest of it

931
00:39:37,510 --> 00:39:35,599
which is why it's called a transmission

932
00:39:38,550 --> 00:39:37,520
spectrum rather than the absorption

933
00:39:41,030 --> 00:39:38,560
spectrum

934
00:39:43,349 --> 00:39:41,040
just to confuse everyone

935
00:39:45,430 --> 00:39:43,359
it confuses everyone that isn't an

936
00:39:48,150 --> 00:39:45,440
exoplanet scientist i think we did it on

937
00:39:51,990 --> 00:39:50,230
so what we're doing is we're looking at

938
00:39:54,390 --> 00:39:52,000

that planet as it passes in front of its

939
00:39:56,790 --> 00:39:54,400
star as it as it does it blocks out a

940
00:39:58,630 --> 00:39:56,800
very small amount of that light

941
00:40:00,950 --> 00:39:58,640
if we look at that in lots of different

942
00:40:03,109 --> 00:40:00,960
wavelengths if we build up our colors we

943
00:40:05,510 --> 00:40:03,119
look at it in say

944
00:40:07,670 --> 00:40:05,520
i don't know red or blue

945
00:40:09,750 --> 00:40:07,680
we get a different amount of absorption

946
00:40:11,910 --> 00:40:09,760
because the atmosphere is going to be

947
00:40:14,150 --> 00:40:11,920
absorbing some of that light

948
00:40:16,150 --> 00:40:14,160
and then we build up our colors we get

949
00:40:18,550 --> 00:40:16,160
our picture and we start putting it

950
00:40:20,870 --> 00:40:18,560
together and we get the change in the

951
00:40:22,390 --> 00:40:20,880
amount of light blocked by that planet

952
00:40:23,750 --> 00:40:22,400
over different wavelengths over

953
00:40:25,990 --> 00:40:23,760
different colors

954
00:40:27,750 --> 00:40:26,000
and then we can start using some of the

955
00:40:30,550 --> 00:40:27,760
physics that we understand we can use

956
00:40:33,190 --> 00:40:30,560
the spectra each element each molecule

957
00:40:35,349 --> 00:40:33,200
has its unique fingerprint if we piece

958
00:40:36,950 --> 00:40:35,359
that together and try to understand it

959
00:40:38,870 --> 00:40:36,960
we can put a model to that and try and

960
00:40:40,470 --> 00:40:38,880
work out what's in the atmosphere in

961
00:40:43,190 --> 00:40:40,480
this case what it's showing you is some

962
00:40:44,710 --> 00:40:43,200
sodium and potassium there

963
00:40:46,069 --> 00:40:44,720

what you're seeing over here is

964
00:40:48,390 --> 00:40:46,079
something that i recently did with the

965
00:40:50,550 --> 00:40:48,400
hubble space telescope and you're seeing

966
00:40:52,630 --> 00:40:50,560
this slope here from hydrogen and helium

967
00:40:54,790 --> 00:40:52,640
in the atmosphere these are big gassy

968
00:40:56,950 --> 00:40:54,800
worlds mostly hydrogen and helium you're

969
00:40:59,109 --> 00:40:56,960
seeing this sodium absorption this

970
00:41:00,309 --> 00:40:59,119
potassium absorption and most

971
00:41:02,230 --> 00:41:00,319
importantly

972
00:41:03,990 --> 00:41:02,240
huge amounts of water vapor in the

973
00:41:05,990 --> 00:41:04,000
atmosphere

974
00:41:07,829 --> 00:41:06,000
they're so close to their star they're

975
00:41:12,470 --> 00:41:07,839
incredibly hot

976
00:41:14,470 --> 00:41:12,480
they're about 1 500 kelvin

977
00:41:16,470 --> 00:41:14,480
they're very very hot everything's in

978
00:41:18,309 --> 00:41:16,480
the gas phase so what we found was

979
00:41:19,750 --> 00:41:18,319
there's lots of water none of it's

980
00:41:21,910 --> 00:41:19,760
liquid it's all

981
00:41:27,349 --> 00:41:21,920
happily floating around in the gas these

982
00:41:30,950 --> 00:41:27,359
are these are boiling pots of material

983
00:41:33,510 --> 00:41:30,960
so that's how we we do that

984
00:41:35,910 --> 00:41:33,520
another way of showing this

985
00:41:38,550 --> 00:41:35,920
showing this change in depth is showing

986
00:41:40,630 --> 00:41:38,560
you how the planet appears to us

987
00:41:42,309 --> 00:41:40,640
what it's doing is it's changing its

988
00:41:43,829 --> 00:41:42,319

relative size it's changing the amount

989
00:41:45,750 --> 00:41:43,839
of light it's blocking out so if you've

990
00:41:47,349 --> 00:41:45,760
got our model and we watch this the

991
00:41:49,510 --> 00:41:47,359
planet looks like it gets bigger and

992
00:41:51,510 --> 00:41:49,520
smaller bigger and smaller as it's

993
00:41:52,790 --> 00:41:51,520
absorbing that light

994
00:41:55,109 --> 00:41:52,800
and that's what we're doing we're

995
00:41:57,190 --> 00:41:55,119
looking for this change in the size of

996
00:41:59,030 --> 00:41:57,200
that planet as you go through all of

997
00:42:00,550 --> 00:41:59,040
those colors

998
00:42:02,470 --> 00:42:00,560
i find that's a very helpful

999
00:42:04,309 --> 00:42:02,480
visualization i even have to go back to

1000
00:42:06,470 --> 00:42:04,319
it every now and again to remember what

1001
00:42:08,390 --> 00:42:06,480
it is we're doing

1002
00:42:10,790 --> 00:42:08,400
so taking all of that

1003
00:42:12,470 --> 00:42:10,800
the techniques that we use

1004
00:42:15,190 --> 00:42:12,480
how do we do that i've already hinted at

1005
00:42:17,270 --> 00:42:15,200
this but we need our eye on that storm

1006
00:42:19,109 --> 00:42:17,280
we need to be looking for this how are

1007
00:42:22,230 --> 00:42:19,119
we doing that

1008
00:42:24,470 --> 00:42:22,240
my favorite workhorse in astronomy the

1009
00:42:27,109 --> 00:42:24,480
hubble space telescope he gave me my phd

1010
00:42:29,109 --> 00:42:27,119
so i'm quite happy with it right now

1011
00:42:31,750 --> 00:42:29,119
the hubble space telescope has been an

1012
00:42:34,069 --> 00:42:31,760
amazing tour de force of looking at

1013
00:42:36,950 --> 00:42:34,079

these exoplanet atmospheres

1014
00:42:38,230 --> 00:42:36,960
and this is showing you ten different

1015
00:42:40,950 --> 00:42:38,240
planets

1016
00:42:43,030 --> 00:42:40,960
you can see them happily rotating there

1017
00:42:44,069 --> 00:42:43,040
these are ten different planets that we

1018
00:42:45,829 --> 00:42:44,079
looked at with the hubble space

1019
00:42:47,270 --> 00:42:45,839
telescope and we got that spectrum we

1020
00:42:48,790 --> 00:42:47,280
got those fingerprints from those

1021
00:42:51,270 --> 00:42:48,800
molecules

1022
00:42:53,109 --> 00:42:51,280
but what we found was that these

1023
00:42:54,230 --> 00:42:53,119
jupiter-sized planets

1024
00:42:58,710 --> 00:42:54,240
all of them

1025
00:43:01,190 --> 00:42:58,720
times closer to their star than we are

1026
00:43:02,950 --> 00:43:01,200
to the sun so we would expect them all

1027
00:43:04,710 --> 00:43:02,960
to be roughly the same

1028
00:43:08,870 --> 00:43:04,720
they're all different of course they are

1029
00:43:13,430 --> 00:43:11,589
we have no clue

1030
00:43:15,510 --> 00:43:13,440
they are all different and what we're

1031
00:43:17,750 --> 00:43:15,520
seeing here is that they go from very

1032
00:43:19,910 --> 00:43:17,760
clear atmospheres so what we would

1033
00:43:21,829 --> 00:43:19,920
expect to be finding all gas phase

1034
00:43:23,430 --> 00:43:21,839
everything's a gas it's so hot it should

1035
00:43:25,829 --> 00:43:23,440
be a gas

1036
00:43:28,230 --> 00:43:25,839
down to these ones which display

1037
00:43:29,829 --> 00:43:28,240
really flat spectra we don't know

1038
00:43:31,030 --> 00:43:29,839

there's something blocking that what is

1039
00:43:33,030 --> 00:43:31,040
blocking that

1040
00:43:34,550 --> 00:43:33,040
down to these ones which show these huge

1041
00:43:36,550 --> 00:43:34,560
slants

1042
00:43:40,309 --> 00:43:36,560
which shows that things are scattering

1043
00:43:42,550 --> 00:43:40,319
in the blue end and then in the red end

1044
00:43:44,630 --> 00:43:42,560
they're not

1045
00:43:46,470 --> 00:43:44,640
what is happening here what i love about

1046
00:43:48,390 --> 00:43:46,480
this little animation is that if you

1047
00:43:50,069 --> 00:43:48,400
watch it carefully you can see that

1048
00:43:52,230 --> 00:43:50,079
they're all rotating at a different

1049
00:43:53,990 --> 00:43:52,240
speed

1050
00:43:57,349 --> 00:43:54,000
and that's because they have different

1051
00:43:59,270 --> 00:43:57,359
orbital periods and their orbital period

1052
00:44:02,390 --> 00:43:59,280
matches

1053
00:44:04,470 --> 00:44:02,400
their their rotation speed

1054
00:44:05,510 --> 00:44:04,480
we have that phenomenon here

1055
00:44:15,109 --> 00:44:05,520
the moon

1056
00:44:17,430 --> 00:44:15,119
these are what is called tidally locked

1057
00:44:19,910 --> 00:44:17,440
to their star they have a permanent

1058
00:44:21,990 --> 00:44:19,920
dayside which is always facing the star

1059
00:44:24,470 --> 00:44:22,000
and a permanent night nightside which is

1060
00:44:27,030 --> 00:44:24,480
always facing away you have

1061
00:44:29,750 --> 00:44:27,040
heat from the star bombarding one side

1062
00:44:31,270 --> 00:44:29,760
and no light at all getting to the other

1063
00:44:33,670 --> 00:44:31,280

side of that planet

1064
00:44:35,430 --> 00:44:33,680
so that does some very strange things to

1065
00:44:36,710 --> 00:44:35,440
a planetary atmosphere

1066
00:44:38,870 --> 00:44:36,720
and i'm going to take you through some

1067
00:44:40,870 --> 00:44:38,880
of those later

1068
00:44:42,390 --> 00:44:40,880
but it's not just these 10 planets that

1069
00:44:43,990 --> 00:44:42,400
we've looked at

1070
00:44:45,990 --> 00:44:44,000
this is just a smattering of some of the

1071
00:44:48,150 --> 00:44:46,000
work that i've been doing

1072
00:44:50,069 --> 00:44:48,160
i've got more now where all of those

1073
00:44:52,230 --> 00:44:50,079
gaps are so i've got some work ahead of

1074
00:44:53,829 --> 00:44:52,240
me but what we're finding is that these

1075
00:44:55,829 --> 00:44:53,839
giant planets

1076
00:44:57,270 --> 00:44:55,839
eighty percent of them show evidence

1077
00:44:58,470 --> 00:44:57,280
that there is water vapor in their

1078
00:45:00,950 --> 00:44:58,480
atmosphere

1079
00:45:02,829 --> 00:45:00,960
we're seeing this fingerprint of water

1080
00:45:06,710 --> 00:45:02,839
gas in the atmosphere of these giant

1081
00:45:09,109 --> 00:45:06,720
planets water is the third most abundant

1082
00:45:11,589 --> 00:45:09,119
molecule in the entire universe it's

1083
00:45:13,270 --> 00:45:11,599
absolutely everywhere we look and we

1084
00:45:15,670 --> 00:45:13,280
need to really understand the balance of

1085
00:45:18,390 --> 00:45:15,680
water in these atmospheres to work out

1086
00:45:20,069 --> 00:45:18,400
where and how they formed

1087
00:45:22,630 --> 00:45:20,079
but unfortunately

1088
00:45:26,230 --> 00:45:22,640

we can't quite get there yet because we

1089
00:45:28,790 --> 00:45:26,240
can't constrain it a lot of these have

1090
00:45:30,790 --> 00:45:28,800
very large uncertainties on them

1091
00:45:33,589 --> 00:45:30,800
that means that we can't

1092
00:45:36,710 --> 00:45:33,599
precisely measure how much water there

1093
00:45:39,430 --> 00:45:36,720
is and only roughly five percent of them

1094
00:45:41,750 --> 00:45:39,440
have this nice precise measurement so

1095
00:45:44,470 --> 00:45:41,760
that we can work out perhaps where that

1096
00:45:47,109 --> 00:45:44,480
planet formed

1097
00:45:48,630 --> 00:45:47,119
enter the james webb space telescope and

1098
00:45:49,990 --> 00:45:48,640
for those of you who were here at the

1099
00:45:51,589 --> 00:45:50,000
last one we had a really nice

1100
00:45:52,710 --> 00:45:51,599
presentation on the james webb space

1101
00:45:55,030 --> 00:45:52,720
telescope

1102
00:45:56,230 --> 00:45:55,040
it's going to be launching in spring of

1103
00:45:59,829 --> 00:45:56,240
next year

1104
00:46:01,589 --> 00:45:59,839
and it is going to be a lot larger than

1105
00:46:03,349 --> 00:46:01,599
hubble it's going to be a lot further

1106
00:46:05,109 --> 00:46:03,359
away from the earth so we're not going

1107
00:46:05,990 --> 00:46:05,119
to have the earth's light getting in the

1108
00:46:08,150 --> 00:46:06,000
way

1109
00:46:10,710 --> 00:46:08,160
and it's going to be looking in the

1110
00:46:12,630 --> 00:46:10,720
infrared in a different wavelength

1111
00:46:14,790 --> 00:46:12,640
and what that allows us to do is look

1112
00:46:16,630 --> 00:46:14,800
for different molecules instead of just

1113
00:46:18,950 --> 00:46:16,640

looking at the water that we can see

1114
00:46:21,670 --> 00:46:18,960
here we're also looking for this carbon

1115
00:46:23,349 --> 00:46:21,680
dioxide in the atmosphere

1116
00:46:25,589 --> 00:46:23,359
and that's really important for us to

1117
00:46:27,109 --> 00:46:25,599
understand the balance between oxygen

1118
00:46:29,109 --> 00:46:27,119
and carbon

1119
00:46:30,470 --> 00:46:29,119
this is just a simulation that was done

1120
00:46:32,950 --> 00:46:30,480
by one of my colleagues natasha

1121
00:46:34,870 --> 00:46:32,960
battaglia and this is simulating the

1122
00:46:36,870 --> 00:46:34,880
atmosphere of one of those those planets

1123
00:46:40,710 --> 00:46:36,880
that i showed you before we're going to

1124
00:46:43,030 --> 00:46:40,720
get absolutely beautiful precision data

1125
00:46:45,270 --> 00:46:43,040
on these so that we can understand this

1126
00:46:47,349 --> 00:46:45,280
planet's atmosphere where did it come

1127
00:46:49,670 --> 00:46:47,359
from how did it get there what is it

1128
00:46:51,750 --> 00:46:49,680
made of

1129
00:46:53,030 --> 00:46:51,760
now that's not the only one there's

1130
00:46:55,750 --> 00:46:53,040
loads of them that we're going to be

1131
00:46:57,670 --> 00:46:55,760
looking at this is just one from a dd

1132
00:46:59,829 --> 00:46:57,680
director's discretionary early release

1133
00:47:02,069 --> 00:46:59,839
science time that has been awarded to

1134
00:47:03,510 --> 00:47:02,079
the exoplanet transiting community and

1135
00:47:07,670 --> 00:47:03,520
we're going to be getting observations

1136
00:47:09,109 --> 00:47:07,680
of this giant planet called wasp 79b

1137
00:47:12,069 --> 00:47:09,119
great name

1138
00:47:13,349 --> 00:47:12,079

was 79b uh from our observations with

1139
00:47:14,790 --> 00:47:13,359
hubble which are in gray in the

1140
00:47:16,630 --> 00:47:14,800
background there

1141
00:47:18,630 --> 00:47:16,640
this is what we predict we're going to

1142
00:47:19,990 --> 00:47:18,640
be observing with the james webb space

1143
00:47:23,750 --> 00:47:20,000
telescope

1144
00:47:26,950 --> 00:47:23,760
amazing precision there on this co and

1145
00:47:28,950 --> 00:47:26,960
co2 features and the water and what you

1146
00:47:31,190 --> 00:47:28,960
can see here in red is what we

1147
00:47:33,589 --> 00:47:31,200
understand based on hubble data alone

1148
00:47:34,870 --> 00:47:33,599
and then in blue how much better we

1149
00:47:36,069 --> 00:47:34,880
would understand this planet's

1150
00:47:38,069 --> 00:47:36,079
atmosphere

1151
00:47:40,150 --> 00:47:38,079
just from adding these observations with

1152
00:47:43,270 --> 00:47:40,160
the james webb space telescope

1153
00:47:45,190 --> 00:47:43,280
so we have a huge amount to learn about

1154
00:47:47,109 --> 00:47:45,200
these exoplanets and it's all going to

1155
00:47:49,589 --> 00:47:47,119
be coming in the next decade we're going

1156
00:47:51,030 --> 00:47:49,599
to know so much more about how planetary

1157
00:47:53,270 --> 00:47:51,040
systems form

1158
00:47:55,030 --> 00:47:53,280
and how a planetary system like our own

1159
00:47:58,230 --> 00:47:55,040
formed

1160
00:48:00,390 --> 00:47:58,240
so that's all to look forward to

1161
00:48:02,550 --> 00:48:00,400
but let's delve into the atmospheres of

1162
00:48:06,630 --> 00:48:02,560
some of these planets a little bit more

1163
00:48:09,190 --> 00:48:06,640

explore some alien worlds with me

1164
00:48:11,190 --> 00:48:09,200
i want you to watch this video

1165
00:48:16,150 --> 00:48:11,200
i want you to tell me

1166
00:48:33,109 --> 00:48:17,670
sunrise

1167
00:48:37,589 --> 00:48:34,470
what you'll notice

1168
00:48:39,510 --> 00:48:37,599
is the colors are remarkably similar

1169
00:48:40,710 --> 00:48:39,520
what i think is immediately apparent is

1170
00:48:42,790 --> 00:48:40,720
that it's a

1171
00:48:44,230 --> 00:48:42,800
bit larger than what we're seeing here

1172
00:48:47,750 --> 00:48:44,240
on the earth

1173
00:48:49,430 --> 00:48:47,760
that is an actual size scale image

1174
00:48:51,270 --> 00:48:49,440
compared to the earth of what the

1175
00:48:52,790 --> 00:48:51,280
sunrise would look like if you were in

1176
00:48:56,390 --> 00:48:52,800
the atmosphere of a planet called

1177
00:49:01,190 --> 00:48:59,030
telephone numbers

1178
00:49:03,430 --> 00:49:01,200
a lot of this audience remember having

1179
00:49:05,589 --> 00:49:03,440
to memorize telephone numbers

1180
00:49:08,710 --> 00:49:05,599
that's what we're doing still

1181
00:49:13,589 --> 00:49:10,870
much like the earth's atmosphere

1182
00:49:15,190 --> 00:49:13,599
scatters all of its light in the blue

1183
00:49:17,910 --> 00:49:15,200
end of the spectrum

1184
00:49:19,109 --> 00:49:17,920
it scatters that light away and if you

1185
00:49:21,349 --> 00:49:19,119
were sitting looking through the

1186
00:49:25,990 --> 00:49:21,359
atmosphere at its star you would see

1187
00:49:28,710 --> 00:49:26,000
this gorgeous red hue across the star

1188
00:49:30,710 --> 00:49:28,720

much like the earth sunset

1189
00:49:33,190 --> 00:49:30,720
you of course on this planet would be 20

1190
00:49:35,910 --> 00:49:33,200
times closer so the star in the sky

1191
00:49:38,230 --> 00:49:35,920
would look a lot bigger

1192
00:49:40,470 --> 00:49:38,240
and also because you're so much closer

1193
00:49:42,950 --> 00:49:40,480
to the star you'd see all of the arrays

1194
00:49:45,829 --> 00:49:42,960
of the colors of a sunset all at once

1195
00:49:48,710 --> 00:49:45,839
so it would be a beautiful spectacle

1196
00:49:49,910 --> 00:49:48,720
now of course another caveat to this

1197
00:49:51,910 --> 00:49:49,920
is that

1198
00:49:54,349 --> 00:49:51,920
you'd be sitting in an atmosphere that

1199
00:49:56,950 --> 00:49:54,359
was at the temperature of

1200
00:49:57,670 --> 00:49:56,960
1200 degrees

1201
00:50:00,309 --> 00:49:57,680
so

1202
00:50:03,349 --> 00:50:00,319
you wouldn't be very happy

1203
00:50:06,870 --> 00:50:03,359
uh you would also be sitting in an

1204
00:50:08,790 --> 00:50:06,880
atmosphere where it's tidally locked so

1205
00:50:11,349 --> 00:50:08,800
the only way you can see the sunset is

1206
00:50:12,870 --> 00:50:11,359
to be sitting specifically at a point on

1207
00:50:15,349 --> 00:50:12,880
the edge of that atmosphere between the

1208
00:50:17,910 --> 00:50:15,359
day and the night

1209
00:50:20,950 --> 00:50:17,920
the boundary between the bright

1210
00:50:23,270 --> 00:50:20,960
sun bombarded dayside and the cold

1211
00:50:25,510 --> 00:50:23,280
frigid lightless night side of this

1212
00:50:30,309 --> 00:50:25,520
planet you'd be looking out at that star

1213
00:50:34,309 --> 00:50:31,990

but that's kind of like the earth it

1214
00:50:37,430 --> 00:50:34,319
scatters it's a bit

1215
00:50:38,829 --> 00:50:37,440
boring sunset we've seen that one before

1216
00:50:40,390 --> 00:50:38,839
what about this

1217
00:50:42,549 --> 00:50:40,400
one

1218
00:50:47,630 --> 00:50:42,559
this is a simulation of a sunset on a

1219
00:50:53,829 --> 00:50:51,670
hd209458b has sodium in its atmosphere

1220
00:50:56,150 --> 00:50:53,839
and it doesn't scatter light like the

1221
00:50:59,109 --> 00:50:56,160
earth's atmosphere it doesn't scatter

1222
00:51:00,950 --> 00:50:59,119
all of this blue light

1223
00:51:03,270 --> 00:51:00,960
it's relatively flat

1224
00:51:04,069 --> 00:51:03,280
but then it's got sodium absorbing that

1225
00:51:06,549 --> 00:51:04,079
light

1226
00:51:09,109 --> 00:51:06,559
now sodium is a nice yellow color street

1227
00:51:10,630 --> 00:51:09,119
lamps are sodium lamps they shine a nice

1228
00:51:16,790 --> 00:51:10,640
orange

1229
00:51:18,549 --> 00:51:16,800
your spectrum

1230
00:51:20,710 --> 00:51:18,559
so it's being absorbed you're not seeing

1231
00:51:21,750 --> 00:51:20,720
that for your sunset so take out that

1232
00:51:23,430 --> 00:51:21,760
orange

1233
00:51:25,990 --> 00:51:23,440
and then see what the sun would look

1234
00:51:27,589 --> 00:51:26,000
like and it would look a nice alien

1235
00:51:30,230 --> 00:51:27,599
green blue

1236
00:51:32,870 --> 00:51:30,240
this is what the sun would look like oh

1237
00:51:35,349 --> 00:51:32,880
the star that hd well i'm going to say

1238
00:51:37,829 --> 00:51:35,359

it wrong hd209458

1239
00:51:38,990 --> 00:51:37,839
is the star the planet is the b

1240
00:51:41,270 --> 00:51:39,000
so this is what

1241
00:51:43,430 --> 00:51:41,280
hg209458 would look like from the

1242
00:51:45,750 --> 00:51:43,440
atmosphere of the planet

1243
00:51:49,190 --> 00:51:45,760
alien green and that's because there's

1244
00:51:51,430 --> 00:51:49,200
sodium in that atmosphere

1245
00:51:53,030 --> 00:51:51,440
absolutely brilliant

1246
00:51:55,430 --> 00:51:53,040
but i want to take you back to this

1247
00:51:56,950 --> 00:51:55,440
boring mundane sunset right now because

1248
00:51:59,670 --> 00:51:56,960
this planet's more interesting than it

1249
00:52:01,190 --> 00:51:59,680
lets it out to be

1250
00:52:03,750 --> 00:52:01,200
this planet

1251
00:52:06,109 --> 00:52:03,760
has shards in the wind

1252
00:52:09,230 --> 00:52:06,119
it is as i said

1253
00:52:15,190 --> 00:52:09,240
1200 degrees

1254
00:52:16,950 --> 00:52:15,200
it is also being bombarded by an active

1255
00:52:19,349 --> 00:52:16,960
star what you're going to see here in

1256
00:52:24,870 --> 00:52:19,359
this video is a flare go off on that

1257
00:52:29,670 --> 00:52:27,190
and this is a simulation that is done

1258
00:52:31,750 --> 00:52:29,680
based on the data down here

1259
00:52:33,349 --> 00:52:31,760
this is showing us that when a flare

1260
00:52:35,589 --> 00:52:33,359
goes off and this was measured with an

1261
00:52:37,589 --> 00:52:35,599
x-ray telescope the flare from the star

1262
00:52:39,589 --> 00:52:37,599
was measured and then the planet was

1263
00:52:42,710 --> 00:52:39,599

looked at during this time

1264
00:52:45,109 --> 00:52:42,720
using a uv telescope and what it saw was

1265
00:52:47,030 --> 00:52:45,119
a really big spike in the lyman alpha

1266
00:52:48,470 --> 00:52:47,040
and that's looking for hydrogen lyman

1267
00:52:51,270 --> 00:52:48,480
alpha lines are

1268
00:52:53,990 --> 00:52:51,280
created by hydrogen

1269
00:52:57,109 --> 00:52:54,000
and what we saw was this humongous tail

1270
00:52:59,829 --> 00:52:57,119
of material that had been blasted off of

1271
00:53:02,150 --> 00:52:59,839
this planet's atmosphere by this flare

1272
00:53:05,589 --> 00:53:02,160
from the star

1273
00:53:07,750 --> 00:53:05,599
that's a violent place to be

1274
00:53:09,430 --> 00:53:07,760
not only is it a violent place to be

1275
00:53:12,150 --> 00:53:09,440
because of the star

1276
00:53:15,750 --> 00:53:12,160
but the winds on this planet remember i

1277
00:53:18,790 --> 00:53:15,760
said neptune's winds 1200

1278
00:53:20,910 --> 00:53:18,800
miles per hour the winds on this planet

1279
00:53:24,790 --> 00:53:20,920
have been measured to be

1280
00:53:27,750 --> 00:53:24,800
5400 miles per hour

1281
00:53:30,069 --> 00:53:27,760
whipping around that planet's equator in

1282
00:53:32,309 --> 00:53:30,079
a huge band

1283
00:53:34,870 --> 00:53:32,319
speeds that are

1284
00:53:37,109 --> 00:53:34,880
absolutely insane you physically cannot

1285
00:53:39,190 --> 00:53:37,119
imagine them

1286
00:53:41,109 --> 00:53:39,200
but because of the temperature of this

1287
00:53:44,230 --> 00:53:41,119
planet's atmosphere there's another

1288
00:53:47,109 --> 00:53:44,240

issue god it's really a horrible place

1289
00:53:49,030 --> 00:53:47,119
the other issue is that there are clouds

1290
00:53:50,790 --> 00:53:49,040
in this planet's atmosphere

1291
00:53:53,670 --> 00:53:50,800
now the clouds here on earth are made of

1292
00:53:56,150 --> 00:53:53,680
water we like water it's a bit painful

1293
00:53:59,030 --> 00:53:56,160
when it's hitting you and it's hail or

1294
00:54:01,829 --> 00:53:59,040
it's a bit cold when it's snow

1295
00:54:04,710 --> 00:54:01,839
these clouds are made of magnesium

1296
00:54:06,950 --> 00:54:04,720
silicates they're made of sand

1297
00:54:07,829 --> 00:54:06,960
but they're not made of

1298
00:54:10,150 --> 00:54:07,839
nice

1299
00:54:11,670 --> 00:54:10,160
beach sand that kind of hurts when it

1300
00:54:15,190 --> 00:54:11,680
blows off the beach

1301
00:54:18,750 --> 00:54:15,200
these are made of molten glass

1302
00:54:23,109 --> 00:54:18,760
and that is flying into you at

1303
00:54:24,390 --> 00:54:23,119
5400 miles per hour horizontal winds of

1304
00:54:27,510 --> 00:54:24,400
molten glass

1305
00:54:28,950 --> 00:54:27,520
over a thousand degrees

1306
00:54:32,470 --> 00:54:28,960
and then every now and again you'll get

1307
00:54:36,710 --> 00:54:32,480
blasted by radiation from the star

1308
00:54:41,589 --> 00:54:39,990
that's just the start of the craziness

1309
00:54:43,190 --> 00:54:41,599
this planet has been studied the most

1310
00:54:44,950 --> 00:54:43,200
out of almost all of the exoplanets that

1311
00:54:46,150 --> 00:54:44,960
we've been observing so we know quite a

1312
00:54:48,790 --> 00:54:46,160
lot about it

1313
00:54:51,109 --> 00:54:48,800

but there are other really wacky worlds

1314
00:54:54,710 --> 00:54:51,119
out there that we're learning about

1315
00:54:55,790 --> 00:54:54,720
one of them is hg80606b

1316
00:55:00,470 --> 00:54:55,800
and

1317
00:55:02,150 --> 00:55:00,480
hd80606b is essentially a jupiter-sized

1318
00:55:04,470 --> 00:55:02,160
comet

1319
00:55:05,430 --> 00:55:04,480
this is its orbit compared to our solar

1320
00:55:08,230 --> 00:55:05,440
system

1321
00:55:10,790 --> 00:55:08,240
it comes in from up here

1322
00:55:12,390 --> 00:55:10,800
close to where the earth orbits

1323
00:55:14,950 --> 00:55:12,400
so it's

1324
00:55:17,510 --> 00:55:14,960
fairly decent quite nice out there and

1325
00:55:19,829 --> 00:55:17,520
then it whips right down close to its

1326
00:55:23,910 --> 00:55:19,839
star

1327
00:55:26,630 --> 00:55:23,920
actually goes much much closer

1328
00:55:28,630 --> 00:55:26,640
and then it slingshots out again and

1329
00:55:31,190 --> 00:55:28,640
then it comes back down

1330
00:55:34,390 --> 00:55:31,200
and then it slingshots out again this is

1331
00:55:37,430 --> 00:55:34,400
a cometary jupiter-sized world can you

1332
00:55:39,589 --> 00:55:37,440
imagine what that does to an atmosphere

1333
00:55:41,750 --> 00:55:39,599
we call this an engineering problem more

1334
00:55:43,109 --> 00:55:41,760
than anything in engineering you hit

1335
00:55:44,549 --> 00:55:43,119
something with a hammer and you wait to

1336
00:55:45,589 --> 00:55:44,559
see how long it takes to go back to

1337
00:55:48,789 --> 00:55:45,599
normal

1338
00:55:50,549 --> 00:55:48,799

the every time this planet orbits gets

1339
00:55:52,470 --> 00:55:50,559
hit by a hammer and we have to wait to

1340
00:55:54,069 --> 00:55:52,480
see how long it goes back to normal and

1341
00:55:56,950 --> 00:55:54,079
actually we've been making those

1342
00:55:59,349 --> 00:55:56,960
observations with the telescopes and we

1343
00:56:01,670 --> 00:55:59,359
can do that measurement

1344
00:56:04,630 --> 00:56:01,680
by looking at the planet over the course

1345
00:56:07,030 --> 00:56:04,640
of this orbit and looking at how that

1346
00:56:09,510 --> 00:56:07,040
atmosphere is reacting by measuring the

1347
00:56:13,349 --> 00:56:09,520
heat now i don't know if this video is

1348
00:56:18,150 --> 00:56:16,309
i think it is now and this is a actual

1349
00:56:20,789 --> 00:56:18,160
this is a model of what happens to this

1350
00:56:24,150 --> 00:56:20,799
planet's atmosphere as it comes close to

1351
00:56:27,030 --> 00:56:24,160
the star it starts to heat up it gets

1352
00:56:29,190 --> 00:56:27,040
smacked in the face and then over time

1353
00:56:31,510 --> 00:56:29,200
it settles back down again and if you

1354
00:56:34,710 --> 00:56:31,520
look towards the end there you can see

1355
00:56:37,109 --> 00:56:34,720
this bow shock coming around here just

1356
00:56:38,950 --> 00:56:37,119
shock waves going around and around the

1357
00:56:40,789 --> 00:56:38,960
planet as it tries to

1358
00:56:43,270 --> 00:56:40,799
calm down and get back to normal the

1359
00:56:45,190 --> 00:56:43,280
adrenaline rush is kind of coming down

1360
00:56:48,150 --> 00:56:45,200
we're sitting nice and happily back out

1361
00:56:50,710 --> 00:56:48,160
here and then roller coaster ride and

1362
00:56:53,430 --> 00:56:50,720
getting hit again this atmosphere goes

1363
00:56:56,589 --> 00:56:53,440

through extreme growing pains every time

1364
00:57:00,950 --> 00:56:56,599
it comes close to the star and it's on a

1365
00:57:02,069 --> 00:57:00,960
111 day orbit so it happens quite often

1366
00:57:04,710 --> 00:57:02,079
for it

1367
00:57:06,549 --> 00:57:04,720
and it's a great kind of

1368
00:57:09,190 --> 00:57:06,559
test tube for us understanding the

1369
00:57:13,990 --> 00:57:09,200
engineering of a planetary atmosphere

1370
00:57:17,589 --> 00:57:15,349
crazy planet

1371
00:57:20,950 --> 00:57:17,599
now the next one is one of my favorites

1372
00:57:25,109 --> 00:57:22,710
what's 12b

1373
00:57:26,789 --> 00:57:25,119
not only is it easier to remember

1374
00:57:29,829 --> 00:57:26,799
bonus

1375
00:57:32,789 --> 00:57:29,839
uh but what we saw when we measured this

1376
00:57:35,670 --> 00:57:32,799
atmosphere was this kind of slope again

1377
00:57:38,390 --> 00:57:35,680
like i showed you with that hd189733

1378
00:57:41,190 --> 00:57:38,400
we saw this scattering from the blue end

1379
00:57:43,190 --> 00:57:41,200
all the way down into the infrared

1380
00:57:44,549 --> 00:57:43,200
now the reason why this sunset's a

1381
00:57:45,910 --> 00:57:44,559
little duller

1382
00:57:48,549 --> 00:57:45,920
than we see

1383
00:57:51,109 --> 00:57:48,559
in 189 is because it's scattering

1384
00:57:53,270 --> 00:57:51,119
uniformly at all wavelengths

1385
00:57:56,150 --> 00:57:53,280
it's just scattering all that light and

1386
00:57:57,990 --> 00:57:56,160
it's a very film noir kind of sunset on

1387
00:58:00,390 --> 00:57:58,000
this one it's all very kind of

1388
00:58:03,910 --> 00:58:00,400

mysterious

1389
00:58:06,349 --> 00:58:03,920
but this planet's even hotter than hd189

1390
00:58:09,710 --> 00:58:06,359
this planet is

1391
00:58:11,990 --> 00:58:09,720
2500 degrees on its day side

1392
00:58:14,309 --> 00:58:12,000
2500 degrees that's hotter than sitting

1393
00:58:15,670 --> 00:58:14,319
under that falcon 9 as it was taking off

1394
00:58:17,829 --> 00:58:15,680
sitting right underneath that that

1395
00:58:19,750 --> 00:58:17,839
planet is sitting in that temperature

1396
00:58:22,309 --> 00:58:19,760
all the time

1397
00:58:23,750 --> 00:58:22,319
now what this scattering tells us is

1398
00:58:25,430 --> 00:58:23,760
that there's something in the atmosphere

1399
00:58:28,230 --> 00:58:25,440
there's liquid droplets in this

1400
00:58:30,870 --> 00:58:28,240
atmosphere it's not all gas at that

1401
00:58:33,030 --> 00:58:30,880
temperature everything we know of should

1402
00:58:35,750 --> 00:58:33,040
be in the gas phase there should not be

1403
00:58:37,589 --> 00:58:35,760
any liquid droplets of anything in this

1404
00:58:40,069 --> 00:58:37,599
atmosphere

1405
00:58:42,549 --> 00:58:40,079
so what this is telling us is that the

1406
00:58:43,630 --> 00:58:42,559
temperature change from that day side

1407
00:58:45,990 --> 00:58:43,640
about

1408
00:58:47,910 --> 00:58:46,000
2500 degrees

1409
00:58:50,549 --> 00:58:47,920
to the night side where we're looking at

1410
00:58:52,230 --> 00:58:50,559
this planet is huge

1411
00:58:57,190 --> 00:58:52,240
the night side where we're observing

1412
00:58:59,630 --> 00:58:57,200
this has to be around 18 1900 degrees

1413
00:59:02,870 --> 00:58:59,640

there is a temperature change of over

1414
00:59:04,549 --> 00:59:02,880
500 degrees from the day side to the

1415
00:59:07,910 --> 00:59:04,559
night side of this planet

1416
00:59:10,630 --> 00:59:07,920
that causes huge amounts of winds around

1417
00:59:12,150 --> 00:59:10,640
the planet's atmosphere

1418
00:59:14,150 --> 00:59:12,160
but that also tells us a little bit

1419
00:59:16,470 --> 00:59:14,160
about what these clouds might be made of

1420
00:59:18,470 --> 00:59:16,480
and there's only really one option left

1421
00:59:20,390 --> 00:59:18,480
in this temperature range for what these

1422
00:59:23,349 --> 00:59:20,400
clouds can be formed of

1423
00:59:24,309 --> 00:59:23,359
and it's a little thing called corundum

1424
00:59:32,470 --> 00:59:24,319
or

1425
00:59:35,589 --> 00:59:32,480
the clouds in this atmosphere are gems

1426
00:59:36,950 --> 00:59:35,599
and they are raining down in this

1427
00:59:39,510 --> 00:59:36,960
atmosphere

1428
00:59:41,510 --> 00:59:39,520
absolutely beautiful and the reason why

1429
00:59:43,670 --> 00:59:41,520
it's all of these colors and the reason

1430
00:59:46,230 --> 00:59:43,680
why rubies and sapphires are different

1431
00:59:48,069 --> 00:59:46,240
colors is because this corundum this

1432
00:59:50,390 --> 00:59:48,079
al2o3

1433
00:59:52,950 --> 00:59:50,400
nice small combination of elements if

1434
00:59:55,430 --> 00:59:52,960
you stick a random metal from a

1435
00:59:57,190 --> 00:59:55,440
different element it changes the color

1436
00:59:59,430 --> 00:59:57,200
so if you stick a different element in

1437
01:00:02,069 --> 00:59:59,440
it could be green or yellow and we find

1438
01:00:04,630 --> 01:00:02,079

all of the spectrum of colors in this

1439
01:00:06,870 --> 01:00:04,640
corundum here on the earth as beautiful

1440
01:00:10,390 --> 01:00:06,880
gems rubies and sapphires being the

1441
01:00:13,270 --> 01:00:10,400
easiest and nicest to make

1442
01:00:14,549 --> 01:00:13,280
so the atmosphere will be a rainbow of

1443
01:00:16,950 --> 01:00:14,559
gems

1444
01:00:21,589 --> 01:00:16,960
that's why it's my favorite it's just

1445
01:00:25,109 --> 01:00:23,750
so we've found some really strange

1446
01:00:26,630 --> 01:00:25,119
worlds and we've been able to look at

1447
01:00:28,549 --> 01:00:26,640
them with this technique and it's only

1448
01:00:30,789 --> 01:00:28,559
going to get better in the future as the

1449
01:00:32,870 --> 01:00:30,799
telescopes get bigger our understanding

1450
01:00:35,270 --> 01:00:32,880
gets better and more planets are found

1451
01:00:36,950 --> 01:00:35,280
that we can do these observations of

1452
01:00:38,950 --> 01:00:36,960
it's really exciting for me because i

1453
01:00:40,549 --> 01:00:38,960
get to just play around with all of this

1454
01:00:43,190 --> 01:00:40,559
stuff and try and understand it and try

1455
01:00:46,069 --> 01:00:43,200
and communicate to everybody here just

1456
01:00:46,870 --> 01:00:46,079
how amazing nature's imagination truly

1457
01:00:48,630 --> 01:00:46,880
is

1458
01:00:51,349 --> 01:00:48,640
so we want to go on an exploration

1459
01:00:53,829 --> 01:00:51,359
beyond our own solar system and we're

1460
01:00:54,789 --> 01:00:53,839
moving outwards we're moving past our

1461
01:00:57,349 --> 01:00:54,799
planets

1462
01:00:59,829 --> 01:00:57,359
we're moving to another bit of our

1463
01:01:02,470 --> 01:00:59,839

galaxy we've only explored a tiny

1464
01:01:04,150 --> 01:01:02,480
portion of where we are

1465
01:01:05,030 --> 01:01:04,160
this is just kind of going to take you

1466
01:01:08,470 --> 01:01:05,040
through

1467
01:01:11,270 --> 01:01:08,480
every bit that we've been exploring

1468
01:01:13,349 --> 01:01:11,280
out from the sun as it becomes a small

1469
01:01:16,549 --> 01:01:13,359
dot

1470
01:01:18,549 --> 01:01:16,559
out to our nearest stars

1471
01:01:20,710 --> 01:01:18,559
and every single one of the lines on

1472
01:01:25,750 --> 01:01:20,720
here shows you a line to the direction

1473
01:01:32,230 --> 01:01:29,910
as we move out to our galaxy

1474
01:01:33,750 --> 01:01:32,240
every single day more exoplanets are

1475
01:01:35,990 --> 01:01:33,760
being discovered

1476
01:01:38,470 --> 01:01:36,000
every single day we're learning more and

1477
01:01:40,470 --> 01:01:38,480
more about these alien worlds and in

1478
01:01:42,150 --> 01:01:40,480
turn learning more about our own solar

1479
01:01:44,069 --> 01:01:42,160
system

1480
01:01:46,870 --> 01:01:44,079
it's not the end there's going to be

1481
01:01:48,870 --> 01:01:46,880
more it's never the end

1482
01:01:50,789 --> 01:01:48,880
this is just the current look again so

1483
01:01:53,109 --> 01:01:50,799
this is the size of the planet versus

1484
01:01:55,109 --> 01:01:53,119
the temperature of that planet

1485
01:01:57,750 --> 01:01:55,119
this is what we currently have thanks to

1486
01:01:58,789 --> 01:01:57,760
kepler and everything else that was not

1487
01:02:01,109 --> 01:01:58,799
kepler

1488
01:02:02,950 --> 01:02:01,119

in the future so towards the end of this

1489
01:02:04,549 --> 01:02:02,960
year a satellite called tess is going to

1490
01:02:08,069 --> 01:02:04,559
be launched and tess is going to find

1491
01:02:12,390 --> 01:02:10,390
down in these smaller worlds much more

1492
01:02:14,230 --> 01:02:12,400
similar to the earth

1493
01:02:15,750 --> 01:02:14,240
down here so we're going to be moving

1494
01:02:17,190 --> 01:02:15,760
towards these smaller planets and trying

1495
01:02:19,270 --> 01:02:17,200
to understand what a smaller planet

1496
01:02:21,510 --> 01:02:19,280
maybe not a jupiter actually looks like

1497
01:02:22,789 --> 01:02:21,520
what its atmosphere is like

1498
01:02:24,630 --> 01:02:22,799
and we're going to be finding colder

1499
01:02:25,829 --> 01:02:24,640
planets colder planets are important

1500
01:02:27,430 --> 01:02:25,839
their atmospheres are going to be very

1501
01:02:28,870 --> 01:02:27,440
different from the ones that i've shown

1502
01:02:31,349 --> 01:02:28,880
you today they're going to have

1503
01:02:34,150 --> 01:02:31,359
atmospheres that are filled with

1504
01:02:36,470 --> 01:02:34,160
hydrocarbons like titan's atmosphere

1505
01:02:38,309 --> 01:02:36,480
filled with soots that are a bit of a

1506
01:02:41,190 --> 01:02:38,319
pain that are really interesting to

1507
01:02:43,670 --> 01:02:41,200
study in the labs they're going to be

1508
01:02:44,710 --> 01:02:43,680
something we don't have in our solar

1509
01:02:46,549 --> 01:02:44,720
system

1510
01:02:48,789 --> 01:02:46,559
and that makes it really exciting

1511
01:02:51,190 --> 01:02:48,799
because we don't have a test tube here

1512
01:02:52,870 --> 01:02:51,200
where we can throw something at it we

1513
01:02:56,789 --> 01:02:52,880

have to learn remotely we have to

1514
01:02:58,630 --> 01:02:56,799
collect every photon we can

1515
01:03:01,109 --> 01:02:58,640
so i'm really looking forward to the

1516
01:03:02,789 --> 01:03:01,119
future of exoplanets and i hope you all

1517
01:03:04,549 --> 01:03:02,799
keep an eye out for some of the most

1518
01:03:05,670 --> 01:03:04,559
exciting discoveries that are coming

1519
01:03:07,670 --> 01:03:05,680
because we're going to be learning so

1520
01:03:10,470 --> 01:03:07,680
much more and there's going to be a lot

1521
01:03:11,430 --> 01:03:10,480
more surprises along the way

1522
01:03:12,470 --> 01:03:11,440
if you

1523
01:03:14,950 --> 01:03:12,480
enjoyed

1524
01:03:17,430 --> 01:03:14,960
hearing me talk i talk

1525
01:03:19,510 --> 01:03:17,440
for about an hour once every month with

1526
01:03:21,270 --> 01:03:19,520
some of my friends um

1527
01:03:23,270 --> 01:03:21,280
as was mentioned before i do a podcast

1528
01:03:25,510 --> 01:03:23,280
called exocast

1529
01:03:27,109 --> 01:03:25,520
i have a colleague called hugh osborne

1530
01:03:28,630 --> 01:03:27,119
who does detections i do the

1531
01:03:29,910 --> 01:03:28,640
classification so i'm actually looking

1532
01:03:32,230 --> 01:03:29,920
at what these atmospheres might be like

1533
01:03:34,910 --> 01:03:32,240
he's finding the planets and then my

1534
01:03:37,029 --> 01:03:34,920
other colleague andrew rushby who does

1535
01:03:39,349 --> 01:03:37,039
astrobiology what

1536
01:03:41,589 --> 01:03:39,359
is life out there in the universe how

1537
01:03:42,870 --> 01:03:41,599
can we find it so the combination of us

1538
01:03:45,510 --> 01:03:42,880

arguing if you think that will be

1539
01:03:47,829 --> 01:03:45,520
entertaining is good i do warn you we're

1540
01:03:49,270 --> 01:03:47,839
all british so the accents might be a

1541
01:03:51,430 --> 01:03:49,280
bit of a pain

1542
01:03:53,910 --> 01:03:51,440
but we also will be getting transcripts

1543
01:03:55,990 --> 01:03:53,920
of all those episodes

1544
01:03:57,990 --> 01:03:56,000
but i just want to to leave you with

1545
01:04:00,069 --> 01:03:58,000
that predicted number of planets that

1546
01:04:03,270 --> 01:04:00,079
we're going to be discovering and just

1547
01:04:06,640 --> 01:04:03,280
the thought that anything is possible

1548
01:04:06,650 --> 01:04:19,990
[Applause]

1549
01:04:32,230 --> 01:04:22,150
okay we have some questions for our

1550
01:04:34,870 --> 01:04:33,589
i have to repeat the question for the

1551
01:04:36,950 --> 01:04:34,880
online audience

1552
01:04:38,230 --> 01:04:36,960
does is neptune tidally locked or does

1553
01:04:39,990 --> 01:04:38,240
it rotate

1554
01:04:41,910 --> 01:04:40,000
so all of the planets in our solar

1555
01:04:44,789 --> 01:04:41,920
system rotate

1556
01:04:47,430 --> 01:04:44,799
so the question then follows uh what

1557
01:04:49,910 --> 01:04:47,440
what then is the source of these 1300

1558
01:04:52,390 --> 01:04:49,920
mile an hour sustained winds all right

1559
01:04:55,029 --> 01:04:52,400
so so pressure variations

1560
01:04:56,710 --> 01:04:55,039
cause winds in our atmosphere on earth

1561
01:04:59,510 --> 01:04:56,720
what is causing these pressure

1562
01:05:00,870 --> 01:04:59,520
variations on neptune

1563
01:05:03,190 --> 01:05:00,880

all right i want to actually add to that

1564
01:05:06,630 --> 01:05:03,200
a question from the online audience um

1565
01:05:09,510 --> 01:05:06,640
so what causes those 300 mile per hour

1566
01:05:12,470 --> 01:05:09,520
winds on neptune and from the online

1567
01:05:14,069 --> 01:05:12,480
audience how are those winds measured on

1568
01:05:16,630 --> 01:05:14,079
neptune what is your reference point

1569
01:05:17,829 --> 01:05:16,640
since there's no hard surface

1570
01:05:19,670 --> 01:05:17,839
so

1571
01:05:21,589 --> 01:05:19,680
the answer's going to be unsatisfying

1572
01:05:22,789 --> 01:05:21,599
i'm not entirely certain

1573
01:05:24,470 --> 01:05:22,799
i imagine it's something to do with

1574
01:05:26,309 --> 01:05:24,480
temperature differences neptune has

1575
01:05:28,710 --> 01:05:26,319
internal heating that's going to be

1576
01:05:31,430 --> 01:05:28,720
causing some differences

1577
01:05:33,589 --> 01:05:31,440
that causes differences in the vertical

1578
01:05:35,589 --> 01:05:33,599
uplift of material so if you're

1579
01:05:37,670 --> 01:05:35,599
uplifting material it's cooling it's

1580
01:05:39,990 --> 01:05:37,680
condensing and then that's going to be

1581
01:05:42,390 --> 01:05:40,000
driving the fluid dynamics of the

1582
01:05:44,230 --> 01:05:42,400
atmosphere in terms of a reference point

1583
01:05:46,069 --> 01:05:44,240
those clouds are very very helpful

1584
01:05:48,230 --> 01:05:46,079
voyager is not the only image we have of

1585
01:05:50,309 --> 01:05:48,240
neptune the hubble space telescope has

1586
01:05:52,309 --> 01:05:50,319
taken some amazing images of neptune and

1587
01:05:53,589 --> 01:05:52,319
some of the ground-based telescopes also

1588
01:05:55,430 --> 01:05:53,599

in lots of different wavelengths have

1589
01:05:57,510 --> 01:05:55,440
been looking at neptune's atmosphere

1590
01:05:59,430 --> 01:05:57,520
trying to understand it one of the

1591
01:06:01,190 --> 01:05:59,440
really impressive things on neptune is

1592
01:06:03,510 --> 01:06:01,200
this dark spot i showed you the one on

1593
01:06:06,150 --> 01:06:03,520
jupiter which is bright red spot on

1594
01:06:08,309 --> 01:06:06,160
neptune there's this big dark cloud

1595
01:06:11,029 --> 01:06:08,319
region which is kind of confined to a

1596
01:06:13,029 --> 01:06:11,039
spot and looking at that rotation we

1597
01:06:14,390 --> 01:06:13,039
know the rotation of neptune and we can

1598
01:06:15,990 --> 01:06:14,400
see the rotation of these cloud

1599
01:06:18,630 --> 01:06:16,000
structures and it's different so we can

1600
01:06:21,270 --> 01:06:18,640
get this differential is what it is

1601
01:06:23,829 --> 01:06:21,280
between the rotation period of neptune

1602
01:06:26,710 --> 01:06:23,839
and the the material that we're seeing

1603
01:06:27,670 --> 01:06:26,720
able to detect in that atmosphere

1604
01:06:29,510 --> 01:06:27,680
okay

1605
01:06:30,710 --> 01:06:29,520
over there

1606
01:06:32,630 --> 01:06:30,720
these um

1607
01:06:34,230 --> 01:06:32,640
when i think of storms

1608
01:06:36,870 --> 01:06:34,240
earthwise to think of

1609
01:06:38,630 --> 01:06:36,880
precipitation does these actually these

1610
01:06:40,950 --> 01:06:38,640
storms in the

1611
01:06:43,430 --> 01:06:40,960
planets also precipitate

1612
01:06:44,789 --> 01:06:43,440
so on the these cre these crazy weather

1613
01:06:46,230 --> 01:06:44,799

that you're having is it actual real

1614
01:06:47,750 --> 01:06:46,240
precipitation falling down through the

1615
01:06:50,309 --> 01:06:47,760
atmosphere

1616
01:06:52,710 --> 01:06:50,319
so that's a really good question

1617
01:06:54,950 --> 01:06:52,720
from the models that we have these 3d

1618
01:06:56,870 --> 01:06:54,960
gcms they're all based on earth gcms

1619
01:06:58,549 --> 01:06:56,880
which is then be expanded and applied to

1620
01:07:00,630 --> 01:06:58,559
these giant planets and to the planets

1621
01:07:03,270 --> 01:07:00,640
in our solar system and what they're

1622
01:07:05,670 --> 01:07:03,280
showing us is that you get these big

1623
01:07:08,150 --> 01:07:05,680
this heat from the dayside causes these

1624
01:07:09,990 --> 01:07:08,160
very huge upwellings and then on the

1625
01:07:12,549 --> 01:07:10,000
night side of the planet at this kind of

1626
01:07:14,710 --> 01:07:12,559
terminator region you get these updrafts

1627
01:07:15,670 --> 01:07:14,720
and downdrafts these upwellings and down

1628
01:07:18,230 --> 01:07:15,680
wellings where you're getting this

1629
01:07:20,309 --> 01:07:18,240
precipitation and it's not only those

1630
01:07:22,309 --> 01:07:20,319
vertical motions that are doing it but

1631
01:07:25,029 --> 01:07:22,319
this temperature contrast from

1632
01:07:27,109 --> 01:07:25,039
the boiling day side around the night

1633
01:07:29,109 --> 01:07:27,119
side means that you could have something

1634
01:07:31,190 --> 01:07:29,119
that is heated to a high temperature

1635
01:07:33,430 --> 01:07:31,200
becomes a vapor on the day side and then

1636
01:07:36,549 --> 01:07:33,440
as it cools down as it goes around the

1637
01:07:37,510 --> 01:07:36,559
planet it cools it condenses it rains

1638
01:07:40,069 --> 01:07:37,520

out

1639
01:07:42,069 --> 01:07:40,079
sometimes it might even become a ice of

1640
01:07:44,470 --> 01:07:42,079
some kind it could be snowing rubies on

1641
01:07:46,950 --> 01:07:44,480
one of these planets and then as it goes

1642
01:07:49,349 --> 01:07:46,960
round as these winds carry it round as

1643
01:07:52,069 --> 01:07:49,359
these dynamics push it around into the

1644
01:07:53,829 --> 01:07:52,079
dayside heat again it heats up and it's

1645
01:07:56,150 --> 01:07:53,839
being pushed up in the atmosphere as a

1646
01:07:57,990 --> 01:07:56,160
gas and then you get this cycle again so

1647
01:07:59,910 --> 01:07:58,000
you see these big upwellings and down

1648
01:08:01,510 --> 01:07:59,920
wellings in the planetary atmosphere

1649
01:08:05,270 --> 01:08:01,520
where this material is just constantly

1650
01:08:08,549 --> 01:08:06,950
okay

1651
01:08:10,710 --> 01:08:08,559
other questions i thought there was one

1652
01:08:12,789 --> 01:08:10,720
over here here's one why is the moon

1653
01:08:14,789 --> 01:08:12,799
gravitationally locked with the earth

1654
01:08:16,789 --> 01:08:14,799
why is the moon gravitationally locked

1655
01:08:20,149 --> 01:08:16,799
to the earth so the gravitational

1656
01:08:22,470 --> 01:08:20,159
locking comes from just um conservation

1657
01:08:24,709 --> 01:08:22,480
of the angular momentum and when we're

1658
01:08:26,070 --> 01:08:24,719
looking at these hot jupiters what would

1659
01:08:28,789 --> 01:08:26,080
have happened they couldn't have formed

1660
01:08:30,709 --> 01:08:28,799
there so as after they formed and

1661
01:08:32,149 --> 01:08:30,719
they're spinning around the disk

1662
01:08:34,950 --> 01:08:32,159
of the star

1663
01:08:37,030 --> 01:08:34,960

as they move inwards as you spiral

1664
01:08:39,189 --> 01:08:37,040
inwards you've got to lose some of that

1665
01:08:41,510 --> 01:08:39,199
energy somehow and as you lose that

1666
01:08:43,590 --> 01:08:41,520
energy you reach this very stable state

1667
01:08:45,349 --> 01:08:43,600
where your orbital period matches your

1668
01:08:47,510 --> 01:08:45,359
rotation period it's an incredibly

1669
01:08:49,829 --> 01:08:47,520
stable position to be in

1670
01:08:50,630 --> 01:08:49,839
so the the earth the earth immune system

1671
01:08:52,470 --> 01:08:50,640
is a little different because the

1672
01:08:55,590 --> 01:08:52,480
earth's the the moon started

1673
01:08:58,070 --> 01:08:55,600
as the earth got bombarded broken off

1674
01:09:00,149 --> 01:08:58,080
formed in this spiral ring structure and

1675
01:09:02,070 --> 01:09:00,159
the most energy efficient way is to be

1676
01:09:04,149 --> 01:09:02,080
tightly locked however the moon's moving

1677
01:09:06,070 --> 01:09:04,159
further and further away from us every

1678
01:09:07,910 --> 01:09:06,080
single year so there might be a point in

1679
01:09:10,070 --> 01:09:07,920
the moon's future where it is no longer

1680
01:09:11,300 --> 01:09:10,080
tidally locked to the earth

1681
01:09:14,470 --> 01:09:11,310
i won't be around then

1682
01:09:16,950 --> 01:09:14,480
[Laughter]

1683
01:09:19,269 --> 01:09:16,960
all right over here question

1684
01:09:21,910 --> 01:09:19,279
you have these uh jupiter and

1685
01:09:23,590 --> 01:09:21,920
a larger size plane that's very close to

1686
01:09:25,269 --> 01:09:23,600
a star

1687
01:09:26,950 --> 01:09:25,279
is there a core that's holding them

1688
01:09:28,470 --> 01:09:26,960

together or are they just the

1689
01:09:30,950 --> 01:09:28,480
aggregations of

1690
01:09:32,870 --> 01:09:30,960
of gas that have accumulated

1691
01:09:34,550 --> 01:09:32,880
provides the stability because it seems

1692
01:09:37,349 --> 01:09:34,560
like the energy

1693
01:09:39,189 --> 01:09:37,359
being that close to the star

1694
01:09:41,430 --> 01:09:39,199
i'm going to summarize that in terms of

1695
01:09:43,749 --> 01:09:41,440
you got these hot jupiters these gas

1696
01:09:45,349 --> 01:09:43,759
giant planets in so close to the star

1697
01:09:46,870 --> 01:09:45,359
why don't they evaporate away what's

1698
01:09:48,709 --> 01:09:46,880
keeping together

1699
01:09:50,149 --> 01:09:48,719
that's a good question and it's mainly

1700
01:09:51,910 --> 01:09:50,159
the mass

1701
01:09:53,590 --> 01:09:51,920
there are actually some planets that

1702
01:09:56,149 --> 01:09:53,600
have been discovered where we think they

1703
01:09:57,830 --> 01:09:56,159
used to be these giant gassy worlds but

1704
01:09:59,830 --> 01:09:57,840
all of their atmosphere has got blown

1705
01:10:03,669 --> 01:09:59,840
away we see evidence of these very

1706
01:10:04,950 --> 01:10:03,679
condensed rocky cause of of planets

1707
01:10:07,270 --> 01:10:04,960
where they don't have an atmosphere and

1708
01:10:08,790 --> 01:10:07,280
they really should so we see evidence

1709
01:10:11,110 --> 01:10:08,800
that some of them have lost their

1710
01:10:13,030 --> 01:10:11,120
atmosphere entirely but as i said before

1711
01:10:15,430 --> 01:10:13,040
these planets did not form there you

1712
01:10:18,709 --> 01:10:15,440
cannot form a giant planet that close to

1713
01:10:21,030 --> 01:10:18,719

a star it had to have moved in from

1714
01:10:22,550 --> 01:10:21,040
earlier in this its system earlier in

1715
01:10:24,630 --> 01:10:22,560
the disc it had to have moved in from

1716
01:10:26,229 --> 01:10:24,640
further out now there's a number of

1717
01:10:27,830 --> 01:10:26,239
theories of planet formation but first

1718
01:10:29,830 --> 01:10:27,840
you need to stick together a load of

1719
01:10:31,669 --> 01:10:29,840
particles and as you stick together

1720
01:10:33,430 --> 01:10:31,679
those particles you accumulate gas

1721
01:10:35,830 --> 01:10:33,440
around you from the disc and it's this

1722
01:10:38,149 --> 01:10:35,840
runaway accumulation of that gas which

1723
01:10:39,510 --> 01:10:38,159
causes you to create a planet like

1724
01:10:42,229 --> 01:10:39,520
jupiter

1725
01:10:44,310 --> 01:10:42,239
now if that had been moved in towards

1726
01:10:46,310 --> 01:10:44,320
its star

1727
01:10:48,550 --> 01:10:46,320
in these positions where they are we've

1728
01:10:50,470 --> 01:10:48,560
seen evidence that the the atmosphere

1729
01:10:53,030 --> 01:10:50,480
gets blown off but we can measure how

1730
01:10:55,189 --> 01:10:53,040
much and it's very very little it's the

1731
01:10:57,270 --> 01:10:55,199
equivalent ratio of a cme coming off of

1732
01:10:58,390 --> 01:10:57,280
our sun it's losing a very small amount

1733
01:11:00,950 --> 01:10:58,400
of its mass

1734
01:11:03,470 --> 01:11:00,960
in any one time so it's not something

1735
01:11:05,910 --> 01:11:03,480
that's going to completely wipe out

1736
01:11:07,910 --> 01:11:05,920
hd18973b's atmosphere

1737
01:11:10,310 --> 01:11:07,920
based on the measurements that we have

1738
01:11:12,070 --> 01:11:10,320

so it's really the mass that's holding

1739
01:11:14,149 --> 01:11:12,080
this atmosphere on it's clinging to it

1740
01:11:15,910 --> 01:11:14,159
and every planet even our own planet has

1741
01:11:17,669 --> 01:11:15,920
something called a roche lobe which is a

1742
01:11:19,189 --> 01:11:17,679
gravitational distance away from that

1743
01:11:21,669 --> 01:11:19,199
planet where something is no longer

1744
01:11:24,149 --> 01:11:21,679
gravitationally bound if the gas was

1745
01:11:25,990 --> 01:11:24,159
energy energized enough so that it got

1746
01:11:27,590 --> 01:11:26,000
outside of this roche lobe it would

1747
01:11:29,590 --> 01:11:27,600
escape forever it wouldn't ever come

1748
01:11:31,590 --> 01:11:29,600
back if it was energized such that it

1749
01:11:34,070 --> 01:11:31,600
kind of escaped and then it fell back

1750
01:11:36,550 --> 01:11:34,080
inside this roche lobe then you wouldn't

1751
01:11:38,229 --> 01:11:36,560
ever lose that bit of the atmosphere

1752
01:11:41,590 --> 01:11:38,239
so there's there's a number of things

1753
01:11:43,110 --> 01:11:41,600
there that are kind of keeping it in

1754
01:11:44,470 --> 01:11:43,120
all right all the way in the far side of

1755
01:11:46,149 --> 01:11:44,480
the room there

1756
01:11:48,550 --> 01:11:46,159
you found any uh

1757
01:11:50,070 --> 01:11:48,560
extra planets with a binary star system

1758
01:11:53,110 --> 01:11:50,080
and how does that effect

1759
01:11:54,630 --> 01:11:53,120
how we found exoplanets in binary star

1760
01:11:56,630 --> 01:11:54,640
systems and how does the presence of the

1761
01:11:59,669 --> 01:11:56,640
binary affect the planet

1762
01:12:01,990 --> 01:11:59,679
we found planets in binary stars in

1763
01:12:04,070 --> 01:12:02,000

triple stars and in quadruple star

1764
01:12:06,790 --> 01:12:04,080
systems

1765
01:12:10,630 --> 01:12:06,800
so binary stars are the most common

1766
01:12:12,310 --> 01:12:10,640
in our galaxy and there's quite a few

1767
01:12:14,790 --> 01:12:12,320
planets that have been discovered around

1768
01:12:16,070 --> 01:12:14,800
binary systems wasp 12b the one i showed

1769
01:12:17,270 --> 01:12:16,080
you at the end is in a triple star

1770
01:12:19,910 --> 01:12:17,280
system

1771
01:12:22,709 --> 01:12:19,920
whilst 12 only orbits one of those stars

1772
01:12:25,030 --> 01:12:22,719
but also orbiting that one star is two

1773
01:12:27,110 --> 01:12:25,040
tiny little stars m stars that orbit

1774
01:12:29,110 --> 01:12:27,120
each other and orbit that star so it's

1775
01:12:31,350 --> 01:12:29,120
in a triple star system

1776
01:12:32,630 --> 01:12:31,360
brilliant world that's also a pain when

1777
01:12:33,910 --> 01:12:32,640
you're trying to do data analysis

1778
01:12:37,590 --> 01:12:33,920
because there's two other stars right

1779
01:12:40,790 --> 01:12:37,600
there um but yes we found planets and

1780
01:12:44,229 --> 01:12:40,800
multi-planet systems

1781
01:12:45,110 --> 01:12:44,239
around stars and that really tells us

1782
01:12:47,910 --> 01:12:45,120
about

1783
01:12:49,830 --> 01:12:47,920
our own solar system and how possible

1784
01:12:52,229 --> 01:12:49,840
that is and some of these have

1785
01:12:53,590 --> 01:12:52,239
interactions and some of them don't and

1786
01:12:55,350 --> 01:12:53,600
that's really important for us to try

1787
01:12:58,630 --> 01:12:55,360
and understand it's an area that we're

1788
01:13:03,590 --> 01:13:01,350

okay down here the difference between

1789
01:13:05,750 --> 01:13:03,600
day and night temperatures on some of

1790
01:13:07,510 --> 01:13:05,760
these what would that range be all right

1791
01:13:10,310 --> 01:13:07,520
so what is the range of day and night

1792
01:13:13,669 --> 01:13:10,320
temperatures on these really hot planets

1793
01:13:16,390 --> 01:13:13,679
so that really depends on your

1794
01:13:18,470 --> 01:13:16,400
dayside temperature the orbital period

1795
01:13:20,310 --> 01:13:18,480
of your planet because the orbital

1796
01:13:22,390 --> 01:13:20,320
period of your planet defines your

1797
01:13:24,390 --> 01:13:22,400
rotation period of your planet and the

1798
01:13:26,390 --> 01:13:24,400
rotation period of your planet defines

1799
01:13:27,189 --> 01:13:26,400
how dynamic the atmosphere is going to

1800
01:13:30,709 --> 01:13:27,199
be

1801
01:13:33,990 --> 01:13:30,719
atmosphere

1802
01:13:36,070 --> 01:13:34,000
so on some of the hottest ones we we

1803
01:13:39,510 --> 01:13:36,080
expect that day night contrast in

1804
01:13:41,910 --> 01:13:39,520
temperatures to be in the range of 500

1805
01:13:43,590 --> 01:13:41,920
plus degrees but on some of the cooler

1806
01:13:46,229 --> 01:13:43,600
ones and i say cooler because my

1807
01:13:49,590 --> 01:13:46,239
temperature scale is completely wacky

1808
01:13:52,390 --> 01:13:49,600
hd189 is a nice cool planet at 1 200

1809
01:13:53,750 --> 01:13:52,400
degrees and on that nice cool planet the

1810
01:13:55,910 --> 01:13:53,760
temperature difference between the day

1811
01:13:59,750 --> 01:13:55,920
and night is only about

1812
01:14:01,830 --> 01:13:59,760
50 to 200 degrees so it ranges based on

1813
01:14:03,990 --> 01:14:01,840

the orbital period of that planet and

1814
01:14:06,229 --> 01:14:04,000
the heat from the star so a bigger star

1815
01:14:08,470 --> 01:14:06,239
a hotter star will also be putting out

1816
01:14:10,310 --> 01:14:08,480
way more heat and therefore you get a

1817
01:14:11,669 --> 01:14:10,320
bigger contrast there and are those

1818
01:14:17,830 --> 01:14:11,679
temperatures we're talking about

1819
01:14:21,430 --> 01:14:19,110
degrees

1820
01:14:22,149 --> 01:14:21,440
almost it's very hot sorry i don't do

1821
01:14:23,830 --> 01:14:22,159
yes

1822
01:14:25,510 --> 01:14:23,840
astronomers i thought that's what was my

1823
01:14:26,310 --> 01:14:25,520
question too because i know astronomers

1824
01:14:29,750 --> 01:14:26,320
always

1825
01:14:32,709 --> 01:14:29,760
working kelvin and such celsius

1826
01:14:34,550 --> 01:14:32,719
i'm learning i'm really trying to

1827
01:14:36,870 --> 01:14:34,560
all right question there

1828
01:14:38,390 --> 01:14:36,880
i'm interested in the time scale of

1829
01:14:40,870 --> 01:14:38,400
variations

1830
01:14:43,350 --> 01:14:40,880
in the conditions on the planet you know

1831
01:14:45,030 --> 01:14:43,360
the earth has been roughly the same for

1832
01:14:48,229 --> 01:14:45,040
billions of years

1833
01:14:49,750 --> 01:14:48,239
and how can you tell anything about many

1834
01:14:51,350 --> 01:14:49,760
of the planets

1835
01:14:53,189 --> 01:14:51,360
uh how long

1836
01:14:56,149 --> 01:14:53,199
will their atmosphere last will the

1837
01:14:58,310 --> 01:14:56,159
temperatures stay the same and so on so

1838
01:15:00,390 --> 01:14:58,320

really he's asking

1839
01:15:02,310 --> 01:15:00,400
research questions

1840
01:15:03,750 --> 01:15:02,320
can we tell how long the atmospheres

1841
01:15:05,590 --> 01:15:03,760
will last on these planets and other

1842
01:15:07,669 --> 01:15:05,600
characteristics like that so these

1843
01:15:09,510 --> 01:15:07,679
planets are fairly old um they've been

1844
01:15:11,110 --> 01:15:09,520
like this for a really long time and as

1845
01:15:13,350 --> 01:15:11,120
i said they're not losing a huge amount

1846
01:15:15,590 --> 01:15:13,360
of mass from that atmosphere

1847
01:15:17,030 --> 01:15:15,600
the planets that we've observed where

1848
01:15:18,630 --> 01:15:17,040
they appear like they've lost all of

1849
01:15:20,550 --> 01:15:18,640
their atmosphere that clearly happened

1850
01:15:22,630 --> 01:15:20,560
very early on and very quickly so it's

1851
01:15:24,390 --> 01:15:22,640
not expected that these giant planets

1852
01:15:26,709 --> 01:15:24,400
will lose a humongous amount of their

1853
01:15:29,030 --> 01:15:26,719
atmosphere at all in the lifetime of us

1854
01:15:32,149 --> 01:15:29,040
looking at them the way that we are

1855
01:15:33,430 --> 01:15:32,159
in terms of intrinsic variations weather

1856
01:15:35,430 --> 01:15:33,440
patterns

1857
01:15:36,709 --> 01:15:35,440
that's a lot harder to do one of the

1858
01:15:38,630 --> 01:15:36,719
reasons we look at those really

1859
01:15:42,390 --> 01:15:38,640
eccentric planets that i showed you

1860
01:15:44,709 --> 01:15:42,400
before that comet planet hd80606b

1861
01:15:47,189 --> 01:15:44,719
is because we can look at this variation

1862
01:15:48,870 --> 01:15:47,199
over time of what an atmosphere does at

1863
01:15:50,630 --> 01:15:48,880

different distances from a star just

1864
01:15:52,390 --> 01:15:50,640
from having one system

1865
01:15:53,510 --> 01:15:52,400
these are fairly consistent from what we

1866
01:15:55,350 --> 01:15:53,520
have

1867
01:15:57,910 --> 01:15:55,360
the other problem with that is your

1868
01:15:59,910 --> 01:15:57,920
measurement has to be so precise

1869
01:16:02,229 --> 01:15:59,920
at every time you measure it

1870
01:16:03,990 --> 01:16:02,239
so if i measured it this year and i got

1871
01:16:05,590 --> 01:16:04,000
a really nice measurement and i measured

1872
01:16:07,030 --> 01:16:05,600
it next year and it was different and

1873
01:16:09,189 --> 01:16:07,040
then i measured it the year after and it

1874
01:16:11,350 --> 01:16:09,199
was different again i need to know that

1875
01:16:12,550 --> 01:16:11,360
it's not the way that i'm doing my data

1876
01:16:13,990 --> 01:16:12,560
analysis i need to know that it's not

1877
01:16:16,470 --> 01:16:14,000
something in the telescope i need to

1878
01:16:17,990 --> 01:16:16,480
know that it is actually something in

1879
01:16:19,750 --> 01:16:18,000
that planet's atmosphere that's causing

1880
01:16:21,430 --> 01:16:19,760
that rather than something that we as

1881
01:16:24,149 --> 01:16:21,440
scientists have done to look at that

1882
01:16:26,390 --> 01:16:24,159
data so it's really hard to say whether

1883
01:16:28,390 --> 01:16:26,400
we've got any kind of

1884
01:16:30,390 --> 01:16:28,400
small weather patterns one of the really

1885
01:16:31,990 --> 01:16:30,400
good examples of of looking for these

1886
01:16:35,270 --> 01:16:32,000
kinds of weather patterns is brown

1887
01:16:37,270 --> 01:16:35,280
dwarfs now brown dwarfs are much further

1888
01:16:38,870 --> 01:16:37,280

off this diagram

1889
01:16:40,870 --> 01:16:38,880
they are

1890
01:16:43,189 --> 01:16:40,880
roughly the size of jupiter

1891
01:16:45,669 --> 01:16:43,199
but they're much much more massive

1892
01:16:49,270 --> 01:16:45,679
they're over 15 times the mass of

1893
01:16:51,189 --> 01:16:49,280
jupiter and that is a lot

1894
01:16:52,630 --> 01:16:51,199
these brown dwarfs aren't quite stars

1895
01:16:55,830 --> 01:16:52,640
but they're not quite planets they're

1896
01:16:57,990 --> 01:16:55,840
actually burning at their core deuterium

1897
01:17:00,310 --> 01:16:58,000
and in these brown dwarfs there's this

1898
01:17:02,229 --> 01:17:00,320
transition between different masses and

1899
01:17:04,870 --> 01:17:02,239
ages of brown dwarfs where we see these

1900
01:17:07,590 --> 01:17:04,880
patchy clouds in the atmosphere

1901
01:17:11,030 --> 01:17:07,600
and the rotation of those clouds so you

1902
01:17:12,630 --> 01:17:11,040
can see and measure this weather pattern

1903
01:17:14,470 --> 01:17:12,640
in a brown dwarf atmosphere because

1904
01:17:15,750 --> 01:17:14,480
you're doing the opposite of what i was

1905
01:17:18,149 --> 01:17:15,760
explaining at the beginning you're doing

1906
01:17:20,070 --> 01:17:18,159
the emission spectrum directly from the

1907
01:17:21,350 --> 01:17:20,080
the brown dwarf rather than the

1908
01:17:23,189 --> 01:17:21,360
absorption spectrum through the

1909
01:17:24,550 --> 01:17:23,199
atmosphere so it's the different

1910
01:17:28,870 --> 01:17:24,560
techniques which allow you to kind of

1911
01:17:32,709 --> 01:17:31,510
okay um we had one question online that

1912
01:17:35,990 --> 01:17:32,719
wanted to know

1913
01:17:38,070 --> 01:17:36,000

uh what is the uh force responsible for

1914
01:17:40,470 --> 01:17:38,080
producing that beautiful hexagon pattern

1915
01:17:42,310 --> 01:17:40,480
on saturn they were speculating that it

1916
01:17:43,669 --> 01:17:42,320
was the moons and i was like no no it's

1917
01:17:45,669 --> 01:17:43,679
not the moons

1918
01:17:47,189 --> 01:17:45,679
is do we know the hydrodynamic forces

1919
01:17:49,750 --> 01:17:47,199
that produce that beautiful hexagon

1920
01:17:52,229 --> 01:17:49,760
pattern fluid dynamics can do it

1921
01:17:54,870 --> 01:17:52,239
we see that hexagon pattern appear in

1922
01:17:57,430 --> 01:17:54,880
multiple places on the earth

1923
01:17:59,750 --> 01:17:57,440
that hexagon pattern appears for a

1924
01:18:02,229 --> 01:17:59,760
number of different reasons it's a very

1925
01:18:04,790 --> 01:18:02,239
stable pattern it's a very strong

1926
01:18:06,870 --> 01:18:04,800
pattern the way in which fluid dynamics

1927
01:18:08,550 --> 01:18:06,880
works we really we really don't know

1928
01:18:10,709 --> 01:18:08,560
specifically for saturn what those

1929
01:18:12,950 --> 01:18:10,719
driving forces are but we see that

1930
01:18:15,350 --> 01:18:12,960
pattern here on the earth mathematically

1931
01:18:17,030 --> 01:18:15,360
it it comes out of a lot of solutions i

1932
01:18:20,390 --> 01:18:17,040
don't know if anyone knows the devil's

1933
01:18:22,709 --> 01:18:20,400
causeway in ireland it's the columns of

1934
01:18:24,950 --> 01:18:22,719
basalt for the volcanic material form

1935
01:18:27,110 --> 01:18:24,960
these hexagons and they form hexagons

1936
01:18:29,990 --> 01:18:27,120
because when you're cooling a material

1937
01:18:32,390 --> 01:18:30,000
down that is the most stably struct at

1938
01:18:33,990 --> 01:18:32,400

the structurally stable shape that

1939
01:18:35,510 --> 01:18:34,000
something comes into because of the

1940
01:18:37,270 --> 01:18:35,520
structure of the materials it's made out

1941
01:18:39,030 --> 01:18:37,280
of so there's a huge number of things

1942
01:18:40,950 --> 01:18:39,040
that make this hexagon pattern we're

1943
01:18:42,630 --> 01:18:40,960
still trying to work out exactly what's

1944
01:18:43,830 --> 01:18:42,640
going on because that is that is on a

1945
01:18:45,910 --> 01:18:43,840
scale that

1946
01:18:48,070 --> 01:18:45,920
we can't produce here on earth right

1947
01:18:50,149 --> 01:18:48,080
yeah yeah and i'd seen a laboratory

1948
01:18:52,950 --> 01:18:50,159
experiment that produced a hexagonal

1949
01:18:55,510 --> 01:18:52,960
pattern from residences but it wasn't

1950
01:18:56,870 --> 01:18:55,520
really a proper analog for it so yeah so

1951
01:18:58,070 --> 01:18:56,880
you have to when you're doing these

1952
01:18:59,430 --> 01:18:58,080
analogs you need to get the pressures

1953
01:19:00,550 --> 01:18:59,440
right you need to get the temperatures

1954
01:19:03,110 --> 01:19:00,560
right you need to get the materials

1955
01:19:06,470 --> 01:19:03,120
right the problem with saturn is is

1956
01:19:07,750 --> 01:19:06,480
hydrogen helium atmosphere

1957
01:19:09,669 --> 01:19:07,760
at

1958
01:19:10,630 --> 01:19:09,679
high and low pressures

1959
01:19:12,950 --> 01:19:10,640
and

1960
01:19:15,189 --> 01:19:12,960
you are not allowed or you will not be

1961
01:19:17,990 --> 01:19:15,199
funded to have a lab that will

1962
01:19:19,669 --> 01:19:18,000
almost certainly explode

1963
01:19:20,950 --> 01:19:19,679

so it's a little bit hard for us to

1964
01:19:22,470 --> 01:19:20,960
simulate so that's why we do it in

1965
01:19:24,470 --> 01:19:22,480
computers and that's the way we kind of

1966
01:19:25,910 --> 01:19:24,480
really explore these worlds all right so

1967
01:19:27,669 --> 01:19:25,920
i think there was one more question

1968
01:19:28,709 --> 01:19:27,679
right there okay last question for the

1969
01:19:31,030 --> 01:19:28,719
evening

1970
01:19:33,430 --> 01:19:31,040
in systems where there's multiple stars

1971
01:19:35,590 --> 01:19:33,440
is there any are there any planets that

1972
01:19:37,510 --> 01:19:35,600
would orbit one star for a while and

1973
01:19:40,070 --> 01:19:37,520
then switch over to the orbit of another

1974
01:19:42,709 --> 01:19:40,080
star so the question is in multiple star

1975
01:19:46,229 --> 01:19:42,719
systems can planets switch from orbiting

1976
01:19:51,110 --> 01:19:48,550
not that i know

1977
01:19:54,470 --> 01:19:51,120
there are three types of binary systems

1978
01:19:56,950 --> 01:19:54,480
uh that i can explain to you there is

1979
01:19:58,470 --> 01:19:56,960
imagine your two stars here you can have

1980
01:20:01,270 --> 01:19:58,480
a binary system where you've got a

1981
01:20:03,030 --> 01:20:01,280
planet orbiting just one of those stars

1982
01:20:04,790 --> 01:20:03,040
you can have a planet orbiting both of

1983
01:20:07,430 --> 01:20:04,800
those stars

1984
01:20:09,110 --> 01:20:07,440
and you can have technically

1985
01:20:11,830 --> 01:20:09,120
we haven't found one yet technically a

1986
01:20:13,510 --> 01:20:11,840
stable orbit where it does this

1987
01:20:15,430 --> 01:20:13,520
so you get this smiley face you can have

1988
01:20:17,510 --> 01:20:15,440

it here you can have it here you can

1989
01:20:20,630 --> 01:20:17,520
have it here or you can have it here the

1990
01:20:23,990 --> 01:20:20,640
smiley face of binary systems

1991
01:20:26,149 --> 01:20:24,000
i don't know about this one

1992
01:20:28,149 --> 01:20:26,159
you'd have to play that what's that game

1993
01:20:30,470 --> 01:20:28,159
called that simulator for gravity

1994
01:20:32,390 --> 01:20:30,480
simulator that would be fun but it just

1995
01:20:33,910 --> 01:20:32,400
it it really strikes me that the

1996
01:20:36,310 --> 01:20:33,920
dynamics really

1997
01:20:37,669 --> 01:20:36,320
you it'd go chaotic and it wouldn't be

1998
01:20:38,790 --> 01:20:37,679
stable

1999
01:20:41,030 --> 01:20:38,800
yeah

2000
01:20:43,350 --> 01:20:41,040
early in like the history of these

2001
01:20:45,430 --> 01:20:43,360
binary systems and different planetary

2002
01:20:47,270 --> 01:20:45,440
systems we know that stars kind of come

2003
01:20:49,430 --> 01:20:47,280
by we know we have evidence that stars

2004
01:20:50,550 --> 01:20:49,440
have passed our solar system pretty

2005
01:20:52,550 --> 01:20:50,560
close

2006
01:20:54,229 --> 01:20:52,560
stars are pretty evil they will grab

2007
01:20:55,270 --> 01:20:54,239
your planetary children and take them

2008
01:20:57,590 --> 01:20:55,280
with them

2009
01:20:59,189 --> 01:20:57,600
um so we have evidence that some of

2010
01:21:01,430 --> 01:20:59,199
these planets that we're looking at have

2011
01:21:02,950 --> 01:21:01,440
been grabbed from somewhere else they've

2012
01:21:04,470 --> 01:21:02,960
been they've been nicked from their

2013
01:21:06,229 --> 01:21:04,480

parent star

2014
01:21:07,750 --> 01:21:06,239
um so

2015
01:21:09,510 --> 01:21:07,760
there's lots of different ways in which

2016
01:21:11,830 --> 01:21:09,520
you can get these configurations but we

2017
01:21:13,110 --> 01:21:11,840
know that the the formation of planets

2018
01:21:14,950 --> 01:21:13,120
we know the formation of stars and we

2019
01:21:17,750 --> 01:21:14,960
know that the dynamics of our galaxy is

2020
01:21:19,430 --> 01:21:17,760
very very chaotic and dynamic so there's

2021
01:21:20,709 --> 01:21:19,440
a lot of things that can happen

2022
01:21:22,630 --> 01:21:20,719
all right so

2023
01:21:23,750 --> 01:21:22,640
lesson for you hold on to your planets

2024
01:21:27,189 --> 01:21:23,760
okay

2025
01:21:28,950 --> 01:21:27,199
all right so next month on march

2026
01:21:30,870 --> 01:21:28,960
mia boval will be talking about mapping

2027
01:21:33,669 --> 01:21:30,880
the united federation of planets and

2028
01:21:35,510 --> 01:21:33,679
astronomers guide to the galaxy and let