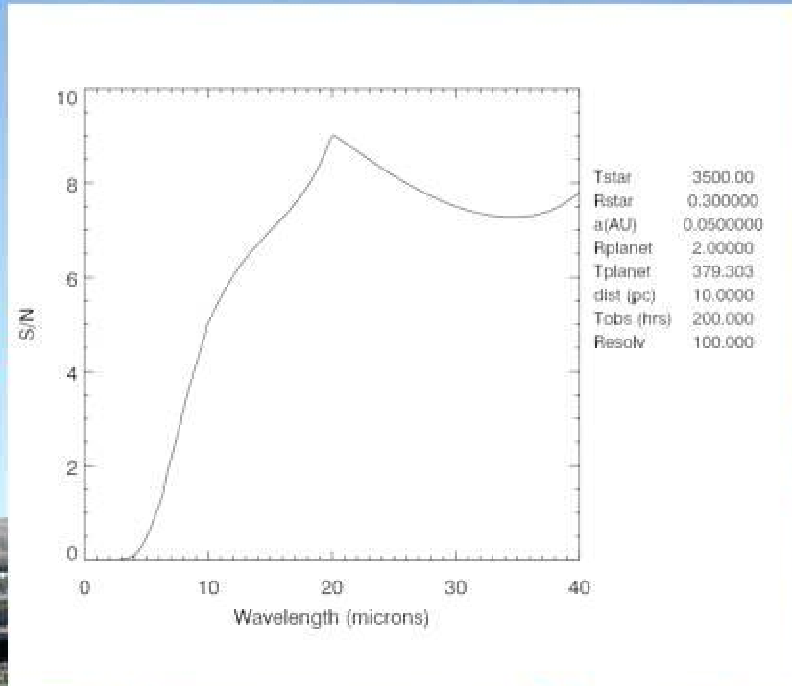
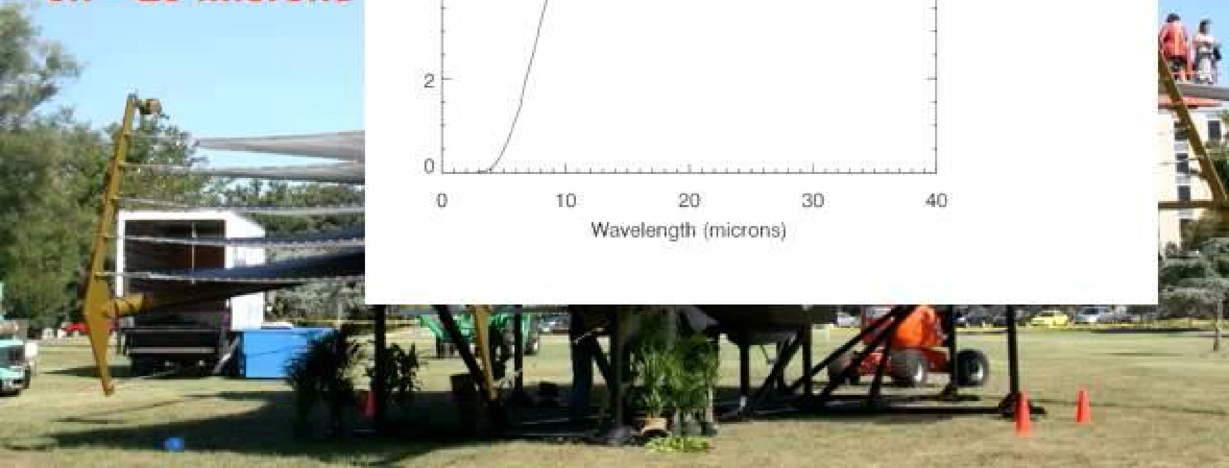
6.5 m diameter
26 m² collecting
0.7 - 25 microns





1
00:00:06,519 --> 00:00:03,350
well good morning or good afternoon

2
00:00:10,480 --> 00:00:06,529
everyone depending on your time zone

3
00:00:14,150 --> 00:00:10,490
it's morning back here on the west coast

4
00:00:17,810 --> 00:00:14,160
I'm Carl Pilcher and I am going to

5
00:00:20,659 --> 00:00:17,820
introduce our speaker today for the NAI

6
00:00:23,120 --> 00:00:20,669
director seminar our speakers Drake gain

7
00:00:24,710 --> 00:00:23,130
from Goddard Space Flight Center a

8
00:00:27,439 --> 00:00:24,720
member of the Goddard Space Flight

9
00:00:29,179 --> 00:00:27,449
Center team I've known drank for a lot

10
00:00:32,319 --> 00:00:29,189
of years and I'm really glad that he was

11
00:00:34,670 --> 00:00:32,329
able to give this but this talk because

12
00:00:39,290 --> 00:00:34,680
there have been some very exciting

13
00:00:42,440 --> 00:00:39,300

recent results particularly based on the

14
00:00:44,510 --> 00:00:42,450
spitzer space craft data and Drake is

15
00:00:46,400 --> 00:00:44,520
also going to tell us about how those

16
00:00:49,540 --> 00:00:46,410
kinds of results might be extrapolated

17
00:00:52,460 --> 00:00:49,550
to what would be possible with jwst

18
00:00:56,080 --> 00:00:52,470
Drake received his PhD in astronomy in

19
00:00:59,000 --> 00:00:56,090
1976 from the University of Illinois at

20
00:01:00,170 --> 00:00:59,010
champaign-urbana and spend some time at

21
00:01:01,940 --> 00:01:00,180
the astronomy department at the

22
00:01:06,279 --> 00:01:01,950
University of Maryland came to Goddard

23
00:01:09,169 --> 00:01:06,289
in 1979 and he has been there ever since

24
00:01:11,560 --> 00:01:09,179
working on infrared observations of

25
00:01:14,749 --> 00:01:11,570
solar system objects and obviously he's

26
00:01:16,310 --> 00:01:14,759
expanded his purview to observations of

27
00:01:18,529 --> 00:01:16,320
planetary objects and other solar

28
00:01:20,419 --> 00:01:18,539
systems so today Drake's going to tell

29
00:01:22,249 --> 00:01:20,429
us about infrared spectra of extrasolar

30
00:01:27,099 --> 00:01:22,259
planets and I will turn it over without

31
00:01:29,480 --> 00:01:27,109
further ado to Drake okay Thank You Carl

32
00:01:31,249 --> 00:01:29,490
first I want to acknowledge my

33
00:01:34,999 --> 00:01:31,259
collaborators in this work Jeremy

34
00:01:38,899 --> 00:01:35,009
Richardson was a NASA postdoctoral

35
00:01:41,270 --> 00:01:38,909
fellow at Goddard and actually I wasn't

36
00:01:43,069 --> 00:01:41,280
his advisor he was Jeremy worked in a

37
00:01:45,010 --> 00:01:43,079
couple of different laboratories and his

38
00:01:47,389 --> 00:01:45,020

advisor was filled Angie over in the

39
00:01:49,879 --> 00:01:47,399
exoplanet and stellar astrophysics

40
00:01:51,289 --> 00:01:49,889
laboratory Karen Horning is an

41
00:01:53,239 --> 00:01:51,299
undergraduate student at Florida

42
00:01:56,779 --> 00:01:53,249
Institute of Technology and she was our

43
00:01:58,639 --> 00:01:56,789
summer astrobiology intern last summer

44
00:02:01,219 --> 00:01:58,649
and Karen did a lot of the really hard

45
00:02:02,090 --> 00:02:01,229
work that's going to make the analysis

46
00:02:04,219 --> 00:02:02,100
that I'm going to show you today

47
00:02:06,050 --> 00:02:04,229
possible Sara Seager is our team's

48
00:02:08,570 --> 00:02:06,060
theorist and in the early stages of this

49
00:02:08,779 --> 00:02:08,580
work she was up to the Carnegie node and

50
00:02:11,630 --> 00:02:08,789
she

51
00:02:13,520 --> 00:02:11,640
since moved to MIT and joe harrington is

52
00:02:17,420 --> 00:02:13,530
our collaborator at the University of

53
00:02:19,759 --> 00:02:17,430
Central Florida and this this talk is

54
00:02:21,740 --> 00:02:19,769
really divided into a series of topics

55
00:02:23,899 --> 00:02:21,750
first since i'm talking about spectra of

56
00:02:27,470 --> 00:02:23,909
extrasolar planets i'm going to just

57
00:02:29,569 --> 00:02:27,480
review that very briefly the status of

58
00:02:32,929 --> 00:02:29,579
that field the the known extrasolar

59
00:02:34,610 --> 00:02:32,939
planets extend from hot Jupiters to in

60
00:02:37,879 --> 00:02:34,620
one or two cases some planets that could

61
00:02:40,039 --> 00:02:37,889
be arguably called potters and I'll

62
00:02:41,899 --> 00:02:40,049
mention the possible detection of

63
00:02:44,780 --> 00:02:41,909

biomarkers I'm not going to show you any

64
00:02:47,589 --> 00:02:44,790
actual biomarkers these are just our

65
00:02:49,699 --> 00:02:47,599
future goal but I'll try to relate the

66
00:02:51,860 --> 00:02:49,709
spectra that we that i'm going to show

67
00:02:55,909 --> 00:02:51,870
you for hot Jupiters to the eventual

68
00:02:57,949 --> 00:02:55,919
detection of biomarkers now in order to

69
00:03:01,069 --> 00:02:57,959
show you that we've measured spectra of

70
00:03:04,009 --> 00:03:01,079
two extrasolar planets i first have to

71
00:03:06,440 --> 00:03:04,019
show you that we can detect photons from

72
00:03:09,470 --> 00:03:06,450
extrasolar planets at all so i'll

73
00:03:11,720 --> 00:03:09,480
briefly describe the first spitzer

74
00:03:15,409 --> 00:03:11,730
detections and follow-up detection using

75
00:03:19,159 --> 00:03:15,419
spitzer using photometry to just measure

76
00:03:20,509 --> 00:03:19,169
the planets in a photometric mode and

77
00:03:22,399 --> 00:03:20,519
then i'll talk about measuring the

78
00:03:24,969 --> 00:03:22,409
spectra of giant planets with spitzer

79
00:03:27,379 --> 00:03:24,979
i'll show you two extrasolar planets

80
00:03:29,649 --> 00:03:27,389
specter of two extrasolar planets one

81
00:03:31,699 --> 00:03:29,659
measured by our group and another by

82
00:03:33,740 --> 00:03:31,709
another group that we work in parallel

83
00:03:35,869 --> 00:03:33,750
with and I'll finish up by saying how

84
00:03:38,479 --> 00:03:35,879
this might eventually lead to this

85
00:03:43,399 --> 00:03:38,489
spectra of what we call hotter or close

86
00:03:46,670 --> 00:03:43,409
in extra solar terrestrial planets okay

87
00:03:48,170 --> 00:03:46,680
well since 1995 the Doppler groups have

88
00:03:51,050 --> 00:03:48,180

detected the bulk of the extrasolar

89
00:03:53,240 --> 00:03:51,060
planets and the way to remind you how

90
00:03:55,460 --> 00:03:53,250
the this works is the Doppler groups

91
00:03:57,199 --> 00:03:55,470
will look at a stellar system and they

92
00:03:59,030 --> 00:03:57,209
won't detect the planet directly that is

93
00:04:00,860 --> 00:03:59,040
they won't see photons from the planet

94
00:04:03,050 --> 00:04:00,870
but they'll see the Doppler reflex of

95
00:04:06,649 --> 00:04:03,060
the parent star as it orbits the center

96
00:04:10,280 --> 00:04:06,659
of mass of its planetary system one of

97
00:04:11,749 --> 00:04:10,290
the earliest surprises of the results

98
00:04:13,369 --> 00:04:11,759
from this group was the fact the very

99
00:04:16,460 --> 00:04:13,379
first planet that was detected was

100
00:04:18,379 --> 00:04:16,470
orbiting the star 51 pegasi and it was

101
00:04:20,659 --> 00:04:18,389
very it was a giant planet of nearly

102
00:04:22,290 --> 00:04:20,669
jupiter-mass and it was in very close

103
00:04:25,770 --> 00:04:22,300
point 05 a you

104
00:04:27,659 --> 00:04:25,780
that's 20 times closer to the to its

105
00:04:29,219 --> 00:04:27,669
star than the earth is to the Sun and

106
00:04:31,170 --> 00:04:29,229
these planets have been called by

107
00:04:32,850 --> 00:04:31,180
various names I prefer to call them hot

108
00:04:35,460 --> 00:04:32,860
Jupiters because they're jupiter-mass

109
00:04:36,960 --> 00:04:35,470
but they're in close to the star and in

110
00:04:39,990 --> 00:04:36,970
that close to the star they're going to

111
00:04:42,149 --> 00:04:40,000
be very strongly irradiated on one side

112
00:04:45,149 --> 00:04:42,159
as as envisioned here by Greg Laughlin

113
00:04:46,499 --> 00:04:45,159

and James Cho by stellar irradiation

114
00:04:50,430 --> 00:04:46,509
where they're going to be heated to very

115
00:04:52,589 --> 00:04:50,440
high temperatures now of course

116
00:04:54,719 --> 00:04:52,599
ultimately what we want to do in the

117
00:04:56,939 --> 00:04:54,729
field of astrobiology has concerns

118
00:04:58,950 --> 00:04:56,949
extrasolar planets is we would like to

119
00:05:01,830 --> 00:04:58,960
measure the spectrum of an earth-like

120
00:05:03,689 --> 00:05:01,840
planet or something at least close to an

121
00:05:05,670 --> 00:05:03,699
earth-like planet being in the habitable

122
00:05:09,260 --> 00:05:05,680
zone and this is some material from

123
00:05:11,610 --> 00:05:09,270
vikki meadows showing model spectra of

124
00:05:13,499 --> 00:05:11,620
first like planets where you could see

125
00:05:16,969 --> 00:05:13,509
an ozone signature near nine and a half

126
00:05:20,850 --> 00:05:16,979
microns methane near 7.8 microns

127
00:05:23,719 --> 00:05:20,860
possibly co2 at 15 microns and to

128
00:05:25,890 --> 00:05:23,729
measure the spectra that the

129
00:05:27,089 --> 00:05:25,900
technologically difficult but

130
00:05:30,059 --> 00:05:27,099
conceptually the most straightforward

131
00:05:32,969 --> 00:05:30,069
way would be to make it a highly

132
00:05:34,649 --> 00:05:32,979
specially resolved image of a star

133
00:05:36,779 --> 00:05:34,659
containing the planet and then to

134
00:05:39,240 --> 00:05:36,789
isolate the planet and observe it with

135
00:05:40,980 --> 00:05:39,250
some very advanced space mission and if

136
00:05:43,439 --> 00:05:40,990
you can separate stellar and Planetary

137
00:05:45,029 --> 00:05:43,449
photons by some high technology method

138
00:05:47,040 --> 00:05:45,039

like this then you can just take these

139
00:05:48,510 --> 00:05:47,050
planetary photons you can put them

140
00:05:50,519 --> 00:05:48,520
through your spectrograph and you have a

141
00:05:52,469 --> 00:05:50,529
spectrum and it's a simple proposition

142
00:05:55,110 --> 00:05:52,479
but technologically this is very

143
00:05:58,350 --> 00:05:55,120
difficult and it will be very expensive

144
00:06:00,480 --> 00:05:58,360
and it hasn't been done yet but for

145
00:06:02,999 --> 00:06:00,490
those of us who are interested in seeing

146
00:06:04,800 --> 00:06:03,009
this done we can't wait so we're

147
00:06:08,209 --> 00:06:04,810
pursuing other techniques and those

148
00:06:11,159 --> 00:06:08,219
other techniques were used transits um

149
00:06:13,619 --> 00:06:11,169
since many of these planets are close in

150
00:06:15,659 --> 00:06:13,629
to their star a closed-end planet has a

151
00:06:18,899 --> 00:06:15,669
high probability to transit its star

152
00:06:22,379 --> 00:06:18,909
that is to cross in front of its star as

153
00:06:24,360 --> 00:06:22,389
seen from the earth the transit

154
00:06:27,180 --> 00:06:24,370
probability if you calculate it is is

155
00:06:30,059 --> 00:06:27,190
the radius of the star divided by the

156
00:06:31,889 --> 00:06:30,069
orbital radius of the planet and for the

157
00:06:33,460 --> 00:06:31,899
closed-end hot Jupiter type planets

158
00:06:37,180 --> 00:06:33,470
that's about ten percent

159
00:06:38,710 --> 00:06:37,190
and early on in the history of this

160
00:06:41,140 --> 00:06:38,720
field when there are about a dozen such

161
00:06:44,530 --> 00:06:41,150
planets known were in clothes from the

162
00:06:45,940 --> 00:06:44,540
Doppler surveys statistically one of

163
00:06:48,310 --> 00:06:45,950

them should transit and that one that

164
00:06:52,900 --> 00:06:48,320
was discovered to transit was hd2 or 945

165
00:06:54,760 --> 00:06:52,910
8b which mrs. Hubble observations of the

166
00:06:57,820 --> 00:06:54,770
transit of that made from space very

167
00:06:59,560 --> 00:06:57,830
high quality very low noise photometry

168
00:07:02,440 --> 00:06:59,570
the transit depth the amount of light

169
00:07:04,710 --> 00:07:02,450
that the planet blocks is about one and

170
00:07:07,210 --> 00:07:04,720
a half percent one-point-six percent

171
00:07:09,970 --> 00:07:07,220
there are now 14 of these known

172
00:07:11,020 --> 00:07:09,980
transiting bright solar-type stars and

173
00:07:12,580 --> 00:07:11,030
of course the transit is very

174
00:07:15,280 --> 00:07:12,590
interesting the depth of this transit

175
00:07:17,680 --> 00:07:15,290
tells us tells us the amount of stellar

176
00:07:20,320 --> 00:07:17,690
life that the planet blocks but we're

177
00:07:22,540 --> 00:07:20,330
not detecting light from the planet this

178
00:07:25,750 --> 00:07:22,550
way in order to detect light from the

179
00:07:28,810 --> 00:07:25,760
planet we have to use what's called the

180
00:07:31,480 --> 00:07:28,820
secondary eclipse the transit is the

181
00:07:33,610 --> 00:07:31,490
primary eclipse planet canít planet

182
00:07:35,710 --> 00:07:33,620
passing in front of the star that tells

183
00:07:37,480 --> 00:07:35,720
us the size of the planet and in

184
00:07:39,280 --> 00:07:37,490
principle we can see and in fact it has

185
00:07:40,810 --> 00:07:39,290
been done radiation from the star

186
00:07:42,580 --> 00:07:40,820
transmitted through the planet's

187
00:07:44,409 --> 00:07:42,590
atmosphere so in fact the first

188
00:07:47,230 --> 00:07:44,419

detection of an atmosphere was made this

189
00:07:49,810 --> 00:07:47,240
way but we can't see photons emitted by

190
00:07:51,909 --> 00:07:49,820
the planet in order to do that we have

191
00:07:54,640 --> 00:07:51,919
to go to the secondary eclipse when the

192
00:07:56,560 --> 00:07:54,650
planet passes behind the star then if we

193
00:07:58,690 --> 00:07:56,570
look in the combined light of the system

194
00:08:00,630 --> 00:07:58,700
with no attempt to specially resolve the

195
00:08:03,040 --> 00:08:00,640
system we will see thermal radiation

196
00:08:06,010 --> 00:08:03,050
from the planet disappear and reappear

197
00:08:07,540 --> 00:08:06,020
and in so doing we will learn particular

198
00:08:09,969 --> 00:08:07,550
about the atmosphere of that planet

199
00:08:12,280 --> 00:08:09,979
because that thermal radiation that we

200
00:08:13,719 --> 00:08:12,290
receive emerges ultimately from the

201
00:08:15,610 --> 00:08:13,729
atmosphere of the planet will also learn

202
00:08:17,409 --> 00:08:15,620
about its orbit and other things but I'm

203
00:08:20,200 --> 00:08:17,419
going to focus here mainly on the

204
00:08:24,219 --> 00:08:20,210
spectra of two of these planets which

205
00:08:26,950 --> 00:08:24,229
tell us about their atmosphere here are

206
00:08:28,630 --> 00:08:26,960
the first detection of photons from

207
00:08:30,550 --> 00:08:28,640
extrasolar planets they were made with

208
00:08:33,659 --> 00:08:30,560
the Spitzer Space Telescope almost

209
00:08:36,940 --> 00:08:33,669
exactly two years ago this month and

210
00:08:39,610 --> 00:08:36,950
there were in fact done one of the great

211
00:08:42,240 --> 00:08:39,620
coincidences of astronomy is that the

212
00:08:43,800 --> 00:08:42,250
two detection papers were submitted

213
00:08:45,840 --> 00:08:43,810

on the same day two different journals

214
00:08:48,960 --> 00:08:45,850
completely uncoordinated the two groups

215
00:08:50,820 --> 00:08:48,970
had known no we're not courting the

216
00:08:54,570 --> 00:08:50,830
coordinating their measurements our

217
00:08:57,660 --> 00:08:54,580
group detected ht-29 458 be using the

218
00:08:59,190 --> 00:08:57,670
using spitzer at 24 microns this shows

219
00:09:02,430 --> 00:08:59,200
the secondary eclipse where the light

220
00:09:04,230 --> 00:09:02,440
from the planet goes goes away then the

221
00:09:06,570 --> 00:09:04,240
radiation comes back again after Eclipse

222
00:09:08,670 --> 00:09:06,580
and then a group led by Dave Charbonneau

223
00:09:11,040 --> 00:09:08,680
at Harvard detected the planet called

224
00:09:12,780 --> 00:09:11,050
trace one at eight microns and they also

225
00:09:16,070 --> 00:09:12,790
detected it at four and a half microns

226
00:09:18,540 --> 00:09:16,080
which isn't isn't shown here now the

227
00:09:20,160 --> 00:09:18,550
eclipse depth of the secondary eclipse

228
00:09:22,320 --> 00:09:20,170
is just the depth of the it's the

229
00:09:24,210 --> 00:09:22,330
projected area ratio this is really just

230
00:09:25,470 --> 00:09:24,220
the depth of the transit and in the

231
00:09:27,090 --> 00:09:25,480
rayleigh jeans limit there's an

232
00:09:29,070 --> 00:09:27,100
additional factor which is the ratio of

233
00:09:32,490 --> 00:09:29,080
temperatures and this is something like

234
00:09:34,560 --> 00:09:32,500
one fifth row one quarter so these these

235
00:09:36,000 --> 00:09:34,570
secondary eclipses are less deep than

236
00:09:37,850 --> 00:09:36,010
the transits and that's why there of

237
00:09:40,830 --> 00:09:37,860
course much noisier than transits and

238
00:09:43,050 --> 00:09:40,840

these initial detection were you know

239
00:09:44,850 --> 00:09:43,060
you can see that the data have a fair

240
00:09:46,530 --> 00:09:44,860
amount of scatter an individual point

241
00:09:49,740 --> 00:09:46,540
wouldn't really be sufficient to detect

242
00:09:51,420 --> 00:09:49,750
these eclipses but in aggregate each of

243
00:09:54,780 --> 00:09:51,430
these eclipses is about a six sigma

244
00:09:58,140 --> 00:09:54,790
detection and the temperature is about

245
00:09:59,670 --> 00:09:58,150
eleven hundred Kelvin now although these

246
00:10:01,410 --> 00:09:59,680
were you know sort of two independent

247
00:10:04,800 --> 00:10:01,420
groups and we both got about the same

248
00:10:06,240 --> 00:10:04,810
result on to two different planets using

249
00:10:07,590 --> 00:10:06,250
different Spitzer instruments

250
00:10:09,990 --> 00:10:07,600
nevertheless if you were a really

251
00:10:12,000 --> 00:10:10,000
skeptical person you might say well at

252
00:10:14,490 --> 00:10:12,010
all six sigma maybe I don't really

253
00:10:16,530 --> 00:10:14,500
believe that well I will in that case I

254
00:10:18,930 --> 00:10:16,540
I welcome that skepticism i will show

255
00:10:24,090 --> 00:10:18,940
you an additional follow-up detection

256
00:10:26,460 --> 00:10:24,100
because a later in 2005 an additional

257
00:10:28,430 --> 00:10:26,470
planet was detected that has an even

258
00:10:31,110 --> 00:10:28,440
greater transit dip and an even greater

259
00:10:33,360 --> 00:10:31,120
secondary eclipse depth due to the fact

260
00:10:36,420 --> 00:10:33,370
that the star that it that it orbits is

261
00:10:38,820 --> 00:10:36,430
much smaller to the ratio of planetary

262
00:10:41,730 --> 00:10:38,830
flux stellar flux is much better and

263
00:10:43,680 --> 00:10:41,740

that's HD 189733 B and here's its

264
00:10:45,600 --> 00:10:43,690
secondary eclipse observed by Spitzer

265
00:10:47,970 --> 00:10:45,610
although you know maybe you could be

266
00:10:49,380 --> 00:10:47,980
skeptical over first detection is no

267
00:10:51,960 --> 00:10:49,390
one's going to be skeptical of this one

268
00:10:53,210 --> 00:10:51,970
this is a 32 sigma detection of this

269
00:10:55,879 --> 00:10:53,220
planet at 16

270
00:10:58,340 --> 00:10:55,889
Brown's man this is the unbend or all

271
00:11:00,019 --> 00:10:58,350
the original spitzer measurements all of

272
00:11:03,740 --> 00:11:00,029
them every 10 seconds and this is a bin

273
00:11:05,780 --> 00:11:03,750
plot just to show it more clearly again

274
00:11:08,150 --> 00:11:05,790
the deputy clips depth is the ratio of

275
00:11:10,420 --> 00:11:08,160
the projected area of the planet to

276
00:11:12,860 --> 00:11:10,430
start times the temperature ratio and

277
00:11:14,119 --> 00:11:12,870
what I wanted to point out with this is

278
00:11:17,210 --> 00:11:14,129
that as you go down the main sequence

279
00:11:18,949 --> 00:11:17,220
two smaller stars this is a case star if

280
00:11:21,619 --> 00:11:18,959
you go to even smaller stars if you go

281
00:11:23,689 --> 00:11:21,629
to M dwarf stars this this becomes even

282
00:11:26,540 --> 00:11:23,699
more favorable situation in the infrared

283
00:11:30,889 --> 00:11:26,550
and the reason is that this this term

284
00:11:33,100 --> 00:11:30,899
this this area ratio was the dominant

285
00:11:34,910 --> 00:11:33,110
term whereas this term is the

286
00:11:36,920 --> 00:11:34,920
temperatures of the planets and the

287
00:11:38,689 --> 00:11:36,930
stars don't vary all that much the

288
00:11:40,460 --> 00:11:38,699

temperature of the planet is the

289
00:11:42,949 --> 00:11:40,470
temperature of the star in thermal

290
00:11:45,889 --> 00:11:42,959
equilibrium times the angular diameter

291
00:11:48,199 --> 00:11:45,899
of the star as seen from the planet and

292
00:11:50,780 --> 00:11:48,209
the square root of that so this varies

293
00:11:53,840 --> 00:11:50,790
relatively mildly where is this term

294
00:11:55,610 --> 00:11:53,850
very predominantly and as you go to

295
00:11:58,280 --> 00:11:55,620
smaller stars this becomes more

296
00:12:00,199 --> 00:11:58,290
favorable so lower main sequence stars

297
00:12:02,030 --> 00:12:00,209
are very good for for high

298
00:12:05,780 --> 00:12:02,040
signal-to-noise planet detection using

299
00:12:07,129 --> 00:12:05,790
secondary eclipses so I think by this

300
00:12:12,499 --> 00:12:07,139
I've convinced you that we're seeing

301
00:12:14,629 --> 00:12:12,509
photons from extrasolar giant planets so

302
00:12:17,240 --> 00:12:14,639
now I want to talk about dissecting

303
00:12:19,790 --> 00:12:17,250
those photons and and looking at their

304
00:12:22,610 --> 00:12:19,800
at their spectrum the previous

305
00:12:26,119 --> 00:12:22,620
detections were photometric and now when

306
00:12:28,850 --> 00:12:26,129
we begin dividing the photons into

307
00:12:30,679 --> 00:12:28,860
smaller wavelength bins it's a more

308
00:12:33,079 --> 00:12:30,689
challenging problem but nevertheless

309
00:12:36,199 --> 00:12:33,089
there are two transiting planets HD

310
00:12:39,590 --> 00:12:36,209
189733 that I just showed you an hd2 a

311
00:12:41,420 --> 00:12:39,600
945 a which are bright enough that we

312
00:12:43,369 --> 00:12:41,430
can measure their spectra using the

313
00:12:46,730 --> 00:12:43,379

relatively modest aperture Spitzer's an

314
00:12:48,740 --> 00:12:46,740
85 centimeter telescope and both of

315
00:12:52,189 --> 00:12:48,750
those detection zwarst earlier this year

316
00:12:54,860 --> 00:12:52,199
our detection was in nature there's a

317
00:12:58,160 --> 00:12:54,870
group headed by Karl grill mayor at the

318
00:13:00,350 --> 00:12:58,170
ipaq at the Spitzer Science Center and

319
00:13:03,319 --> 00:13:00,360
Dave Charbonneau collaborated with him

320
00:13:04,819 --> 00:13:03,329
who detected HD 189733 and I'll show you

321
00:13:05,540 --> 00:13:04,829
their results also there's another

322
00:13:07,970 --> 00:13:05,550
analysis

323
00:13:10,190 --> 00:13:07,980
done by mark Swain who reanalyzed our

324
00:13:13,759 --> 00:13:10,200
data and i won't i won't discuss marks

325
00:13:17,870 --> 00:13:13,769
result unless someone asks here's the

326
00:13:19,579 --> 00:13:17,880
principle that we use and i emphasize

327
00:13:20,900 --> 00:13:19,589
this is the principle this is not what

328
00:13:23,360 --> 00:13:20,910
we actually do but this is the

329
00:13:25,550 --> 00:13:23,370
conceptual basis of what we do before

330
00:13:28,190 --> 00:13:25,560
the secondary Eclipse we use spitzer to

331
00:13:30,980 --> 00:13:28,200
measure the combined light the spectrum

332
00:13:32,780 --> 00:13:30,990
of the star plus planet now we know when

333
00:13:34,850 --> 00:13:32,790
the planet is going to be in Eclipse so

334
00:13:38,060 --> 00:13:34,860
during that time we observe the stellar

335
00:13:40,069 --> 00:13:38,070
spectrum Spitzer's in a very stable

336
00:13:44,000 --> 00:13:40,079
heliocentric orbit the instrument

337
00:13:46,550 --> 00:13:44,010
doesn't change very very much and so we

338
00:13:49,660 --> 00:13:46,560

can subtract the two and drive the

339
00:13:53,000 --> 00:13:49,670
planet spectrum so it's a very simple a

340
00:13:54,410 --> 00:13:53,010
simple idea we'd practice it gets more

341
00:13:57,740 --> 00:13:54,420
complicated and I'm going to show you

342
00:14:00,290 --> 00:13:57,750
some of the actual you know nitty gritty

343
00:14:02,930 --> 00:14:00,300
dirty laundry of how we do this analysis

344
00:14:05,300 --> 00:14:02,940
here's an actual here's an actual

345
00:14:07,100 --> 00:14:05,310
imaging frame from Spitzer and I'm

346
00:14:08,990 --> 00:14:07,110
tempted to say this is raw data that the

347
00:14:11,510 --> 00:14:09,000
Spitzer people would correct me this is

348
00:14:13,850 --> 00:14:11,520
what they call BCD or basic calibrated

349
00:14:16,910 --> 00:14:13,860
data it's an image of the spectrum of

350
00:14:19,400 --> 00:14:16,920
hd2 0945 8v here's the eight we observed

351
00:14:22,430 --> 00:14:19,410
between a rap about seven and a half

352
00:14:24,050 --> 00:14:22,440
microns to about 14 microns here this

353
00:14:27,400 --> 00:14:24,060
street this bright streak is the

354
00:14:30,260 --> 00:14:27,410
spectrum of the star plus the planet and

355
00:14:32,630 --> 00:14:30,270
you can see all you know bad pixels on

356
00:14:34,340 --> 00:14:32,640
the array the hot pixels over at the

357
00:14:36,319 --> 00:14:34,350
right side of the detector array there

358
00:14:39,310 --> 00:14:36,329
what are called the peak up arrays which

359
00:14:42,380 --> 00:14:39,320
are just regions which which receive

360
00:14:45,110 --> 00:14:42,390
which are not dispersed so the star

361
00:14:47,389 --> 00:14:45,120
first the telescope places the star here

362
00:14:49,430 --> 00:14:47,399
to center it and then offsets it to the

363
00:14:50,930 --> 00:14:49,440

slid to the spectrograph we actually can

364
00:14:52,670 --> 00:14:50,940
use the peak up arrays for various

365
00:14:55,220 --> 00:14:52,680
things they're very bright here because

366
00:14:56,660 --> 00:14:55,230
they're not seeing this first light

367
00:14:59,510 --> 00:14:56,670
they're looking at the at the background

368
00:15:02,210 --> 00:14:59,520
radiation from our zodiacal background

369
00:15:04,880 --> 00:15:02,220
directly but we actually observe two

370
00:15:07,689 --> 00:15:04,890
full eclipses of this planet each

371
00:15:10,250 --> 00:15:07,699
eclipse was a six-hour sequence of

372
00:15:12,860 --> 00:15:10,260
observation each of one is let each one

373
00:15:14,730 --> 00:15:12,870
of which is like this these were made in

374
00:15:16,960 --> 00:15:14,740
july 2005

375
00:15:18,850 --> 00:15:16,970
shortly after we did the photometric

376
00:15:20,850 --> 00:15:18,860
protections we immediately jumped on

377
00:15:23,200 --> 00:15:20,860
this spectroscopic technique our

378
00:15:25,360 --> 00:15:23,210
observations are basically 60-second

379
00:15:27,820 --> 00:15:25,370
exposures there are two hundred and

380
00:15:29,500 --> 00:15:27,830
eighty of them her eclipse and we have

381
00:15:32,140 --> 00:15:29,510
two eclipses so we have a total of five

382
00:15:34,780 --> 00:15:32,150
hundred and sixty data frames that look

383
00:15:36,400 --> 00:15:34,790
like this there is a telescope nod at

384
00:15:38,650 --> 00:15:36,410
the center of the eclipse we move the

385
00:15:40,690 --> 00:15:38,660
spectrum so that we can subtract the

386
00:15:43,630 --> 00:15:40,700
background and what's under the spectrum

387
00:15:45,690 --> 00:15:43,640
or more accurately the spectral

388
00:15:48,220 --> 00:15:45,700

resolving power is about a hundred and

389
00:15:50,650 --> 00:15:48,230
that's just sort of barely what a

390
00:15:52,480 --> 00:15:50,660
spectroscopy would call a spectrum but

391
00:15:54,160 --> 00:15:52,490
it is a legitimate that's a high enough

392
00:15:56,530 --> 00:15:54,170
spectral resolution it's not photometry

393
00:15:59,410 --> 00:15:56,540
it's spectroscopy now we can immediately

394
00:16:02,350 --> 00:15:59,420
estimate what signal-to-noise we expect

395
00:16:04,480 --> 00:16:02,360
on the planet in combined light the

396
00:16:07,330 --> 00:16:04,490
signal to noise on this spectrum Star

397
00:16:10,860 --> 00:16:07,340
Plus planet is about 100 in a given

398
00:16:16,300 --> 00:16:10,870
pixel a pixel meaning a given wavelength

399
00:16:18,760 --> 00:16:16,310
/ spectrum since we have 560 spectrum

400
00:16:20,830 --> 00:16:18,770
about half of which are in Eclipse and

401
00:16:22,390 --> 00:16:20,840
half of which are out of Eclipse to

402
00:16:23,530 --> 00:16:22,400
detect the spectrum of the planet we

403
00:16:26,200 --> 00:16:23,540
have to basically at each wavelength

404
00:16:28,870 --> 00:16:26,210
define two levels and in Eclipse level

405
00:16:30,940 --> 00:16:28,880
and an out of Eclipse level each level

406
00:16:33,430 --> 00:16:30,950
is defined by there are five hundred and

407
00:16:35,590 --> 00:16:33,440
sixty total spectra each level is

408
00:16:37,420 --> 00:16:35,600
defined by half of those are about 280

409
00:16:39,220 --> 00:16:37,430
so the signal Foyle is on each level

410
00:16:41,890 --> 00:16:39,230
improves by a hundred times the square

411
00:16:44,650 --> 00:16:41,900
root of 280 but then since we have to

412
00:16:46,600 --> 00:16:44,660
compare two independent levels we lose

413
00:16:50,020 --> 00:16:46,610

the square root of two and if you work

414
00:16:52,150 --> 00:16:50,030
that out in our combined data at each at

415
00:16:54,250 --> 00:16:52,160
each wavelength we would have a signal

416
00:16:57,490 --> 00:16:54,260
to noise on the combined system of about

417
00:16:59,350 --> 00:16:57,500
1,200 on Star Plus planet the planet is

418
00:17:01,840 --> 00:16:59,360
about three-tenths of a percent of this

419
00:17:03,550 --> 00:17:01,850
total therefore our signal to noise on

420
00:17:07,300 --> 00:17:03,560
the planet at a given wavelength will be

421
00:17:09,310 --> 00:17:07,310
about 4 which is low signal-to-noise we

422
00:17:14,829 --> 00:17:09,320
are limited by the number of photons

423
00:17:20,480 --> 00:17:18,559
now in order to get to that photon limit

424
00:17:23,319 --> 00:17:20,490
we have to deal with some some

425
00:17:25,549 --> 00:17:23,329
instrument and telescope on

426
00:17:27,769 --> 00:17:25,559
uncertainties some systemic effects

427
00:17:29,899 --> 00:17:27,779
there are two principal systemic effects

428
00:17:34,460 --> 00:17:29,909
first of all there's something we call

429
00:17:37,759 --> 00:17:34,470
the ramp and it what happens is when you

430
00:17:39,350 --> 00:17:37,769
first put light on on the specter on the

431
00:17:41,299 --> 00:17:39,360
detector in the infrared spectrograph

432
00:17:43,700 --> 00:17:41,309
but also on some of the other Spitzer

433
00:17:46,269 --> 00:17:43,710
detectors see the same effect the

434
00:17:48,470 --> 00:17:46,279
intensity that comes out of the detector

435
00:17:51,049 --> 00:17:48,480
even though the source isn't changing

436
00:17:53,570 --> 00:17:51,059
the intensity gradually ramps up with

437
00:17:57,049 --> 00:17:53,580
time that asymptotically approaches some

438
00:17:59,840 --> 00:17:57,059

constant value over many hours and this

439
00:18:02,330 --> 00:17:59,850
is recently the physical cause of this

440
00:18:04,399 --> 00:18:02,340
as has recently been identified by the

441
00:18:06,230 --> 00:18:04,409
effect by the Iraq group at the Center

442
00:18:07,850 --> 00:18:06,240
for Astrophysics and they believe this

443
00:18:10,399 --> 00:18:07,860
is due to charge trapping in the

444
00:18:13,039 --> 00:18:10,409
detector material the first photons that

445
00:18:14,899 --> 00:18:13,049
come in don't produce electrons instead

446
00:18:17,570 --> 00:18:14,909
the electrons that get freed from the

447
00:18:19,490 --> 00:18:17,580
detector get trapped by ionized

448
00:18:21,320 --> 00:18:19,500
impurities in the detector and you don't

449
00:18:23,240 --> 00:18:21,330
really reach full sensitivity until you

450
00:18:25,730 --> 00:18:23,250
fill all those charged traps and that

451
00:18:27,230 --> 00:18:25,740
makes for this ramping up baseline so we

452
00:18:29,659 --> 00:18:27,240
have to we have to deal with this we

453
00:18:31,310 --> 00:18:29,669
have to subtract this from our data the

454
00:18:33,169 --> 00:18:31,320
other effect is there's a telescope

455
00:18:36,169 --> 00:18:33,179
oscillation and we're taking spectrum

456
00:18:39,710 --> 00:18:36,179
the the Spitzer telescope is is

457
00:18:42,950 --> 00:18:39,720
wonderful but it has a point 05 arc

458
00:18:45,019 --> 00:18:42,960
second oscillation in position with it

459
00:18:47,240 --> 00:18:45,029
with a period of about one hour and

460
00:18:49,310 --> 00:18:47,250
because the telescope is oscillating

461
00:18:51,350 --> 00:18:49,320
that means the slit that the star is

462
00:18:53,560 --> 00:18:51,360
moving on the slit and the amount of

463
00:18:56,450 --> 00:18:53,570

light that comes through our slit is

464
00:18:59,570 --> 00:18:56,460
oscillating by several percent do to

465
00:19:01,759 --> 00:18:59,580
that telescope oscillation well you can

466
00:19:03,769 --> 00:19:01,769
imagine if we didn't subtract this we're

467
00:19:05,720 --> 00:19:03,779
looking for the spectra of a planet

468
00:19:06,860 --> 00:19:05,730
which is a few tenths of a percent this

469
00:19:08,180 --> 00:19:06,870
is an order of magnitude this

470
00:19:10,899 --> 00:19:08,190
oscillation is an order of magnitude

471
00:19:14,960 --> 00:19:10,909
larger than the planet signal

472
00:19:16,879 --> 00:19:14,970
fortunately that the where the telescope

473
00:19:20,210 --> 00:19:16,889
is pointed is not a function of

474
00:19:22,639 --> 00:19:20,220
wavelength it's so the phase of this

475
00:19:25,039 --> 00:19:22,649
oscillation is absolutely independent of

476
00:19:25,830 --> 00:19:25,049
wavelength its amplitude is slightly

477
00:19:28,950 --> 00:19:25,840
dependent

478
00:19:32,460 --> 00:19:28,960
wavelength but we can nevertheless

479
00:19:36,269 --> 00:19:32,470
subtract it if you that we do see the

480
00:19:39,419 --> 00:19:36,279
planet at all I've simply summed all of

481
00:19:40,860 --> 00:19:39,429
the wavelengths over time and you can

482
00:19:43,049 --> 00:19:40,870
see here is that here is the total

483
00:19:44,610 --> 00:19:43,059
intensity in our spectra as a function

484
00:19:47,519 --> 00:19:44,620
and this is both eclipses averaged

485
00:19:49,980 --> 00:19:47,529
together and you can see the ramp see

486
00:19:52,350 --> 00:19:49,990
how it rises up and then approaches some

487
00:19:54,480 --> 00:19:52,360
asymptotic value this these dotted lines

488
00:19:56,430 --> 00:19:54,490

are where ingress and egress of the

489
00:19:58,980 --> 00:19:56,440
planets eclipses occur you can see there

490
00:20:00,659 --> 00:19:58,990
is a decrease at this time and that's

491
00:20:03,630 --> 00:20:00,669
the eclipse of the planet you can also

492
00:20:05,490 --> 00:20:03,640
see the residual oscillation since we've

493
00:20:07,500 --> 00:20:05,500
averaged two independent eclipses the

494
00:20:09,060 --> 00:20:07,510
oscillations not a big because the

495
00:20:10,740 --> 00:20:09,070
oscillation had a different phase

496
00:20:12,510 --> 00:20:10,750
because those in those eclipses were

497
00:20:14,850 --> 00:20:12,520
measured a week apart the telescope

498
00:20:16,680 --> 00:20:14,860
repointed to completely reset the phase

499
00:20:19,470 --> 00:20:16,690
of the oscillation so it tends to

500
00:20:21,180 --> 00:20:19,480
average out here but we'd what we do is

501
00:20:23,250 --> 00:20:21,190
we independently subtract it in each

502
00:20:24,779 --> 00:20:23,260
eclipse but I average these together

503
00:20:29,060 --> 00:20:24,789
because I have to show you first of all

504
00:20:32,159 --> 00:20:29,070
that we do see the eclipse of the planet

505
00:20:35,639 --> 00:20:32,169
now here's how we actually get the

506
00:20:36,960 --> 00:20:35,649
spectra it's a multi-step process the

507
00:20:39,149 --> 00:20:36,970
first thing we have to do is we have

508
00:20:41,220 --> 00:20:39,159
images of the spectra we have to

509
00:20:43,320 --> 00:20:41,230
actually get spectra that means we have

510
00:20:45,269 --> 00:20:43,330
to remove all those bad pixels we have

511
00:20:47,610 --> 00:20:45,279
to subtract the background and we have

512
00:20:51,240 --> 00:20:47,620
to sum over a special window and we

513
00:20:52,500 --> 00:20:51,250

actually spent about three months doing

514
00:20:54,840 --> 00:20:52,510
this and we did it three different ways

515
00:20:56,820 --> 00:20:54,850
we had to sort of custom ways to do it

516
00:20:58,500 --> 00:20:56,830
where we would look at the actual time

517
00:21:00,930 --> 00:20:58,510
dependence of the intensity in each

518
00:21:03,630 --> 00:21:00,940
pixel and we would throw away bad pixels

519
00:21:06,019 --> 00:21:03,640
we literally every pixel in the detector

520
00:21:09,090 --> 00:21:06,029
had to become our personal friend and

521
00:21:11,010 --> 00:21:09,100
and we had to two members of our team do

522
00:21:13,200 --> 00:21:11,020
this with their own custom procedures

523
00:21:15,450 --> 00:21:13,210
then there are their standard software

524
00:21:17,669 --> 00:21:15,460
to do it by the Spitzer method and we

525
00:21:18,990 --> 00:21:17,679
did that too and we then we took all

526
00:21:21,269 --> 00:21:19,000
those results and put them through our

527
00:21:24,240 --> 00:21:21,279
entire analysis to get the spectrum of

528
00:21:26,850 --> 00:21:24,250
the planet and we can't just pick the

529
00:21:29,070 --> 00:21:26,860
method we like the best we have to have

530
00:21:31,049 --> 00:21:29,080
some objective way of doing it and the

531
00:21:33,029 --> 00:21:31,059
objective method that we decided to pick

532
00:21:36,050 --> 00:21:33,039
the best method who is we would compare

533
00:21:38,630 --> 00:21:36,060
the planets spectrum on the two eclipses

534
00:21:40,220 --> 00:21:38,640
and we would do a chi-squared of the

535
00:21:41,870 --> 00:21:40,230
difference between the two eclipses from

536
00:21:44,180 --> 00:21:41,880
the planet spectrum and the method that

537
00:21:47,030 --> 00:21:44,190
produced the minimum chi-squared is a

538
00:21:49,250 --> 00:21:47,040

method we used it turned out to be one

539
00:21:51,850 --> 00:21:49,260
of our custom extraction methods which

540
00:21:53,630 --> 00:21:51,860
isn't surprising because the

541
00:21:56,180 --> 00:21:53,640
characteristics of the detector do

542
00:21:58,550 --> 00:21:56,190
change with time so if we use something

543
00:22:01,330 --> 00:21:58,560
care to customize for our own data

544
00:22:05,030 --> 00:22:01,340
that's going to produce the best results

545
00:22:07,280 --> 00:22:05,040
then what we do is we really don't we

546
00:22:10,630 --> 00:22:07,290
really don't subtract spectra we really

547
00:22:13,790 --> 00:22:10,640
treat these spectra as a series of

548
00:22:16,160 --> 00:22:13,800
photometry measurements in other words

549
00:22:18,920 --> 00:22:16,170
we normalize the intensities at each

550
00:22:21,590 --> 00:22:18,930
wavelength to into an average value of

551
00:22:24,770 --> 00:22:21,600
unity another way of saying that is we

552
00:22:27,740 --> 00:22:24,780
divide every spectrum by the average

553
00:22:29,390 --> 00:22:27,750
spectrum of the star and that normalizes

554
00:22:31,840 --> 00:22:29,400
the intensity of each wavelength to

555
00:22:34,400 --> 00:22:31,850
unity and it puts our final results in

556
00:22:38,050 --> 00:22:34,410
in what's called contrast units the

557
00:22:42,980 --> 00:22:38,060
ratio of the planet to the star we then

558
00:22:45,290 --> 00:22:42,990
give up the average eclipse and in other

559
00:22:49,220 --> 00:22:45,300
words we subtract the average time

560
00:22:53,330 --> 00:22:49,230
series and when we do that this average

561
00:22:55,220 --> 00:22:53,340
eclipse goes away we subtract it out of

562
00:22:57,290 --> 00:22:55,230
the data what we're left with are the

563
00:23:00,770 --> 00:22:57,300

differences in that eclipse from one

564
00:23:03,290 --> 00:23:00,780
wavelength to the next so if the planets

565
00:23:05,540 --> 00:23:03,300
spectrum were constant over our

566
00:23:08,630 --> 00:23:05,550
wavelength range we would see nothing

567
00:23:10,610 --> 00:23:08,640
but because we do see the average

568
00:23:12,230 --> 00:23:10,620
eclipse we would know that the point

569
00:23:13,700 --> 00:23:12,240
that we are detecting the flux from the

570
00:23:17,030 --> 00:23:13,710
planet but that it's constant with

571
00:23:18,740 --> 00:23:17,040
wavelength now the advantage of

572
00:23:21,650 --> 00:23:18,750
subtracting that average time series is

573
00:23:24,200 --> 00:23:21,660
it removes most of the systematics it

574
00:23:26,480 --> 00:23:24,210
removes the intensity ramp apart from a

575
00:23:28,070 --> 00:23:26,490
linear term and it and it very

576
00:23:33,260 --> 00:23:28,080
effectively removes the telescope

577
00:23:35,840 --> 00:23:33,270
oscillation we then to each time series

578
00:23:37,040 --> 00:23:35,850
we fit in eclipse curve and we do allow

579
00:23:39,260 --> 00:23:37,050
that eclipse curve to have a linear

580
00:23:42,620 --> 00:23:39,270
baseline a sloping up or down at each

581
00:23:44,360 --> 00:23:42,630
wavelength and we derive the planet

582
00:23:46,460 --> 00:23:44,370
spectrum from the amplitude of those

583
00:23:47,560 --> 00:23:46,470
eclipse curve we those are differential

584
00:23:49,810 --> 00:23:47,570
eclipses

585
00:23:51,660 --> 00:23:49,820
let's say that the planet is brighter at

586
00:23:54,310 --> 00:23:51,670
one wavelength than it is at another

587
00:23:56,200 --> 00:23:54,320
then when we subtract the average time

588
00:23:58,570 --> 00:23:56,210

series we will have a little bit of

589
00:24:00,010 --> 00:23:58,580
residual extra eclipse at that

590
00:24:04,480 --> 00:24:00,020
wavelength with the planet is brighter

591
00:24:06,490 --> 00:24:04,490
and thus will and and our Eclipse our

592
00:24:09,250 --> 00:24:06,500
method of fitting the Eclipse curve will

593
00:24:11,650 --> 00:24:09,260
detect that little extra Eclipse and we

594
00:24:14,590 --> 00:24:11,660
would take that extra Eclipse depth and

595
00:24:16,660 --> 00:24:14,600
translate it into an extra depth for an

596
00:24:18,340 --> 00:24:16,670
extra brightness for the planet we then

597
00:24:21,730 --> 00:24:18,350
go through and reject any wavelengths

598
00:24:23,680 --> 00:24:21,740
that have for fits if if this fit to the

599
00:24:26,920 --> 00:24:23,690
Eclipse curve doesn't show the correct

600
00:24:28,840 --> 00:24:26,930
ingress time the correct egress time the

601
00:24:30,490 --> 00:24:28,850
correct central phase we throw it away

602
00:24:33,730 --> 00:24:30,500
and about five percent of the

603
00:24:35,260 --> 00:24:33,740
wavelengths have residual you know ramp

604
00:24:37,600 --> 00:24:35,270
effect so the systematics are not

605
00:24:39,600 --> 00:24:37,610
effectively removed or those pixels are

606
00:24:43,230 --> 00:24:39,610
very poorly behaved we throw those away

607
00:24:47,710 --> 00:24:43,240
we then compared to independent eclipses

608
00:24:50,140 --> 00:24:47,720
and this is an example of a differential

609
00:24:54,790 --> 00:24:50,150
eclipse this is our the point where we

610
00:24:56,050 --> 00:24:54,800
find the brightest peak in the planet

611
00:24:59,890 --> 00:24:56,060
spectrum and this is a differential

612
00:25:02,740 --> 00:24:59,900
eclipse it's centered at phase 0.5 where

613
00:25:06,610 --> 00:25:02,750

it's supposed to whisk this dash line is

614
00:25:09,130 --> 00:25:06,620
is a theoretical eclipse curve that has

615
00:25:10,900 --> 00:25:09,140
the correct ingress time and egress time

616
00:25:13,000 --> 00:25:10,910
in the correct central phase we don't

617
00:25:14,650 --> 00:25:13,010
ship this back and forth all we do is we

618
00:25:19,630 --> 00:25:14,660
fit its amplitude we stretch it up and

619
00:25:23,350 --> 00:25:19,640
down here are the aggregate results for

620
00:25:26,830 --> 00:25:23,360
two eclipses of this planet 0 is right

621
00:25:28,300 --> 00:25:26,840
here so you can see we're detecting at

622
00:25:30,790 --> 00:25:28,310
the longest wavelength we basically

623
00:25:33,250 --> 00:25:30,800
don't we barely detect the planets

624
00:25:36,310 --> 00:25:33,260
continuum we know we can't really say

625
00:25:39,250 --> 00:25:36,320
anything about any structure there are

626
00:25:41,710 --> 00:25:39,260
there are two features in this spectrum

627
00:25:43,360 --> 00:25:41,720
that we regard as real in the sense that

628
00:25:45,700 --> 00:25:43,370
although there are only three or four

629
00:25:47,620 --> 00:25:45,710
Sigma detection and we would like not to

630
00:25:49,870 --> 00:25:47,630
be in the three or four Sigma domain but

631
00:25:52,030 --> 00:25:49,880
that's the amount of photons we have but

632
00:25:54,310 --> 00:25:52,040
these features have to have passed at

633
00:25:56,110 --> 00:25:54,320
least all of our tests and actually

634
00:25:57,580 --> 00:25:56,120
there's another of there's another

635
00:25:58,899 --> 00:25:57,590
aspect that I'll talk about that it's

636
00:26:01,659 --> 00:25:58,909
even more robust

637
00:26:03,460 --> 00:26:01,669
but the two peaks near about nine and a

638
00:26:05,499 --> 00:26:03,470

half microns we see this kind of broad

639
00:26:07,930 --> 00:26:05,509
peak in the spectrum and you notice that

640
00:26:09,489 --> 00:26:07,940
the blue points and the red points both

641
00:26:13,239 --> 00:26:09,499
show it these are two independent

642
00:26:14,710 --> 00:26:13,249
eclipses this is the stretching

643
00:26:17,440 --> 00:26:14,720
resonance between silicon and oxygen

644
00:26:20,049 --> 00:26:17,450
there are many many Astrophysical

645
00:26:22,690 --> 00:26:20,059
sources not extrasolar planets but no

646
00:26:24,669 --> 00:26:22,700
proto planetary objects and disks and

647
00:26:28,749 --> 00:26:24,679
support which shall silicate emission at

648
00:26:31,389 --> 00:26:28,759
this wavelength and so this is a very

649
00:26:33,849 --> 00:26:31,399
familiar feature to astronomers we think

650
00:26:36,330 --> 00:26:33,859
that this is indicative of silicate

651
00:26:38,859 --> 00:26:36,340
clouds in the atmosphere of the planet

652
00:26:42,430 --> 00:26:38,869
there is another sharper feature in the

653
00:26:43,989 --> 00:26:42,440
spectrum that that passes our tests to

654
00:26:47,049 --> 00:26:43,999
be real in fact that differential

655
00:26:48,729 --> 00:26:47,059
eclipse that I showed you this eclipse

656
00:26:53,950 --> 00:26:48,739
is made at the at the peak of that

657
00:26:55,899 --> 00:26:53,960
narrow feature and initially we this is

658
00:26:57,430 --> 00:26:55,909
at seven point seven eight microns and

659
00:26:59,589 --> 00:26:57,440
initially we thought this was the q

660
00:27:01,119 --> 00:26:59,599
branch of methane that was showing an

661
00:27:03,999 --> 00:27:01,129
emission because the planet had a hot

662
00:27:06,369 --> 00:27:04,009
stratosphere and we've since been able

663
00:27:07,960 --> 00:27:06,379

to determine that its wavelength is not

664
00:27:09,519 --> 00:27:07,970
coincident with the q branch the q

665
00:27:11,799 --> 00:27:09,529
branch is at like seven point six five

666
00:27:13,389 --> 00:27:11,809
microns and it shifts the longer

667
00:27:16,330 --> 00:27:13,399
wavelengths at hotter temperatures but

668
00:27:17,919 --> 00:27:16,340
not enough and we very carefully checked

669
00:27:19,989 --> 00:27:17,929
the wavelength calibration and we talked

670
00:27:22,269 --> 00:27:19,999
to the folks at the Spitzer Science

671
00:27:24,609 --> 00:27:22,279
Center and they tell us that there is

672
00:27:26,440 --> 00:27:24,619
that the wavelength calibration of

673
00:27:28,419 --> 00:27:26,450
Spitzer it's out of the question for it

674
00:27:31,869 --> 00:27:28,429
to be off by it would have to be off by

675
00:27:34,690 --> 00:27:31,879
like two pixels so this teacher can't be

676
00:27:37,269 --> 00:27:34,700
messing about the only thing that we

677
00:27:38,950 --> 00:27:37,279
can't eliminate we don't know what it is

678
00:27:41,649 --> 00:27:38,960
but we can't eliminate that it's due to

679
00:27:44,169 --> 00:27:41,659
some feature due to the there's a

680
00:27:47,820 --> 00:27:44,179
carbon-carbon stretching residence near

681
00:27:50,560 --> 00:27:47,830
near about 7.8 microns and in most

682
00:27:54,339 --> 00:27:50,570
Astrophysical sources this is seen in

683
00:27:59,409 --> 00:27:54,349
polycyclic aromatic hydrocarbons pah the

684
00:28:01,029 --> 00:27:59,419
pah has another emission feature at 11.3

685
00:28:03,729 --> 00:28:01,039
microns which we don't see anything

686
00:28:06,580 --> 00:28:03,739
there but the reason we can't eliminate

687
00:28:08,499 --> 00:28:06,590
this as being pah is that is that that

688
00:28:09,640 --> 00:28:08,509

other resonance weakens in high

689
00:28:12,400 --> 00:28:09,650
radiation environment

690
00:28:14,830 --> 00:28:12,410
it's and we're in point oh five AU from

691
00:28:17,620 --> 00:28:14,840
a relatively hot star certainly a high

692
00:28:20,050 --> 00:28:17,630
radiation environment so it's possible

693
00:28:22,420 --> 00:28:20,060
that we're only seeing this CC stretch

694
00:28:24,940 --> 00:28:22,430
there is another carbon-carbon stretch

695
00:28:27,070 --> 00:28:24,950
at 6.2 microns and we have proposed that

696
00:28:29,530 --> 00:28:27,080
Spitzer observed at shorter wavelengths

697
00:28:31,630 --> 00:28:29,540
so we won't really conclude anything

698
00:28:33,010 --> 00:28:31,640
about this until we can look at that but

699
00:28:35,740 --> 00:28:33,020
that other at the wavelength of that

700
00:28:36,790 --> 00:28:35,750
other resonance now this lower panel

701
00:28:38,910 --> 00:28:36,800
shows you the average of these two

702
00:28:43,480 --> 00:28:38,920
spectra the red line is just a blackbody

703
00:28:45,520 --> 00:28:43,490
the blue line is a fancy model our team

704
00:28:48,460 --> 00:28:45,530
fear of Sara Seager this is one of her

705
00:28:50,440 --> 00:28:48,470
hot models models by Adam Burroughs

706
00:28:52,330 --> 00:28:50,450
showed the same general behavior what

707
00:28:54,070 --> 00:28:52,340
what these hot extrasolar planets are

708
00:28:55,840 --> 00:28:54,080
supposed to have their supposed to be a

709
00:28:59,440 --> 00:28:55,850
fall off at Short wavelengths due to

710
00:29:01,570 --> 00:28:59,450
water absorption here the blue line is

711
00:29:03,340 --> 00:29:01,580
supposed to decrease downwards you can

712
00:29:05,800 --> 00:29:03,350
see that the points certainly don't do

713
00:29:07,360 --> 00:29:05,810

that if anything they tend to trim the

714
00:29:11,080 --> 00:29:07,370
other direction and then jump up in this

715
00:29:16,540 --> 00:29:11,090
silicate residence another aspect of

716
00:29:22,660 --> 00:29:16,550
this we bend it in these broad bins and

717
00:29:24,760 --> 00:29:22,670
you can see this is the really coarse

718
00:29:28,270 --> 00:29:24,770
bidding of the spectrum if we in the two

719
00:29:30,640 --> 00:29:28,280
points here are if we if we include or

720
00:29:33,610 --> 00:29:30,650
not include this narrow feature in the

721
00:29:36,280 --> 00:29:33,620
bin we use this to convince ourselves

722
00:29:38,320 --> 00:29:36,290
that this peak due to the near the SiO

723
00:29:40,120 --> 00:29:38,330
stretching resonance is real in the data

724
00:29:42,250 --> 00:29:40,130
actually we only claim that this

725
00:29:45,280 --> 00:29:42,260
difference is is real this difference

726
00:29:48,070 --> 00:29:45,290
here is a little it that's a little not

727
00:29:49,630 --> 00:29:48,080
so significant so it's in a sense it's

728
00:29:50,890 --> 00:29:49,640
only half significant it's only

729
00:29:55,110 --> 00:29:50,900
significant if you come from the

730
00:30:00,160 --> 00:29:58,180
to show you a similar result this is the

731
00:30:03,640 --> 00:30:00,170
grill mayor a towel result their their

732
00:30:06,070 --> 00:30:03,650
spectrum of HD 189733 B they have better

733
00:30:07,990 --> 00:30:06,080
signal to noise because their planet has

734
00:30:10,720 --> 00:30:08,000
a higher contrast to the star the star

735
00:30:12,490 --> 00:30:10,730
is smaller the planet too stark contrast

736
00:30:15,700 --> 00:30:12,500
ratio is better by about a factor of two

737
00:30:18,220 --> 00:30:15,710
or three here's their data points and a

738
00:30:22,210 --> 00:30:18,230

similar model I believe this is an atom

739
00:30:24,280 --> 00:30:22,220
burrows model again water absorption

740
00:30:25,900 --> 00:30:24,290
would cause this model to trend

741
00:30:28,090 --> 00:30:25,910
downwards you can see the data don't do

742
00:30:30,340 --> 00:30:28,100
that they're flat we know that the

743
00:30:32,470 --> 00:30:30,350
specter of these planets will turn down

744
00:30:34,600 --> 00:30:32,480
at some point below beyond this because

745
00:30:37,030 --> 00:30:34,610
the Spitzer photometry at four and a

746
00:30:39,670 --> 00:30:37,040
half microns show a much lower contrast

747
00:30:41,860 --> 00:30:39,680
so somewhere this this spectrum falls

748
00:30:48,130 --> 00:30:41,870
off the cliff towards lower values but

749
00:30:51,820 --> 00:30:48,140
not in this wavelength range so why are

750
00:30:55,090 --> 00:30:51,830
we seeing no water absorption the sort

751
00:30:57,580 --> 00:30:55,100
of the most naive possibility would be

752
00:31:00,190 --> 00:30:57,590
that the planets have no water and

753
00:31:03,130 --> 00:31:00,200
that's we considered that for about

754
00:31:07,060 --> 00:31:03,140
three milliseconds and the reason that

755
00:31:08,710 --> 00:31:07,070
we have to reject that is that it's so

756
00:31:10,450 --> 00:31:08,720
easy to make water it's hard to avoid

757
00:31:13,120 --> 00:31:10,460
wat wat oxygen is the third most

758
00:31:15,340 --> 00:31:13,130
abundant element in the universe and

759
00:31:16,870 --> 00:31:15,350
hydrogen is certainly very molecular

760
00:31:19,120 --> 00:31:16,880
hydrogen is very abundant in these

761
00:31:21,220 --> 00:31:19,130
objects it seems virtually physically

762
00:31:22,870 --> 00:31:21,230
impossible to make these planets for

763
00:31:25,330 --> 00:31:22,880

that significant amounts of water vapor

764
00:31:27,520 --> 00:31:25,340
in their atmosphere so they have to have

765
00:31:29,800 --> 00:31:27,530
some water so the only really two

766
00:31:32,230 --> 00:31:29,810
explanations are that perhaps their

767
00:31:34,200 --> 00:31:32,240
masked by high clouds that would be

768
00:31:37,380 --> 00:31:34,210
consistent with the fact that we see is

769
00:31:40,259 --> 00:31:37,390
we see a silicate emission feature

770
00:31:43,269 --> 00:31:40,269
notice that

771
00:31:46,090 --> 00:31:43,279
real maridel don't see really a silicate

772
00:31:49,239 --> 00:31:46,100
emission feature but the star that this

773
00:31:51,039 --> 00:31:49,249
planet orbits is a que drawer and if

774
00:31:53,440 --> 00:31:51,049
there are features in emission we would

775
00:31:55,659 --> 00:31:53,450
expect them to be excited more when you

776
00:31:57,879 --> 00:31:55,669
orbit a hotter star our planet was a

777
00:32:00,369 --> 00:31:57,889
hundred star so that's consistent so

778
00:32:02,200 --> 00:32:00,379
maybe there are high clouds and maybe

779
00:32:04,149 --> 00:32:02,210
their silicate clouds that are masking

780
00:32:06,099 --> 00:32:04,159
the water absorption below it there's

781
00:32:07,499 --> 00:32:06,109
other evidence for high clouds and the

782
00:32:09,999 --> 00:32:07,509
atmospheres of these hot Jupiters

783
00:32:11,590 --> 00:32:10,009
another possibility is that there's some

784
00:32:14,769 --> 00:32:11,600
perturbation to the temperature gradient

785
00:32:16,989 --> 00:32:14,779
in fact since we see features in

786
00:32:18,969 --> 00:32:16,999
emission if there are thermal features

787
00:32:22,180 --> 00:32:18,979
that would require a reverse temperature

788
00:32:23,889 --> 00:32:22,190

gradient the stratosphere in effect it

789
00:32:27,009 --> 00:32:23,899
takes less than that to mask the high

790
00:32:29,979 --> 00:32:27,019
water this is a this is a result by

791
00:32:32,649 --> 00:32:29,989
Jonathan Kourtney it's a model in which

792
00:32:35,229 --> 00:32:32,659
they incorporate the effects of dynamics

793
00:32:36,759 --> 00:32:35,239
that is strong circulation that is

794
00:32:39,969 --> 00:32:36,769
believed to occur in the hot Jupiter

795
00:32:42,129 --> 00:32:39,979
atmospheres and they show you what that

796
00:32:43,509 --> 00:32:42,139
it fit with that strong circulation the

797
00:32:46,869 --> 00:32:43,519
effect that it has on the emerging

798
00:32:48,399 --> 00:32:46,879
spectrum when the when you observe here

799
00:32:50,440 --> 00:32:48,409
you are looking at the planet here

800
00:32:52,629 --> 00:32:50,450
here's the star when the planet is

801
00:32:54,549 --> 00:32:52,639
behind the star at secondary eclipse or

802
00:32:57,999 --> 00:32:54,559
is opposite from you then you're looking

803
00:33:00,339 --> 00:32:58,009
at the dayside of the planet and the

804
00:33:03,099 --> 00:33:00,349
what Courtney I'll find is that the

805
00:33:05,499 --> 00:33:03,109
temperature profile on the dayside the

806
00:33:07,479 --> 00:33:05,509
effect of the strong circulation is to

807
00:33:10,060 --> 00:33:07,489
is to make the temperature profile much

808
00:33:11,889 --> 00:33:10,070
more isothermal so the spectra on the

809
00:33:15,009 --> 00:33:11,899
dayside are much more like a black body

810
00:33:17,680 --> 00:33:15,019
in this spectral range and this dip

811
00:33:19,629 --> 00:33:17,690
downwards due to water at seven microns

812
00:33:22,029 --> 00:33:19,639
is not nearly so prominent at secondary

813
00:33:24,099 --> 00:33:22,039

eclipse so in other words when we can

814
00:33:26,229 --> 00:33:24,109
measure the spectra that secondary

815
00:33:28,450 --> 00:33:26,239
eclipse that's when the spectra are

816
00:33:30,070 --> 00:33:28,460
least interesting in this respect and

817
00:33:33,489 --> 00:33:30,080
that's unfortunate but that would

818
00:33:35,229 --> 00:33:33,499
explain the and my colleague Sara Seager

819
00:33:37,690 --> 00:33:35,239
also has other ideas on how the

820
00:33:39,519 --> 00:33:37,700
temperature gradient could be perturbed

821
00:33:41,589 --> 00:33:39,529
she thinks that there might be affected

822
00:33:43,509 --> 00:33:41,599
deep stratosphere a temperature reversal

823
00:33:45,999 --> 00:33:43,519
that extends to fairly high pressures

824
00:33:48,129 --> 00:33:46,009
now I can't really articulate the

825
00:33:50,109 --> 00:33:48,139
physics underlying these models in

826
00:33:50,409 --> 00:33:50,119
particular I would like Jonathan if he's

827
00:33:57,820 --> 00:33:50,419
on

828
00:33:59,379 --> 00:33:57,830
profile isothermal but maybe he's not

829
00:34:03,129 --> 00:33:59,389
online maybe one of his collaborators

830
00:34:04,749 --> 00:34:03,139
can explain that to me well what I will

831
00:34:07,299 --> 00:34:04,759
do is I want to try to extend these a

832
00:34:09,099 --> 00:34:07,309
little bit because what we're really

833
00:34:13,359 --> 00:34:09,109
interested in is the spectroscopy of

834
00:34:15,250 --> 00:34:13,369
habitable planets and we can't where we

835
00:34:17,530 --> 00:34:15,260
probably can't do that with Spitzer

836
00:34:19,240 --> 00:34:17,540
there are several sort of super

837
00:34:21,399 --> 00:34:19,250
earth-mass planets that are known to

838
00:34:25,720 --> 00:34:21,409

orbit close to M Dwarfs for example

839
00:34:27,789 --> 00:34:25,730
Gliese 876 D of is a 7.5 earth-mass

840
00:34:31,930 --> 00:34:27,799
planet that orbits close to the M dwarf

841
00:34:34,569 --> 00:34:31,940
lewis at 876 and this system is five

842
00:34:37,149 --> 00:34:34,579
parsecs from Earth and in fact Sara

843
00:34:39,220 --> 00:34:37,159
Seager and I have a room have a

844
00:34:42,490 --> 00:34:39,230
photometric program to try to measure

845
00:34:44,470 --> 00:34:42,500
the phase modulation of the infrared

846
00:34:47,079 --> 00:34:44,480
phase modulation to try to detect the

847
00:34:49,750 --> 00:34:47,089
planet at all photometrically but we

848
00:34:53,980 --> 00:34:49,760
haven't dared to try to measure its

849
00:34:56,020 --> 00:34:53,990
spectrum in order to measure the specter

850
00:34:58,690 --> 00:34:56,030
of these planets we have to go to what I

851
00:35:01,240 --> 00:34:58,700
regard as the as NASA's most important

852
00:35:03,670 --> 00:35:01,250
planet measuring mission even though

853
00:35:05,319 --> 00:35:03,680
it's not build that way and this is this

854
00:35:08,319 --> 00:35:05,329
is a model of the James Webb Space

855
00:35:10,829 --> 00:35:08,329
Telescope if Spitzer can measure the

856
00:35:14,500 --> 00:35:10,839
specter of two bright giant planets

857
00:35:17,170 --> 00:35:14,510
Spitzer's 85 centimeters in aperture

858
00:35:19,559 --> 00:35:17,180
this james webb space telescope is six

859
00:35:22,839 --> 00:35:19,569
point six point five meters in diameter

860
00:35:26,200 --> 00:35:22,849
25 square meter collecting area runs

861
00:35:28,539 --> 00:35:26,210
from point six to 25 microns the this

862
00:35:31,539 --> 00:35:28,549
this telescope will have fantastic

863
00:35:34,780 --> 00:35:31,549

capabilities if it is even half a stable

864
00:35:36,490 --> 00:35:34,790
and it's in you know will be it is not

865
00:35:38,109 --> 00:35:36,500
earth orbiting it's a little groggy in

866
00:35:40,270 --> 00:35:38,119
point where it should be in a thermally

867
00:35:43,299 --> 00:35:40,280
stable environment you can see this

868
00:35:47,319 --> 00:35:43,309
model here this is set up at Goddard and

869
00:35:49,420 --> 00:35:47,329
this these layers of material here are

870
00:35:52,510 --> 00:35:49,430
the sunshield what I like most are these

871
00:35:54,069 --> 00:35:52,520
potted plants that go below it I think

872
00:35:57,160 --> 00:35:54,079
these are the in case there are any more

873
00:35:59,240 --> 00:35:57,170
budget cuts these are the D scope option

874
00:36:04,520 --> 00:35:59,250
NASA will watch these in lieu of the

875
00:36:07,490 --> 00:36:04,530
shield now we've been doing calculations

876
00:36:10,370 --> 00:36:07,500
of what jwst would see if we did our

877
00:36:13,940 --> 00:36:10,380
Spitzer investigation with jwst for a

878
00:36:15,590 --> 00:36:13,950
nearby bright M dwarf we have this IDL

879
00:36:17,720 --> 00:36:15,600
code that will calculate we'll go

880
00:36:20,180 --> 00:36:17,730
through our analysis and calculate the

881
00:36:23,540 --> 00:36:20,190
signal to noise in the planet spectrum

882
00:36:26,090 --> 00:36:23,550
at a given spectral resolving power for

883
00:36:28,460 --> 00:36:26,100
a postulated stellar temperature we've

884
00:36:31,820 --> 00:36:28,470
input here on M dwarf which is point

885
00:36:35,840 --> 00:36:31,830
three stellar radii 3,500 Kelvin we

886
00:36:38,270 --> 00:36:35,850
placed a planet at point O five AU the

887
00:36:40,130 --> 00:36:38,280
nice thing about M Dwarfs is that if the

888
00:36:42,200 --> 00:36:40,140

planet transits if it's in clothes in it

889
00:36:43,850 --> 00:36:42,210
transits that has a hike transit

890
00:36:46,700 --> 00:36:43,860
probability that's also where the

891
00:36:49,190 --> 00:36:46,710
habitable zone is so planets transiting

892
00:36:51,890 --> 00:36:49,200
M Dwarfs may be in the habitable zone

893
00:36:54,890 --> 00:36:51,900
this planet we've made it a super

894
00:36:56,960 --> 00:36:54,900
earth-mass planet to earth radii its

895
00:37:00,110 --> 00:36:56,970
temperature follows from these

896
00:37:02,120 --> 00:37:00,120
parameters and an assumed albedo which

897
00:37:04,550 --> 00:37:02,130
in this case we assume point three its

898
00:37:07,400 --> 00:37:04,560
temperatures 379 Kelvin much cooler than

899
00:37:08,840 --> 00:37:07,410
the planet that I just then the giant

900
00:37:11,960 --> 00:37:08,850
planets I've just been talking about we

901
00:37:14,540 --> 00:37:11,970
placed it 10 parsecs from Earth this is

902
00:37:17,090 --> 00:37:14,550
the signal to noise that jwst would hat

903
00:37:19,730 --> 00:37:17,100
would would obtain in 200 hours of

904
00:37:21,860 --> 00:37:19,740
observation and you may scoff and you

905
00:37:25,130 --> 00:37:21,870
may think we'll we will never get 200

906
00:37:27,560 --> 00:37:25,140
hours on jwst oh yes we will if we can

907
00:37:31,520 --> 00:37:27,570
measure we can measure the spectrum of a

908
00:37:33,560 --> 00:37:31,530
habitable planet orbiting an m-dwarf 200

909
00:37:35,510 --> 00:37:33,570
hours is not out of line compared to

910
00:37:37,580 --> 00:37:35,520
like things like the Hubble Deep Field

911
00:37:40,070 --> 00:37:37,590
and the are what our extra galactic

912
00:37:42,140 --> 00:37:40,080
colleagues do so we think that in fact

913
00:37:44,510 --> 00:37:42,150

that the way to measure spectra of

914
00:37:47,360 --> 00:37:44,520
habitable at least some kinds of

915
00:37:49,460 --> 00:37:47,370
habitable earth-like planets is to look

916
00:37:54,110 --> 00:37:49,470
for planets transiting m dwarfs and to

917
00:37:58,100 --> 00:37:54,120
go after them with jwst so i'm going to

918
00:38:00,290 --> 00:37:58,110
end by concluding there are two seven to

919
00:38:03,020 --> 00:38:00,300
14 micron spectra of hot Jupiters they

920
00:38:05,450 --> 00:38:03,030
show evan evidence both planets show

921
00:38:07,430 --> 00:38:05,460
measured by two independent groups show

922
00:38:08,750 --> 00:38:07,440
evidence for masking of their predicted

923
00:38:10,520 --> 00:38:08,760
water absorption

924
00:38:12,020 --> 00:38:10,530
that there's evidence for silicate

925
00:38:14,540 --> 00:38:12,030
clouds on at least one of those planets

926
00:38:15,890 --> 00:38:14,550
in either case we need some kind of

927
00:38:17,510 --> 00:38:15,900
perturbations to the temperature

928
00:38:20,480 --> 00:38:17,520
gradient as compared to simple

929
00:38:23,840 --> 00:38:20,490
equilibrium models and finally we're

930
00:38:26,480 --> 00:38:23,850
looking forward to jwst taking this to

931
00:38:32,510 --> 00:38:26,490
the spectra of hot Earth's and I will

932
00:38:35,350 --> 00:38:32,520
entertain questions and I'm sure there

933
00:38:37,400 --> 00:38:35,360
are lots of questions for the

934
00:38:41,150 --> 00:38:37,410
sequestering of oxygen to make hear him

935
00:38:46,120 --> 00:38:41,160
I'll repeat the question boy there's one

936
00:38:49,100 --> 00:38:46,130
of Hoover's grab the huggable for the

937
00:38:50,960 --> 00:38:49,110
sequestering in the legend let me just

938
00:38:52,730 --> 00:38:50,970

ask people around the net if they would

939
00:38:54,170 --> 00:38:52,740
raise their hands on webex and will

940
00:38:55,900 --> 00:38:54,180
calling them from here but let's go

941
00:39:01,340 --> 00:38:55,910
ahead with the questions it's got it

942
00:39:03,440 --> 00:39:01,350
okay okay I recall that toured for brown

943
00:39:07,600 --> 00:39:03,450
dwarfs in the late L and early tee

944
00:39:11,240 --> 00:39:07,610
sequence there's a dichotomy of how you

945
00:39:12,860 --> 00:39:11,250
sequester how you the taxonomy of those

946
00:39:14,810 --> 00:39:12,870
things whether how cloudy there are and

947
00:39:16,700 --> 00:39:14,820
so in fact that reinforces the idea of a

948
00:39:19,880 --> 00:39:16,710
cloud of something so loquacious

949
00:39:22,100 --> 00:39:19,890
material over a great hot Jupiter but

950
00:39:23,810 --> 00:39:22,110
also there's limbs evidence for carbon

951
00:39:25,370 --> 00:39:23,820
monoxide as well I wondered what the

952
00:39:28,600 --> 00:39:25,380
arguments are against putting all the

953
00:39:30,830 --> 00:39:28,610
oxygen into co as opposed to water a

954
00:39:32,900 --> 00:39:30,840
Glenn's question is why can't you just

955
00:39:34,670 --> 00:39:32,910
put all the oxygen in the co formation

956
00:39:36,560 --> 00:39:34,680
and I think the sort of simple-minded

957
00:39:38,750 --> 00:39:36,570
answer is that cosmically there's more

958
00:39:40,250 --> 00:39:38,760
oxygen in their carbon so if you do that

959
00:39:42,980 --> 00:39:40,260
you have oxygen left over and that goes

960
00:39:45,800 --> 00:39:42,990
into water you can there are suggestions

961
00:39:47,090 --> 00:39:45,810
that there are carbon planets if there

962
00:39:49,490 --> 00:39:47,100
are carbon planets where there's more

963
00:39:51,410 --> 00:39:49,500

carbon than oxygen than carbon will then

964
00:39:53,150 --> 00:39:51,420
all the oxygen or most of it will go

965
00:39:54,950 --> 00:39:53,160
into co formation and you won't have

966
00:39:59,300 --> 00:39:54,960
water advanced but I think carbon

967
00:40:04,430 --> 00:39:59,310
planets are considered exotic so that's

968
00:40:11,130 --> 00:40:07,950
have a question here hecka go to bright

969
00:40:14,099 --> 00:40:11,140
you actually show is the nice high road

970
00:40:15,510 --> 00:40:14,109
drive the spectra I show the question is

971
00:40:17,130 --> 00:40:15,520
are the spectra show for the night side

972
00:40:19,440 --> 00:40:17,140
the spectra were measured during

973
00:40:20,940 --> 00:40:19,450
secondary Eclipse secondary Eclipse

974
00:40:22,770 --> 00:40:20,950
we're looking at the dayside of the

975
00:40:24,539 --> 00:40:22,780
planet the planet on the opposite side

976
00:40:27,480 --> 00:40:24,549
of the star will start shining directly

977
00:40:29,099 --> 00:40:27,490
out of it I mean I mean you're planning

978
00:40:31,289 --> 00:40:29,109
design is behind so if you don't get to

979
00:40:34,559 --> 00:40:31,299
cope and putting trevino onions are

980
00:40:36,420 --> 00:40:34,569
being behind this time then you get when

981
00:40:38,370 --> 00:40:36,430
you get this is truck from here when

982
00:40:44,220 --> 00:40:38,380
it's in front of you minus the one in

983
00:40:46,279 --> 00:40:44,230
fact we're seeing we're seeing that the

984
00:40:49,020 --> 00:40:46,289
internet in Eclipse and out of eclipse

985
00:40:51,089 --> 00:40:49,030
phase difference is very small compared

986
00:40:52,980 --> 00:40:51,099
to the orbit of the planet so we're

987
00:40:54,990 --> 00:40:52,990
we're essentially looking at the same

988
00:40:58,470 --> 00:40:55,000

subtracting the same phase out of

989
00:40:59,730 --> 00:40:58,480
eclipses in Eclipse so we're the

990
00:41:01,920 --> 00:40:59,740
different that difference is just the

991
00:41:05,160 --> 00:41:01,930
thermal readmission of the photons from

992
00:41:06,569 --> 00:41:05,170
the planet I can try that what you're

993
00:41:10,170 --> 00:41:06,579
really doing it each wavelength

994
00:41:12,329 --> 00:41:10,180
immeasurably contrast between out of the

995
00:41:15,690 --> 00:41:12,339
coach genetic codes it's that contrast

996
00:41:17,940 --> 00:41:15,700
we can show the spectral signature at

997
00:41:19,559 --> 00:41:17,950
that waiver that's correct yes we're

998
00:41:21,779 --> 00:41:19,569
measuring the white button the excess

999
00:41:24,269 --> 00:41:21,789
intensity at 7.8 minor enhancements

1000
00:41:25,829 --> 00:41:24,279
we're reconstructing here we're

1001
00:41:27,990 --> 00:41:25,839
reconstructing the spectrum of the

1002
00:41:31,400 --> 00:41:28,000
planet from the wavelength dependence of

1003
00:41:33,670 --> 00:41:31,410
the secondary Eclipse amplitude correct

1004
00:41:37,160 --> 00:41:33,680
my question

1005
00:41:39,470 --> 00:41:37,170
okay Goddard still asking just a Drake

1006
00:41:44,210 --> 00:41:39,480
there's 14 planets that have been

1007
00:41:46,310 --> 00:41:44,220
detected in an eclipse they're 14 bright

1008
00:41:48,110 --> 00:41:46,320
extrasolar transiting planets and

1009
00:41:50,030 --> 00:41:48,120
clients and fainter ones what are the

1010
00:41:54,200 --> 00:41:50,040
chances of getting structure from the

1011
00:41:58,010 --> 00:41:54,210
other 12 the the two that I've shown you

1012
00:42:00,140 --> 00:41:58,020
are but by far the two brightest so I at

1013
00:42:01,610 --> 00:42:00,150

least have not proposed to use fitzer on

1014
00:42:04,070 --> 00:42:01,620
the fainter runs maybe someone else has

1015
00:42:06,050 --> 00:42:04,080
I think you would really be photon stars

1016
00:42:08,990 --> 00:42:06,060
in that case and you would require

1017
00:42:12,320 --> 00:42:09,000
multiple multiple eclipses to obtain

1018
00:42:18,980 --> 00:42:12,330
spectra jwst on the other hand will

1019
00:42:21,380 --> 00:42:18,990
really do these planets really well come

1020
00:42:23,150 --> 00:42:21,390
up to the table and ask ask the question

1021
00:42:27,260 --> 00:42:23,160
actually and then maybe we shout at the

1022
00:42:29,870 --> 00:42:27,270
other notes you've shown the silicon

1023
00:42:31,880 --> 00:42:29,880
emission from the planetary potential a

1024
00:42:33,830 --> 00:42:31,890
haze how do you know that those

1025
00:42:36,290 --> 00:42:33,840
silicates aren't in the disk of the

1026
00:42:37,790 --> 00:42:36,300
system ah that's a good question he

1027
00:42:39,410 --> 00:42:37,800
asked how do we know that the silicate

1028
00:42:42,590 --> 00:42:39,420
is really associated with the planets

1029
00:42:46,640 --> 00:42:42,600
and not associated with it with a disk

1030
00:42:48,530 --> 00:42:46,650
around the star well because what we see

1031
00:42:50,600 --> 00:42:48,540
is in eclipse minus out of it clicks

1032
00:42:52,610 --> 00:42:50,610
that's a very short that's a very short

1033
00:42:55,310 --> 00:42:52,620
Kemp relatively short temporal

1034
00:42:57,590 --> 00:42:55,320
modulation only really a small fraction

1035
00:43:00,170 --> 00:42:57,600
of any disk could be if there's a lump

1036
00:43:02,870 --> 00:43:00,180
in the disk it would have to be very

1037
00:43:04,700 --> 00:43:02,880
closely associated to the planet we

1038
00:43:06,590 --> 00:43:04,710

couldn't rule out the possibility that

1039
00:43:08,810 --> 00:43:06,600
there's some extended dust envelope

1040
00:43:10,310 --> 00:43:08,820
around the planet that's emitting but

1041
00:43:12,500 --> 00:43:10,320
people but you don't see that during

1042
00:43:14,060 --> 00:43:12,510
transfer the radius of this planet

1043
00:43:16,370 --> 00:43:14,070
during transit at infrared wavelengths

1044
00:43:18,110 --> 00:43:16,380
is the same as in the visible so if

1045
00:43:20,950 --> 00:43:18,120
there's if there's some dust around the

1046
00:43:23,060 --> 00:43:20,960
planet it's very low optical depth and

1047
00:43:26,089 --> 00:43:23,070
it would have to get very close to the

1048
00:43:31,579 --> 00:43:28,339
Drake I'd like to ask a question and

1049
00:43:33,319 --> 00:43:31,589
then we have a question at Colorado okay

1050
00:43:37,489 --> 00:43:33,329
question I'd like to ask comes back to

1051
00:43:39,229 --> 00:43:37,499
the discussion you included about the

1052
00:43:40,729 --> 00:43:39,239
effects of the temperature gradient

1053
00:43:42,979 --> 00:43:40,739
since you're looking in the thermal

1054
00:43:44,359 --> 00:43:42,989
infrared of course the visibility of

1055
00:43:46,579 --> 00:43:44,369
spectral features is going to depend

1056
00:43:48,410 --> 00:43:46,589
upon a vertical temperature contrast in

1057
00:43:50,450 --> 00:43:48,420
the atmosphere you mentioned the

1058
00:43:52,219 --> 00:43:50,460
possible effects of circulation could

1059
00:43:55,370 --> 00:43:52,229
you just talk a little bit more about

1060
00:43:57,890 --> 00:43:55,380
what you expect the vertical temperature

1061
00:44:01,489 --> 00:43:57,900
profiles in these atmospheres to be and

1062
00:44:03,289 --> 00:44:01,499
how variations in that or uncertainty in

1063
00:44:05,299 --> 00:44:03,299

your understanding of that affects your

1064
00:44:07,069 --> 00:44:05,309
interpretation of the spectra

1065
00:44:11,660 --> 00:44:07,079
particularly whether or not you see a

1066
00:44:14,749 --> 00:44:11,670
feature well you do expect when these

1067
00:44:17,089 --> 00:44:14,759
planets were initially discovered my

1068
00:44:18,979 --> 00:44:17,099
first reaction was that they probably

1069
00:44:21,680 --> 00:44:18,989
have very hot stratosphere scuzz there

1070
00:44:23,630 --> 00:44:21,690
so in so close to this star we know

1071
00:44:27,940 --> 00:44:23,640
jupiter has a stratosphere because it's

1072
00:44:31,279 --> 00:44:27,950
it no it has methane methane absorbs

1073
00:44:33,200 --> 00:44:31,289
solar radiation heats the atmosphere if

1074
00:44:34,430 --> 00:44:33,210
you put a planet in that close to the

1075
00:44:36,440 --> 00:44:34,440
star I would think it would have a very

1076
00:44:39,620 --> 00:44:36,450
strong stratosphere but when people that

1077
00:44:42,229 --> 00:44:39,630
shows that shows how poor my intuition

1078
00:44:44,839 --> 00:44:42,239
is because when people actually put the

1079
00:44:47,089 --> 00:44:44,849
opacities of water vapor and the various

1080
00:44:49,430 --> 00:44:47,099
molecules into their codes they found

1081
00:44:51,979 --> 00:44:49,440
that indeed the the temperature in the

1082
00:44:53,479 --> 00:44:51,989
outer atmosphere was raised slightly but

1083
00:44:55,759 --> 00:44:53,489
not enough to actually invert the

1084
00:44:57,650 --> 00:44:55,769
temperature so the temperature profiles

1085
00:45:00,499 --> 00:44:57,660
of these planets are not all that

1086
00:45:03,339 --> 00:45:00,509
different from brown dwarf atmospheres

1087
00:45:05,749 --> 00:45:03,349
in the sense that their their their

1088
00:45:08,450 --> 00:45:05,759

highest temperatures are down deep and

1089
00:45:11,150 --> 00:45:08,460
the external boundary temperatures are

1090
00:45:12,920 --> 00:45:11,160
on the order of a hundred Kelvin versus

1091
00:45:16,370 --> 00:45:12,930
fifteen hundred Kelvin deeper deeper

1092
00:45:18,349 --> 00:45:16,380
down now maybe the observations are

1093
00:45:21,380 --> 00:45:18,359
showing maybe the Spitzer observations

1094
00:45:23,630 --> 00:45:21,390
are showing us that didn't we have more

1095
00:45:26,420 --> 00:45:23,640
to learn there but at least that's the

1096
00:45:28,130 --> 00:45:26,430
current understanding i guess the second

1097
00:45:30,739 --> 00:45:28,140
part of my question was is that

1098
00:45:33,400 --> 00:45:30,749
affecting the visibility of features so

1099
00:45:35,630 --> 00:45:33,410
for example when you don't see a feature

1100
00:45:37,100 --> 00:45:35,640
could it be that the

1101
00:45:38,600 --> 00:45:37,110
that you're looking for is there but the

1102
00:45:41,120 --> 00:45:38,610
temperature contrast to enable you to

1103
00:45:46,430 --> 00:45:41,130
see it isn't yes yes that's that's

1104
00:45:51,830 --> 00:45:46,440
that's the predominant view yes okay I'm

1105
00:45:57,680 --> 00:45:51,840
University of Colorado hydrate god this

1106
00:46:00,800 --> 00:45:57,690
is Tom ears nice talk um I wanted to ask

1107
00:46:02,990 --> 00:46:00,810
a question actually two questions on the

1108
00:46:05,750 --> 00:46:03,000
first one is what are the prospects of

1109
00:46:09,290 --> 00:46:05,760
performing this type of experiment with

1110
00:46:11,540 --> 00:46:09,300
a large telescope from the ground in the

1111
00:46:13,610 --> 00:46:11,550
same name for red and what are the

1112
00:46:16,400 --> 00:46:13,620
prospects for doing this in the

1113
00:46:18,770 --> 00:46:16,410

ultraviolet from space and then the

1114
00:46:21,710 --> 00:46:18,780
second question is that you described an

1115
00:46:22,910 --> 00:46:21,720
alternative analysis of your own data by

1116
00:46:24,980 --> 00:46:22,920
another group and I wonder if you could

1117
00:46:28,340 --> 00:46:24,990
just mention what their results were now

1118
00:46:30,260 --> 00:46:28,350
they differ from yours um okay let's see

1119
00:46:31,670 --> 00:46:30,270
let's take the first part of that

1120
00:46:34,040 --> 00:46:31,680
question first can we do this from the

1121
00:46:35,780 --> 00:46:34,050
ground the ground-based observers are

1122
00:46:37,640 --> 00:46:35,790
knocking on the door of Planet

1123
00:46:40,460 --> 00:46:37,650
protection there is a tentative like

1124
00:46:42,550 --> 00:46:40,470
three sigma detection of one of the oval

1125
00:46:46,580 --> 00:46:42,560
transiting planets at two microns

1126
00:46:48,320 --> 00:46:46,590
bye-bye snellen that we think that the

1127
00:46:50,930 --> 00:46:48,330
way to do this from the ground is to is

1128
00:46:53,240 --> 00:46:50,940
to find a system with a bright nearby

1129
00:46:54,830 --> 00:46:53,250
comparison star so we can take out the

1130
00:46:57,110 --> 00:46:54,840
effects of the Earth's atmosphere and

1131
00:46:58,850 --> 00:46:57,120
that would add an additional

1132
00:47:01,370 --> 00:46:58,860
complication to the analysis that we

1133
00:47:04,430 --> 00:47:01,380
think it's possibly and there are

1134
00:47:05,600 --> 00:47:04,440
proposals being submitted to try that

1135
00:47:08,420 --> 00:47:05,610
and we think it's eventually that will

1136
00:47:10,780 --> 00:47:08,430
be possible of the advantage of course

1137
00:47:13,370 --> 00:47:10,790
doing it from the ground is that is that

1138
00:47:17,000 --> 00:47:13,380

Spitzer will run out of cryogen in the

1139
00:47:18,440 --> 00:47:17,010
spring of 2009 and and also Spitzer has

1140
00:47:19,820 --> 00:47:18,450
limited wavelength coverage there are

1141
00:47:21,620 --> 00:47:19,830
important features in the spectra

1142
00:47:24,140 --> 00:47:21,630
between two to five microns where

1143
00:47:25,520 --> 00:47:24,150
Spitzer has no wavelength we were not

1144
00:47:28,160 --> 00:47:25,530
accessible to those wavelengths been

1145
00:47:29,840 --> 00:47:28,170
Spitzer then the second part of the

1146
00:47:32,480 --> 00:47:29,850
question was what about the Swain

1147
00:47:35,290 --> 00:47:32,490
analysis and so I have to go back to my

1148
00:47:37,370 --> 00:47:35,300
talk you make my talk come up again

1149
00:47:39,110 --> 00:47:37,380
Martha we need the presenter ballbag

1150
00:47:41,480 --> 00:47:39,120
yeah you should be able to control right

1151
00:47:51,330 --> 00:47:41,490
now this one

1152
00:47:53,640 --> 00:47:51,340
okay okay how do I make it oh in

1153
00:48:03,800 --> 00:47:53,650
tribute go down to the bottom vertical

1154
00:48:03,810 --> 00:48:18,440
ok

1155
00:48:24,020 --> 00:48:21,380
whereas our analysis uses these

1156
00:48:26,240 --> 00:48:24,030
differential eclipses what what marks

1157
00:48:27,740 --> 00:48:26,250
Wayne's analysis well I guess his papers

1158
00:48:29,900 --> 00:48:27,750
still under review what he does is he

1159
00:48:32,990 --> 00:48:29,910
actually subtracts the spectra out of

1160
00:48:35,480 --> 00:48:33,000
eclipse minus in eclipse and we do that

1161
00:48:38,000 --> 00:48:35,490
too only we do that as a check on the

1162
00:48:40,490 --> 00:48:38,010
analysis we have we we rely on these

1163
00:48:42,079 --> 00:48:40,500

differential eclipses and and I would

1164
00:48:45,349 --> 00:48:42,089
argue that you really have to rely on

1165
00:48:47,000 --> 00:48:45,359
the differential eclipses because if you

1166
00:48:50,180 --> 00:48:47,010
don't do that there can be effects in

1167
00:48:52,370 --> 00:48:50,190
the time series that that are

1168
00:48:54,440 --> 00:48:52,380
unaccounted for in your analysis and in

1169
00:48:56,810 --> 00:48:54,450
fact if you look at marks paper you find

1170
00:49:00,560 --> 00:48:56,820
that he has a term called G of T which

1171
00:49:02,930 --> 00:49:00,570
is the gain of the of the detector

1172
00:49:05,780 --> 00:49:02,940
system and he explicitly assumes that

1173
00:49:09,859 --> 00:49:05,790
that is wavelength independent let me go

1174
00:49:12,890 --> 00:49:09,869
back a little further this ramp this

1175
00:49:15,380 --> 00:49:12,900
ramp is like a game because it's due to

1176
00:49:17,540 --> 00:49:15,390
charge trapping in the detector when you

1177
00:49:20,450 --> 00:49:17,550
illuminate the detector with a faint

1178
00:49:22,430 --> 00:49:20,460
source that is the stellar spectrum at

1179
00:49:24,410 --> 00:49:22,440
long wavelengths it takes a lot longer

1180
00:49:27,620 --> 00:49:24,420
for it to ramp up to full sensitivity

1181
00:49:31,430 --> 00:49:27,630
than it does at at Short wavelengths

1182
00:49:32,990 --> 00:49:31,440
where there is a high intensity being

1183
00:49:34,790 --> 00:49:33,000
shown on the detector in other words the

1184
00:49:37,430 --> 00:49:34,800
gaining of the detector is effectively

1185
00:49:40,550 --> 00:49:37,440
wavelength dependent whereas marks

1186
00:49:43,880 --> 00:49:40,560
analysis explicitly assumes that it is

1187
00:49:45,319 --> 00:49:43,890
not and that's not correct and for that

1188
00:49:47,300 --> 00:49:45,329

reason I think he's probably not

1189
00:49:52,870 --> 00:49:47,310
deriving the spectrum of the planet at

1190
00:49:59,209 --> 00:49:55,759
second one hey there is a spectra from

1191
00:50:04,009 --> 00:49:59,219
space UV spectra from space have been

1192
00:50:09,289 --> 00:50:04,019
measured by Hubble okay Arizona have a

1193
00:50:13,269 --> 00:50:09,299
question if there were a ring around

1194
00:50:16,519 --> 00:50:13,279
this planet it would of course produce

1195
00:50:20,029 --> 00:50:16,529
likely emission lines or omission bands

1196
00:50:23,449 --> 00:50:20,039
whatever one calls it and one would help

1197
00:50:26,929 --> 00:50:23,459
distinguish that because the Eclipse

1198
00:50:30,069 --> 00:50:26,939
would be broader because of the diameter

1199
00:50:32,719 --> 00:50:30,079
of the ring system would be broader and

1200
00:50:36,109 --> 00:50:32,729
therefore I'd like to know what evidence

1201
00:50:38,929 --> 00:50:36,119
you have that in this omission that the

1202
00:50:42,079 --> 00:50:38,939
Eclipse does indeed have the threats

1203
00:50:46,069 --> 00:50:42,089
associated exactly with that you see of

1204
00:50:48,109 --> 00:50:46,079
the planet continuum well at one time at

1205
00:50:50,509 --> 00:50:48,119
one time rings around this planet were

1206
00:50:52,399 --> 00:50:50,519
my favorite theory because they're as

1207
00:50:54,139 --> 00:50:52,409
you know the planets radius is larger

1208
00:50:57,139 --> 00:50:54,149
than can be accounted for by simple

1209
00:50:58,999 --> 00:50:57,149
models one way to explain that would be

1210
00:51:00,409 --> 00:50:59,009
perhaps ring a ring system which was

1211
00:51:03,409 --> 00:51:00,419
increasing the effective area of the

1212
00:51:07,999 --> 00:51:03,419
planet that beautiful theory has been

1213
00:51:09,679 --> 00:51:08,009

contradicted by ugly facts the transit

1214
00:51:12,079 --> 00:51:09,689
of the planet was measured at Spitzer

1215
00:51:13,879 --> 00:51:12,089
way the transit the primary eclipse of

1216
00:51:16,069 --> 00:51:13,889
the planet was measured by Spitzer

1217
00:51:19,189 --> 00:51:16,079
wavelengths by Jeremy Richardson at 24

1218
00:51:21,620 --> 00:51:19,199
microns and he obtains an a radius for

1219
00:51:23,689 --> 00:51:21,630
the planet in very close agreement with

1220
00:51:25,879 --> 00:51:23,699
the visible results so if there are

1221
00:51:27,469 --> 00:51:25,889
rings they have almost the same optical

1222
00:51:31,519 --> 00:51:27,479
depth at two very very different

1223
00:51:34,339 --> 00:51:31,529
wavelengths which is may be possible but

1224
00:51:36,709 --> 00:51:34,349
but it does argue against it somewhat

1225
00:51:38,539 --> 00:51:36,719
then the other the the other argument

1226
00:51:40,370 --> 00:51:38,549
that is the width of the Eclipse is that

1227
00:51:41,479 --> 00:51:40,380
we have additional observations that we

1228
00:51:43,519 --> 00:51:41,489
haven't published yet and I haven't

1229
00:51:47,029 --> 00:51:43,529
shown you and I know that's a terrible

1230
00:51:49,189 --> 00:51:47,039
thing to say but what but add to

1231
00:51:50,779 --> 00:51:49,199
original discovery observations and if

1232
00:51:53,120 --> 00:51:50,789
the Eclipse were significantly broader

1233
00:51:55,159 --> 00:51:53,130
you know the aggressor egress Tom were

1234
00:51:57,559 --> 00:51:55,169
significantly different then we would

1235
00:51:59,280 --> 00:51:57,569
have seen that and also de Charbonneau

1236
00:52:01,050 --> 00:51:59,290
has additional data that he hasn't

1237
00:52:11,000 --> 00:52:01,060
published yet and he would have seen it

1238
00:52:17,700 --> 00:52:14,880

he's red light on them hello this is

1239
00:52:19,710 --> 00:52:17,710
paul davis at aims to operational

1240
00:52:23,310 --> 00:52:19,720
questions one you said you took half

1241
00:52:25,170 --> 00:52:23,320
your data before the secondary transept

1242
00:52:28,170 --> 00:52:25,180
and half the data during the secondary

1243
00:52:30,030 --> 00:52:28,180
transit wouldn't it be better in regard

1244
00:52:32,100 --> 00:52:30,040
to system editors to take a quarter

1245
00:52:33,630 --> 00:52:32,110
before a half during and a quarter after

1246
00:52:35,840 --> 00:52:33,640
yeah that's that's what we actually do

1247
00:52:40,230 --> 00:52:35,850
we started we take a quarter before

1248
00:52:42,000 --> 00:52:40,240
patent yes with some variation on that

1249
00:52:44,520 --> 00:52:42,010
depending on how quickly the telescope

1250
00:52:46,860 --> 00:52:44,530
people can the exact starting time and

1251
00:52:49,740 --> 00:52:46,870
give them a window okay so thank you the

1252
00:52:53,250 --> 00:52:49,750
other question is you mentioned the one

1253
00:52:55,320 --> 00:52:53,260
hour point 05 arcsecond oscillation and

1254
00:52:58,320 --> 00:52:55,330
you also mention doing a nod in the

1255
00:53:00,180 --> 00:52:58,330
middle of the transit measurement to get

1256
00:53:03,180 --> 00:53:00,190
a reference does the nod reset the

1257
00:53:05,100 --> 00:53:03,190
oscillation and can you use the knob to

1258
00:53:06,870 --> 00:53:05,110
control the oscillations or is it better

1259
00:53:09,480 --> 00:53:06,880
to deal with in calculation a lot

1260
00:53:12,530 --> 00:53:09,490
calculation alee the nod does the nod

1261
00:53:15,840 --> 00:53:12,540
does not seem to reset the oscillation

1262
00:53:17,610 --> 00:53:15,850
the having the telescope nod is both

1263
00:53:19,620 --> 00:53:17,620

good and bad i want to comment about the

1264
00:53:21,420 --> 00:53:19,630
nod that it's good in the sense that

1265
00:53:23,790 --> 00:53:21,430
when we see this like this differential

1266
00:53:27,000 --> 00:53:23,800
eclipse that i have shown you on the

1267
00:53:28,890 --> 00:53:27,010
screen up here that the that the ingress

1268
00:53:30,600 --> 00:53:28,900
of this eclipse is actually measured

1269
00:53:33,180 --> 00:53:30,610
with different pixels of pixels of the

1270
00:53:34,380 --> 00:53:33,190
detector than the egress because we're

1271
00:53:36,750 --> 00:53:34,390
always worried that you know there's

1272
00:53:39,480 --> 00:53:36,760
some rogue pixel who is causing a

1273
00:53:41,700 --> 00:53:39,490
spurious result so in so by having a

1274
00:53:44,550 --> 00:53:41,710
telescope nod there have to be sort of

1275
00:53:46,470 --> 00:53:44,560
two sets of rogue pixels and have to

1276
00:53:49,290 --> 00:53:46,480
conspire together to make an ingress and

1277
00:53:50,940 --> 00:53:49,300
egress at the right time and at that

1278
00:53:54,120 --> 00:53:50,950
point you just you don't worry about

1279
00:53:56,880 --> 00:53:54,130
things that bizarre the disadvantage of

1280
00:53:59,549 --> 00:53:56,890
the nod is that it may reset the ramp to

1281
00:53:59,549 --> 00:53:59,559
some extent

1282
00:54:05,489 --> 00:54:03,269
you can see right here there's a there's

1283
00:54:08,219 --> 00:54:05,499
a the charge trapping in the detector

1284
00:54:10,109 --> 00:54:08,229
when we move the spectrum when we move

1285
00:54:11,999 --> 00:54:10,119
the spectrum there's a little bit of a

1286
00:54:14,449 --> 00:54:12,009
reset of the ramp I would like not to

1287
00:54:17,370 --> 00:54:14,459
have that I've since concluded that for

1288
00:54:19,439 --> 00:54:17,380

true and also for reasons of comparing

1289
00:54:23,459 --> 00:54:19,449
to Karl grill mayer where they don't nod

1290
00:54:29,579 --> 00:54:23,469
that we propose to redo this to do it

1291
00:54:36,839 --> 00:54:29,589
without the nod that's that's a real

1292
00:54:39,390 --> 00:54:36,849
subtlety of the other day thank you okay

1293
00:54:40,799 --> 00:54:39,400
there are no more hands raised we can

1294
00:54:42,420 --> 00:54:40,809
send it back to Goddard for any more

1295
00:54:45,150 --> 00:54:42,430
questions at Goddard if there are any

1296
00:54:48,779 --> 00:54:45,160
there oh god it always has question oh I

1297
00:54:50,699 --> 00:54:48,789
know I know drink in the spectrum they

1298
00:54:53,069 --> 00:54:50,709
seem to be another feature at the longer

1299
00:54:54,779 --> 00:54:53,079
wavelength is that another feature at

1300
00:54:57,029 --> 00:54:54,789
the hunger way Ron Paul than I have

1301
00:54:58,709 --> 00:54:57,039
microns or somewhere around there well

1302
00:55:01,769 --> 00:54:58,719
some kind of scrubs but look at the

1303
00:55:03,719 --> 00:55:01,779
error bars here and look at the look at

1304
00:55:05,339 --> 00:55:03,729
the agreement or disagreement between

1305
00:55:08,130 --> 00:55:05,349
the two different eclipses which is what

1306
00:55:09,630 --> 00:55:08,140
we have to go by you can treat basically

1307
00:55:12,120 --> 00:55:09,640
just scatter at the long wavelengths and

1308
00:55:14,939 --> 00:55:12,130
in fact the spectrum goes the spectre go

1309
00:55:16,589 --> 00:55:14,949
out to 14 microns but the Spitzer people

1310
00:55:19,890 --> 00:55:16,599
say that they're scattered light beyond

1311
00:55:23,839 --> 00:55:19,900
13.2 so we don't even we don't even try

1312
00:55:26,489 --> 00:55:23,849
be on there it's called the teardrop

1313
00:55:32,339 --> 00:55:26,499

short low that's a short guy this is

1314
00:55:33,599 --> 00:55:32,349
this is short glo SL this is SL too we

1315
00:55:36,020 --> 00:55:33,609
don't have enough photons to get a high

1316
00:55:39,980 --> 00:55:37,880
have a question have you ever done here

1317
00:55:42,560 --> 00:55:39,990
Anunnaki effects for some of these

1318
00:55:46,940 --> 00:55:42,570
missions or have we considered non-lte

1319
00:55:49,310 --> 00:55:46,950
effects if if get this if if this

1320
00:55:52,010 --> 00:55:49,320
feature is is really due to a

1321
00:55:54,380 --> 00:55:52,020
carbon-carbon stretch which we think is

1322
00:55:55,790 --> 00:55:54,390
kind of speculative but if it were then

1323
00:56:00,470 --> 00:55:55,800
it would have to be due to fluorescence

1324
00:56:04,250 --> 00:56:00,480
which is non a non-thermal so yeah there

1325
00:56:08,720 --> 00:56:04,260
could be non thermal effects yeah okay

1326
00:56:11,600 --> 00:56:08,730
well when I look at the spectrum it

1327
00:56:14,300 --> 00:56:11,610
seems to me that both grill mares

1328
00:56:16,460 --> 00:56:14,310
respect that the image and yours could

1329
00:56:18,620 --> 00:56:16,470
be interpreted as having a double Pete

1330
00:56:21,820 --> 00:56:18,630
structure that was had a minimum near

1331
00:56:24,470 --> 00:56:21,830
7.6 microns and two beats one if I'm

1332
00:56:27,890 --> 00:56:24,480
firefight like wanna lower way life is

1333
00:56:31,670 --> 00:56:27,900
that supportable is that not correct hmm

1334
00:56:34,300 --> 00:56:31,680
I mean I think you could argue in favor

1335
00:56:37,460 --> 00:56:34,310
of a lot of different explanations but

1336
00:56:40,970 --> 00:56:37,470
but since there are proposals to

1337
00:56:42,530 --> 00:56:40,980
reabsorb oath systems and those and in

1338
00:56:44,930 --> 00:56:42,540

at these wavelengths and at other

1339
00:56:47,870 --> 00:56:44,940
wavelengths a lot much will be clarified

1340
00:56:49,580 --> 00:56:47,880
after this summer these these are

1341
00:56:55,220 --> 00:56:49,590
observable by Spitzer during the summers

1342
00:56:56,540 --> 00:56:55,230
open which I believe me what we proposed

1343
00:56:58,940 --> 00:56:56,550
to observe it at somewhat shorter

1344
00:57:01,100 --> 00:56:58,950
wavelengths 528 micron where we expect

1345
00:57:03,230 --> 00:57:01,110
the flux to decrease the contrast to

1346
00:57:05,300 --> 00:57:03,240
decrease strongly and Karl grill mayor

1347
00:57:08,840 --> 00:57:05,310
has observed it as proposed to observe

1348
00:57:11,210 --> 00:57:08,850
HD 189733 at many other wavelengths I

1349
00:57:16,130 --> 00:57:11,220
don't know the specifics where we do

1350
00:57:18,320 --> 00:57:16,140
next expect to see water where would we

1351
00:57:19,760 --> 00:57:18,330
next expect to see water actually I

1352
00:57:23,360 --> 00:57:19,770
think the best prospects for seeing

1353
00:57:26,210 --> 00:57:23,370
water are from the ground to detect the

1354
00:57:28,640 --> 00:57:26,220
there's a peek at 3.8 microns between

1355
00:57:30,020 --> 00:57:28,650
water and carbon dioxide absorption that

1356
00:57:31,850 --> 00:57:30,030
I think can be detected using

1357
00:57:35,030 --> 00:57:31,860
ground-based observations in these

1358
00:57:37,730 --> 00:57:35,040
planets so that's that's the way I think

1359
00:57:40,730 --> 00:57:37,740
is the real way to detect water Drake

1360
00:57:42,350 --> 00:57:40,740
could you just amplify for a second on

1361
00:57:45,319 --> 00:57:42,360
the comment you made just a minute ago

1362
00:57:48,349 --> 00:57:45,329
that if that featured around

1363
00:57:50,569 --> 00:57:48,359

just short of 8 microns is carbon-carbon

1364
00:57:55,849 --> 00:57:50,579
stretch it has to be fluorescence why is

1365
00:57:59,930 --> 00:57:55,859
that um because that's the way that's

1366
00:58:01,910 --> 00:57:59,940
the way a mission from PAH molecules is

1367
00:58:03,499 --> 00:58:01,920
seen in Astrophysical sources at these

1368
00:58:05,390 --> 00:58:03,509
wavelengths so I guess it doesn't have

1369
00:58:09,440 --> 00:58:05,400
to be but I would expect that it would

1370
00:58:10,969 --> 00:58:09,450
be in that case because you know

1371
00:58:13,670 --> 00:58:10,979
carbon-carbon stretch wouldn't would

1372
00:58:16,670 --> 00:58:13,680
indicate PAH and pah is seen in many

1373
00:58:18,229 --> 00:58:16,680
sources now by Spitzer and it's always

1374
00:58:21,140 --> 00:58:18,239
in a mission and it's new to

1375
00:58:22,609 --> 00:58:21,150
fluorescence certainly you're in you

1376
00:58:24,140 --> 00:58:22,619
know this planet is in close enough to a

1377
00:58:26,479 --> 00:58:24,150
hot enough star there's enough UV

1378
00:58:28,069 --> 00:58:26,489
because fluorescence and you're giving

1379
00:58:30,049 --> 00:58:28,079
up in dirty extremity region I mean

1380
00:58:32,749 --> 00:58:30,059
we're being speculative now but if there

1381
00:58:34,549 --> 00:58:32,759
are there are silicate clouds those

1382
00:58:37,009 --> 00:58:34,559
silicate grains could be associated with

1383
00:58:39,769 --> 00:58:37,019
pah molecules also and they could

1384
00:58:43,130 --> 00:58:39,779
fluoresce well when I think in this case

1385
00:58:44,870 --> 00:58:43,140
the fluorescence is not the same as kind

1386
00:58:47,239 --> 00:58:44,880
of fluorescence as if you had a diatomic

1387
00:58:49,640 --> 00:58:47,249
molecule which was pumped at a higher

1388
00:58:51,829 --> 00:58:49,650

statement re-radiated at different

1389
00:58:55,999 --> 00:58:51,839
wavelengths it's really more that you

1390
00:58:59,390 --> 00:58:56,009
might have a pH grain or macro molecule

1391
00:59:01,150 --> 00:58:59,400
that is flash heated by UV photon and

1392
00:59:04,819 --> 00:59:01,160
then you get vibrational excitation

1393
00:59:07,699 --> 00:59:04,829
which is seen in addition but the grain

1394
00:59:10,039 --> 00:59:07,709
itself is probably slightly warm welcome

1395
00:59:13,249 --> 00:59:10,049
by that UV photon that's that's exactly

1396
00:59:14,870 --> 00:59:13,259
correct yeah it's not quite the same

1397
00:59:16,400 --> 00:59:14,880
it's not question say but it's still

1398
00:59:19,009 --> 00:59:16,410
referred to as fluorescence because it's

1399
00:59:21,890 --> 00:59:19,019
a repercussion a roomie it's a

1400
00:59:29,400 --> 00:59:21,900
readmission of the UV radiation from the

1401
00:59:33,690 --> 00:59:31,620
well drink there aren't any hands raised

1402
00:59:38,570 --> 00:59:33,700
around the net and so I just wanted to

1403
00:59:52,020 --> 00:59:49,230
weekly and thank you again and look