

Kepler's Optical Secondary Eclipse Of HAT-P-7b
And Probable Detection Of Planet-Induced Stellar
Gravity Darkening



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1
00:00:11,230 --> 00:00:09,549
so hello my name is Brett Morris and I'm

2
00:00:13,600 --> 00:00:11,240
currently at NASA Goddard Space Flight

3
00:00:15,100 --> 00:00:13,610
Center normal university maryland and

4
00:00:17,890 --> 00:00:15,110
i'm going to present to you some Kepler

5
00:00:19,600 --> 00:00:17,900
data particularly on a hot Jupiter which

6
00:00:22,120 --> 00:00:19,610
I promise I will try to motivate at AB

7
00:00:25,150 --> 00:00:22,130
grad calm and a particular cool feature

8
00:00:26,800 --> 00:00:25,160
for it so you've heard this a few times

9
00:00:28,210 --> 00:00:26,810
already fortunately I don't need to give

10
00:00:29,889 --> 00:00:28,220
you too much background I'm going to try

11
00:00:31,740 --> 00:00:29,899
to put in enough against that Daniels

12
00:00:33,819 --> 00:00:31,750
talk makes a little more sense as well

13
00:00:35,920 --> 00:00:33,829

transiting exoplanets are what Kepler

14

00:00:39,189 --> 00:00:35,930

studies there was the Doppler method

15

00:00:41,349 --> 00:00:39,199

where you can see planet hosting

16

00:00:44,139 --> 00:00:41,359

stars move towards you and away from you

17

00:00:45,669 --> 00:00:44,149

in spectra but then also just by looking

18

00:00:47,979 --> 00:00:45,679

at the brightness of stars that host

19

00:00:49,689 --> 00:00:47,989

exoplanets if their inclination of their

20

00:00:51,759 --> 00:00:49,699

orbit takes them in front of their star

21

00:00:54,099 --> 00:00:51,769

you can see a decrease in the brightness

22

00:00:58,270 --> 00:00:54,109

of the star over time and that's what

23

00:01:00,790 --> 00:00:58,280

Kepler does Kepler has a very high

24

00:01:02,560 --> 00:01:00,800

precision photometer the CCD on it's

25

00:01:04,600 --> 00:01:02,570

very good for measuring brightness

26
00:01:07,930 --> 00:01:04,610
changes and it measures those changes

27
00:01:09,550 --> 00:01:07,940
for 150,000 stars continuously for most

28
00:01:12,160 --> 00:01:09,560
of those stars it measures once every

29
00:01:15,219 --> 00:01:12,170
half hour forest a select group of about

30
00:01:16,899 --> 00:01:15,229
500 it measures once a minute every

31
00:01:19,539 --> 00:01:16,909
minute for the four years that it took

32
00:01:21,280 --> 00:01:19,549
continuous data so that's a lot of

33
00:01:24,819 --> 00:01:21,290
photometry and we can get out a lot of

34
00:01:26,830 --> 00:01:24,829
cool effects from them so far the last

35
00:01:28,749 --> 00:01:26,840
time I checked it was 3200 candidate

36
00:01:31,209 --> 00:01:28,759
planets so we're getting up there in the

37
00:01:32,770 --> 00:01:31,219
numbers I'm going to talk to you about

38
00:01:35,429 --> 00:01:32,780

one planet in particular it's called

39

00:01:37,090 --> 00:01:35,439

happy 7b they'll have these crazy names

40

00:01:40,749 --> 00:01:37,100

fortunately mine doesn't have too many

41

00:01:42,520 --> 00:01:40,759

numbers so happy 7b is a hot Jupiter and

42

00:01:44,139 --> 00:01:42,530

this is what the transit light curve

43

00:01:46,840 --> 00:01:44,149

looks like for happy 7b that's not a

44

00:01:49,060 --> 00:01:46,850

model that's the data and you get this

45

00:01:50,649 --> 00:01:49,070

particular transit light curve by taking

46

00:01:53,469 --> 00:01:50,659

each transit light curve the Kepler

47

00:01:54,849 --> 00:01:53,479

recorded over four years or in this set

48

00:01:57,639 --> 00:01:54,859

i'm showing about two years worth of

49

00:01:59,620 --> 00:01:57,649

data and you put them one over the other

50

00:02:01,840 --> 00:01:59,630

and overlap them and then bend down the

51
00:02:03,609 --> 00:02:01,850
data that you really been out the signal

52
00:02:05,800 --> 00:02:03,619
to noise so you get very little scatter

53
00:02:07,450 --> 00:02:05,810
in your data I didn't show a fit here

54
00:02:08,560 --> 00:02:07,460
because the fit would have just been

55
00:02:10,900 --> 00:02:08,570
right on top of the data you can't

56
00:02:12,610 --> 00:02:10,910
really see it on the scale and the shape

57
00:02:14,140 --> 00:02:12,620
of the transit light curve tells you

58
00:02:16,150 --> 00:02:14,150
everything you know about the planet

59
00:02:17,980 --> 00:02:16,160
when you're doing the transit method so

60
00:02:19,270 --> 00:02:17,990
what have we learn we know that the

61
00:02:20,920 --> 00:02:19,280
period is two point

62
00:02:23,620 --> 00:02:20,930
two days if you compare that to solar

63
00:02:25,240 --> 00:02:23,630

system planets Mercury takes 88 days to

64

00:02:26,800 --> 00:02:25,250

go around the Sun this planet takes two

65

00:02:30,460 --> 00:02:26,810

so you can imagine this one's much much

66

00:02:32,199 --> 00:02:30,470

closer it's the semi-major axis of its

67

00:02:34,360 --> 00:02:32,209

orbit which is the distance it orbits

68

00:02:37,030 --> 00:02:34,370

from its star is only four times the

69

00:02:40,510 --> 00:02:37,040

radius of the star it's nearly on top of

70

00:02:43,059 --> 00:02:40,520

the star kind of sterile so again I'm

71

00:02:44,199 --> 00:02:43,069

going to motivate this later the radius

72

00:02:46,059 --> 00:02:44,209

of the planet it's about seven percent

73

00:02:49,330 --> 00:02:46,069

of the radius of the star it's pretty

74

00:02:52,420 --> 00:02:49,340

chunky and it's its orbit takes it

75

00:02:53,440 --> 00:02:52,430

within seven degrees of edge on from us

76

00:02:55,690 --> 00:02:53,450

which is why we can see it in the

77

00:02:57,729 --> 00:02:55,700

transit method so I did not show you a

78

00:02:59,500 --> 00:02:57,739

fit overlaid onto this transit light

79

00:03:01,870 --> 00:02:59,510

curve because it would be too close but

80

00:03:03,580 --> 00:03:01,880

if you do that fit and then you subtract

81

00:03:06,520 --> 00:03:03,590

the data from the fit you get these

82

00:03:08,320 --> 00:03:06,530

residuals these leftovers let's note the

83

00:03:09,820 --> 00:03:08,330

scale of these leftovers the residuals

84

00:03:12,580 --> 00:03:09,830

are in parts per million to borrow a

85

00:03:14,110 --> 00:03:12,590

term from you chemists and so these are

86

00:03:16,390 --> 00:03:14,120

very very very fine changes in

87

00:03:18,520 --> 00:03:16,400

brightness Kepler was designed to

88

00:03:20,710 --> 00:03:18,530

measure about 10 per per million change

89

00:03:23,440 --> 00:03:20,720

in brightness because that's what you

90

00:03:25,810 --> 00:03:23,450

need to see an earth radius planet at 1a

91

00:03:29,860 --> 00:03:25,820

you which was kind of a big goal of

92

00:03:31,210 --> 00:03:29,870

Kepler there's a very questionable bump

93

00:03:33,130 --> 00:03:31,220

there it's kind of a smear in the

94

00:03:34,630 --> 00:03:33,140

residuals I'm not going to claim that

95

00:03:36,460 --> 00:03:34,640

that's a discovery of something amazing

96

00:03:38,740 --> 00:03:36,470

but I'm going to ask what might that

97

00:03:42,009 --> 00:03:38,750

bump be and we're going to talk about

98

00:03:44,110 --> 00:03:42,019

that a little bit the model that we use

99

00:03:46,180 --> 00:03:44,120

to fit this is from mandolin Eagle which

100

00:03:48,400 --> 00:03:46,190

really just considers the shadow of the

101
00:03:50,259 --> 00:03:48,410
planet on the star it doesn't consider

102
00:03:52,720 --> 00:03:50,269
too many extra fancy things so if you

103
00:03:54,370 --> 00:03:52,730
get residuals from that model cool

104
00:03:55,390 --> 00:03:54,380
things could be happening especially in

105
00:03:58,690 --> 00:03:55,400
this regime where the brightness changes

106
00:04:00,610 --> 00:03:58,700
are very small so one way that you can

107
00:04:02,319 --> 00:04:00,620
get a positive bump in like heard

108
00:04:05,259 --> 00:04:02,329
residuals is by putting a dark spot on

109
00:04:07,509 --> 00:04:05,269
your star if we imagine a big dark

110
00:04:10,210 --> 00:04:07,519
sunspot like that on our cartoon model

111
00:04:11,590 --> 00:04:10,220
and the planet begins to transit you get

112
00:04:12,849 --> 00:04:11,600
a dip in the light curve just like you

113
00:04:15,160 --> 00:04:12,859

would expect from what you just saw on

114

00:04:17,170 --> 00:04:15,170

the model but as the planet passes over

115

00:04:19,210 --> 00:04:17,180

the dark spot it's as though it didn't

116

00:04:21,069 --> 00:04:19,220

fully cover the star anymore because

117

00:04:22,600 --> 00:04:21,079

compared to your other model the star

118

00:04:24,130 --> 00:04:22,610

was darker there and so you get a big

119

00:04:26,320 --> 00:04:24,140

positive bump in your light curve for

120

00:04:29,860 --> 00:04:26,330

this cartoon model if it's a very dim

121

00:04:31,899 --> 00:04:29,870

bump you only get a smaller dark spot

122

00:04:32,789 --> 00:04:31,909

that's not as dark and you get a

123

00:04:35,799 --> 00:04:32,799

positive on

124

00:04:38,229 --> 00:04:35,809

what can cause dark spots on stars you

125

00:04:41,559 --> 00:04:38,239

probably know about sun spots those are

126

00:04:43,239 --> 00:04:41,569

common on all kinds of stars on

127

00:04:44,409 --> 00:04:43,249

particularly the sun if you've ever

128

00:04:47,529 --> 00:04:44,419

gotten to observe it through a telescope

129

00:04:49,600 --> 00:04:47,539

on earth and star spots have a few

130

00:04:51,039 --> 00:04:49,610

qualities that we can use to wonder if

131

00:04:53,799 --> 00:04:51,049

they are actually the source of this

132

00:04:57,009 --> 00:04:53,809

dark spot they only persist on the scale

133

00:04:59,079 --> 00:04:57,019

of a few weeks and they happen at more

134

00:05:01,869 --> 00:04:59,089

or less well distributed latitudes

135

00:05:04,689 --> 00:05:01,879

almost-stars and so it's probably not

136

00:05:06,100 --> 00:05:04,699

likely that our exoplanet transited over

137

00:05:07,959 --> 00:05:06,110

the same spot for four years

138

00:05:11,319 --> 00:05:07,969

continuously at the same point in its

139

00:05:14,439 --> 00:05:11,329

latitude and you can measure the

140

00:05:16,269 --> 00:05:14,449

activity of a given star using spectral

141

00:05:17,649 --> 00:05:16,279

qualities of that star and according to

142

00:05:19,179 --> 00:05:17,659

some studies this isn't a particularly

143

00:05:21,759 --> 00:05:19,189

active star so we wouldn't expect

144

00:05:24,339 --> 00:05:21,769

magnetically driven star spots to be

145

00:05:25,869 --> 00:05:24,349

quite active our referee on the paper

146

00:05:28,059 --> 00:05:25,879

that we put out mention that it could

147

00:05:30,489 --> 00:05:28,069

also be due to stellar rotation it stars

148

00:05:31,779 --> 00:05:30,499

rotate really quickly kind of like a ice

149

00:05:33,609 --> 00:05:31,789

skater with their arms getting pulled

150

00:05:35,109 --> 00:05:33,619

out the outer layers of the photosphere

151
00:05:37,329 --> 00:05:35,119
of that star might get pulled away from

152
00:05:38,979 --> 00:05:37,339
the star when that happens if you get

153
00:05:40,989 --> 00:05:38,989
pulled away from the core you cool off a

154
00:05:43,359 --> 00:05:40,999
little bit cooling off darkens the

155
00:05:45,069 --> 00:05:43,369
surface and then the planet passing over

156
00:05:47,499 --> 00:05:45,079
the darkened surface could have leftover

157
00:05:48,609 --> 00:05:47,509
residuals in your light curve but that

158
00:05:50,649 --> 00:05:48,619
would have caused a symmetric difference

159
00:05:51,729 --> 00:05:50,659
across the rotation of the star we don't

160
00:05:54,040 --> 00:05:51,739
see that we just see a little bump

161
00:05:57,939 --> 00:05:54,050
that's pretty localized so how do we

162
00:06:00,159 --> 00:05:57,949
explain a small amplitude spot that's

163
00:06:02,049 --> 00:06:00,169

very localized and always seems to cross

164

00:06:05,169 --> 00:06:02,059

the planet always seems to cross over it

165

00:06:07,419 --> 00:06:05,179

at the same time over four years there's

166

00:06:08,919 --> 00:06:07,429

a very exotic effect that's a big claim

167

00:06:10,299 --> 00:06:08,929

and so we're not claiming a discovery

168

00:06:13,569 --> 00:06:10,309

we're going to claim a maybe this is

169

00:06:16,199 --> 00:06:13,579

what it is and we say maybe it's planet

170

00:06:18,790 --> 00:06:16,209

induced stellar gravity darkening

171

00:06:21,999 --> 00:06:18,800

gravity darkening happens when the tides

172

00:06:24,100 --> 00:06:22,009

of a planet pull the layers of the star

173

00:06:25,629 --> 00:06:24,110

towards the planet kind of like the

174

00:06:28,719 --> 00:06:25,639

tides of the Moon pulled the ocean

175

00:06:29,919 --> 00:06:28,729

towards the moon except when a photo

176

00:06:31,959 --> 00:06:29,929

sphere is pulled away from it stars

177

00:06:33,969 --> 00:06:31,969

mentioned a little bit earlier getting

178

00:06:36,189 --> 00:06:33,979

pulled away means cooling down cooling

179

00:06:38,409 --> 00:06:36,199

down means getting dimmer so if there

180

00:06:40,719 --> 00:06:38,419

were a dim spot on the surface of the

181

00:06:43,019 --> 00:06:40,729

star that came from the planet pulling

182

00:06:46,719 --> 00:06:43,029

tides on the surface on the photosphere

183

00:06:48,730 --> 00:06:46,729

that dark spot would slightly lag

184

00:06:51,549 --> 00:06:48,740

the orbit of the planet just like the

185

00:06:53,320 --> 00:06:51,559

tides of the the ocean slightly lagged

186

00:06:55,239 --> 00:06:53,330

the orbit of the moon because it takes

187

00:06:56,739 --> 00:06:55,249

gas time to respond to the gravitational

188

00:06:58,929 --> 00:06:56,749

kick of the planet passing over it and

189

00:07:00,249 --> 00:06:58,939

so you would expect that if the planets

190

00:07:03,610 --> 00:07:00,259

rotating around this way

191

00:07:06,820 --> 00:07:03,620

counterclockwise or you would expect

192

00:07:09,640 --> 00:07:06,830

that the dark spot would be behind the

193

00:07:11,829 --> 00:07:09,650

planet in its orbit which means the

194

00:07:14,890 --> 00:07:11,839

viewed from down below where observer

195

00:07:17,739 --> 00:07:14,900

would be in this cartoon the planet

196

00:07:19,179 --> 00:07:17,749

would transit the dark spot in between

197

00:07:20,679 --> 00:07:19,189

the beginning of the transit event and

198

00:07:26,139 --> 00:07:20,689

the middle of the transit event which is

199

00:07:28,239 --> 00:07:26,149

where we see our spot we can predict how

200

00:07:30,100 --> 00:07:28,249

much cooler the surface of the star is

201
00:07:31,839 --> 00:07:30,110
at the center of the dark spot compared

202
00:07:34,269 --> 00:07:31,849
to the rest of the star based on how

203
00:07:36,100 --> 00:07:34,279
much dimmer that spot is so if this

204
00:07:37,570 --> 00:07:36,110
actually is what we're seeing the

205
00:07:39,070 --> 00:07:37,580
effective temperature difference between

206
00:07:40,480 --> 00:07:39,080
the center of the dark spot and the rest

207
00:07:42,879 --> 00:07:40,490
of the surface of the star has two

208
00:07:46,209 --> 00:07:42,889
tenths of a kelvin gives you an idea why

209
00:07:47,829 --> 00:07:46,219
this is a bold claim but this is kind of

210
00:07:49,719 --> 00:07:47,839
thing when that you can do when you have

211
00:07:51,730 --> 00:07:49,729
high precision photometers like Kepler

212
00:07:53,320 --> 00:07:51,740
Kepler can really give us really amazing

213
00:07:55,059 --> 00:07:53,330

signs that we haven't seen from stars

214

00:07:56,649 --> 00:07:55,069

before and a lot of stellar

215

00:07:58,239 --> 00:07:56,659

astrophysicists are having a lot of fun

216

00:08:00,070 --> 00:07:58,249

with the rebirth of their field sort of

217

00:08:03,339 --> 00:08:00,080

among younger people because Kepler is

218

00:08:05,850 --> 00:08:03,349

giving them new things to look at we can

219

00:08:08,230 --> 00:08:05,860

also then use first principles of

220

00:08:10,179 --> 00:08:08,240

photosphere physics that have been done

221

00:08:12,550 --> 00:08:10,189

by other scientists over the years to

222

00:08:14,230 --> 00:08:12,560

get an idea of how the gas in a photo

223

00:08:16,570 --> 00:08:14,240

sphere should respond to a gravitational

224

00:08:18,909 --> 00:08:16,580

kick from a planet that orbits it and if

225

00:08:20,409 --> 00:08:18,919

you measure up what we believe in the

226

00:08:23,230 --> 00:08:20,419

pressure and density of the photosphere

227

00:08:24,549 --> 00:08:23,240

of this star should be against how long

228

00:08:26,379 --> 00:08:24,559

it took the atmosphere to respond and

229

00:08:28,629 --> 00:08:26,389

create the dark spot given by that phase

230

00:08:30,459 --> 00:08:28,639

lag you can get an idea of whether or

231

00:08:31,869 --> 00:08:30,469

not the timing is consistent because the

232

00:08:33,730 --> 00:08:31,879

timing is the parameter we can best

233

00:08:37,029 --> 00:08:33,740

constrain from where that bump was in

234

00:08:39,459 --> 00:08:37,039

the anomaly and they match up to be more

235

00:08:41,829 --> 00:08:39,469

or less consistent so our timing works

236

00:08:43,540 --> 00:08:41,839

out well but this is a mega three sigma

237

00:08:44,740 --> 00:08:43,550

detection and if we want to actually

238

00:08:46,300 --> 00:08:44,750

claim anything we need to wait a little

239

00:08:48,579 --> 00:08:46,310

bit longer unfortunately there's more

240

00:08:50,290 --> 00:08:48,589

Kepler data coming in still that hasn't

241

00:08:52,180 --> 00:08:50,300

been run through the pipeline even

242

00:08:54,129 --> 00:08:52,190

though a coupler is not collecting data

243

00:08:56,110 --> 00:08:54,139

currently and so there's a little bit

244

00:08:58,790 --> 00:08:56,120

hope that this model can be continued to

245

00:09:01,340 --> 00:08:59,870

I'm going to talk to you a little bit

246

00:09:02,840 --> 00:09:01,350

about the Eclipse to we've heard it

247

00:09:05,269 --> 00:09:02,850

given a few names that we had the

248

00:09:06,620 --> 00:09:05,279

occultation word before exoplanet

249

00:09:08,269 --> 00:09:06,630

scientists have had a fun time coming

250

00:09:10,130 --> 00:09:08,279

into the field of binaries which have

251
00:09:11,870 --> 00:09:10,140
existed in astronomy for a long time and

252
00:09:13,610 --> 00:09:11,880
trying to reinvent the vocabulary and

253
00:09:16,550 --> 00:09:13,620
calling occultation solipsism clips

254
00:09:17,990 --> 00:09:16,560
things but I'm going to call the this

255
00:09:19,910 --> 00:09:18,000
particular event the secondary eclipse

256
00:09:21,110 --> 00:09:19,920
we've been talking about the transit

257
00:09:22,490 --> 00:09:21,120
event which is when the planet passes in

258
00:09:25,190 --> 00:09:22,500
front of the star which you get a nice

259
00:09:27,139 --> 00:09:25,200
big signal from but when the planet goes

260
00:09:29,030 --> 00:09:27,149
behind the star there's a very small

261
00:09:31,130 --> 00:09:29,040
effect that you can measure as well as

262
00:09:32,600 --> 00:09:31,140
the planets light gets blocked out by

263
00:09:33,920 --> 00:09:32,610

the star and the light that you're

264

00:09:35,569 --> 00:09:33,930

seeing from the planet comes from

265

00:09:37,670 --> 00:09:35,579

thermal emission from the planet and

266

00:09:41,210 --> 00:09:37,680

also from reflection of the Starlight

267

00:09:43,310 --> 00:09:41,220

off of the cloud tops essentially this

268

00:09:45,050 --> 00:09:43,320

is what that light curve looks like for

269

00:09:47,090 --> 00:09:45,060

a happy seven if you sum up the two

270

00:09:49,130 --> 00:09:47,100

years of data the planet was going

271

00:09:51,290 --> 00:09:49,140

around behind the star and then as soon

272

00:09:53,060 --> 00:09:51,300

as it passes behind the star the white

273

00:09:56,720 --> 00:09:53,070

drops down to just the solar brightness

274

00:09:58,310 --> 00:09:56,730

and then goes back up again after we

275

00:10:01,490 --> 00:09:58,320

don't have crazy bumps to claim this

276
00:10:03,290 --> 00:10:01,500
time one of the things we wanted to look

277
00:10:05,990 --> 00:10:03,300
at with this is if there's variability

278
00:10:07,790 --> 00:10:06,000
in the secondary Eclipse depth because

279
00:10:09,620 --> 00:10:07,800
variability in the depth of the

280
00:10:11,480 --> 00:10:09,630
secondary Eclipse would be variability

281
00:10:13,069 --> 00:10:11,490
in how much light is coming to you from

282
00:10:15,980 --> 00:10:13,079
the planet if you were to imagine

283
00:10:18,079 --> 00:10:15,990
looking at Earth transit or eclipse

284
00:10:20,780 --> 00:10:18,089
again and again from somewhere else the

285
00:10:22,400 --> 00:10:20,790
amount of clouds on Earth's atmosphere

286
00:10:23,630 --> 00:10:22,410
would change how bright the earth

287
00:10:26,030 --> 00:10:23,640
appeared to be clouds are very

288
00:10:28,340 --> 00:10:26,040

reflective the ocean absorbs a lot of

289

00:10:29,690 --> 00:10:28,350

light so what if the cloud tops on this

290

00:10:32,060 --> 00:10:29,700

planet we're changing what if their

291

00:10:35,960 --> 00:10:32,070

color changed kind of an interesting

292

00:10:37,730 --> 00:10:35,970

question to think about this is a

293

00:10:41,630 --> 00:10:37,740

measure of the secondary Eclipse step

294

00:10:44,360 --> 00:10:41,640

over 355 eclipses there's a lot of

295

00:10:46,160 --> 00:10:44,370

scatter not a lot of smell of anything

296

00:10:49,310 --> 00:10:46,170

interesting to talk about which you

297

00:10:50,750 --> 00:10:49,320

could expect because based on the radius

298

00:10:53,960 --> 00:10:50,760

of the planet which we constrained from

299

00:10:56,060 --> 00:10:53,970

the transit light curve and where we

300

00:10:58,009 --> 00:10:56,070

know it's semi major axis puts it away

301
00:11:00,439 --> 00:10:58,019
from its star we know how much light

302
00:11:02,180 --> 00:11:00,449
hits the planet and then we can measure

303
00:11:03,410 --> 00:11:02,190
how much light we get from the planet to

304
00:11:04,699 --> 00:11:03,420
understand how much light is being

305
00:11:07,130 --> 00:11:04,709
reflected and how much is being emitted

306
00:11:09,050 --> 00:11:07,140
if you do that you come up with a very

307
00:11:10,939 --> 00:11:09,060
low albedo albedo is the fraction of

308
00:11:12,290 --> 00:11:10,949
light that comes back to you only about

309
00:11:14,690 --> 00:11:12,300
three percent of

310
00:11:16,850 --> 00:11:14,700
light or less that hits the planet gets

311
00:11:20,420 --> 00:11:16,860
reflected to you this is blacker than

312
00:11:21,590 --> 00:11:20,430
coal it's a very dark planet so most of

313
00:11:23,510 --> 00:11:21,600

the light you see in the secondary

314

00:11:26,090 --> 00:11:23,520

Eclipse is just thermal emission because

315

00:11:27,770 --> 00:11:26,100

it's hot we can also tell how hot it is

316

00:11:29,810 --> 00:11:27,780

then by how much light is coming back

317

00:11:34,250 --> 00:11:29,820

it's about two thousand seven hundred

318

00:11:36,110 --> 00:11:34,260

Kelvin that's pretty sterile and there's

319

00:11:38,660 --> 00:11:36,120

no significant variations in how bright

320

00:11:40,880 --> 00:11:38,670

it appears to be now I'm going to try to

321

00:11:43,700 --> 00:11:40,890

motivate why I'm giving you a talk about

322

00:11:46,160 --> 00:11:43,710

this planet at a beard con I promised

323

00:11:48,260 --> 00:11:46,170

you I would so as security men sioned a

324

00:11:50,510 --> 00:11:48,270

little bit earlier hot Jupiters are some

325

00:11:53,210 --> 00:11:50,520

of the easiest planets to observe in

326

00:11:55,640 --> 00:11:53,220

transmission and emission spectroscopy

327

00:11:57,350 --> 00:11:55,650

they have big extended atmospheres that

328

00:12:00,260 --> 00:11:57,360

give us the best chance to get some

329

00:12:02,720 --> 00:12:00,270

signal and so in our efforts to get

330

00:12:05,120 --> 00:12:02,730

spectra of super earth-sized planets

331

00:12:06,830 --> 00:12:05,130

ideally in one day we need to kind of

332

00:12:09,440 --> 00:12:06,840

refine our methods on the bigger easier

333

00:12:11,240 --> 00:12:09,450

targets and since they have quick

334

00:12:12,860 --> 00:12:11,250

orbital periods they're really easy to

335

00:12:14,390 --> 00:12:12,870

observe again and again and again and

336

00:12:15,620 --> 00:12:14,400

beat down your signal to noise like you

337

00:12:18,080 --> 00:12:15,630

saw in the nice light curve that we had

338

00:12:20,630 --> 00:12:18,090

for this planet but then there's also

339

00:12:23,090 --> 00:12:20,640

the question of dynamics this planet

340

00:12:25,580 --> 00:12:23,100

orbits over the rotation axis of its

341

00:12:28,100 --> 00:12:25,590

star so if its star rotates this way the

342

00:12:29,540 --> 00:12:28,110

planet rotates kind of at 90 degrees to

343

00:12:32,690 --> 00:12:29,550

the inclination of everything in our

344

00:12:35,210 --> 00:12:32,700

solar system so why is it doing that how

345

00:12:37,340 --> 00:12:35,220

did it get there to form a gas giant it

346

00:12:39,500 --> 00:12:37,350

can't have formed at a distance of four

347

00:12:41,180 --> 00:12:39,510

stellar radii from the star something

348

00:12:43,540 --> 00:12:41,190

catastrophic must have happened to put

349

00:12:45,920 --> 00:12:43,550

it there so we can ask the question if

350

00:12:48,920 --> 00:12:45,930

there were potentially habitable

351

00:12:50,270 --> 00:12:48,930

terrestrial planets in this system they

352

00:12:51,500 --> 00:12:50,280

probably would have gotten kicked out in

353

00:12:53,690 --> 00:12:51,510

the event that put this planet where it

354

00:12:55,550 --> 00:12:53,700

is so there's an interesting question of

355

00:12:58,010 --> 00:12:55,560

dynamics to that hot Jupiters raises in

356

00:13:00,410 --> 00:12:58,020

terms of questions of habitability of

357

00:13:02,450 --> 00:13:00,420

extrasolar planets and I'd like to thank

358

00:13:04,820 --> 00:13:02,460

my mentors dr. Harvey Mandel professor

359

00:13:06,290 --> 00:13:04,830

Drake Deming and nasa astrobiology

360

00:13:13,730 --> 00:13:06,300

institute that i didn't put on here

361

00:13:31,480 --> 00:13:15,480

and we have a few minutes for questions

362

00:13:37,370 --> 00:13:33,770

why do you think that planet has such a

363

00:13:40,400 --> 00:13:37,380

low albedo I wish I had a cool answer

364

00:13:41,960 --> 00:13:40,410

for you so one of the things you're

365

00:13:44,990 --> 00:13:41,970

seeing in the transmission spectroscopy

366

00:13:46,520 --> 00:13:45,000

is we don't know that we fully

367

00:13:48,650 --> 00:13:46,530

understand the compositions of these

368

00:13:51,410 --> 00:13:48,660

atmosphere is very well yet there's

369

00:13:53,960 --> 00:13:51,420

still a huge amount of uncertainty as to

370

00:13:55,700 --> 00:13:53,970

what's in these atmospheres one of the

371

00:13:57,710 --> 00:13:55,710

best ideas right now as to why the

372

00:14:00,440 --> 00:13:57,720

albedo is so low is that if these

373

00:14:02,630 --> 00:14:00,450

atmospheres are very very long columns

374

00:14:04,580 --> 00:14:02,640

of gases kind of like the solar

375

00:14:06,620 --> 00:14:04,590

atmosphere if you think about the Sun

376

00:14:08,780 --> 00:14:06,630

there's just this huge column of gas and

377

00:14:10,670 --> 00:14:08,790

if the Sun weren't shining there's a

378

00:14:13,040 --> 00:14:10,680

immense column of gas that could just

379

00:14:15,110 --> 00:14:13,050

absorb lots and lots of light and so

380

00:14:16,640 --> 00:14:15,120

that's kind of one of the only real

381

00:14:18,740 --> 00:14:16,650

ideas out there we don't think it's

382

00:14:20,090 --> 00:14:18,750

covered in soot or something towed to

383

00:14:22,070 --> 00:14:20,100

really make it black and even so it

384

00:14:28,040 --> 00:14:22,080

wouldn't make it that black so there's

385

00:14:29,600 --> 00:14:28,050

there's a lot of questions about that so

386

00:14:32,180 --> 00:14:29,610

I was wondering if there was a moon

387

00:14:33,350 --> 00:14:32,190

orbiting that planet like could that you

388

00:14:36,230 --> 00:14:33,360

know would you actually be able to pick

389

00:14:38,390 --> 00:14:36,240

up that signal noise as well so there's

390

00:14:40,730 --> 00:14:38,400

going to be a talk on exomoons today so

391

00:14:43,430 --> 00:14:40,740

I'm going to try not to talk over that

392

00:14:45,170 --> 00:14:43,440

speaker too much but one of the ways

393

00:14:49,280 --> 00:14:45,180

that you would see moons in transit

394

00:14:51,590 --> 00:14:49,290

Lakers input in potentially one of the

395

00:14:54,350 --> 00:14:51,600

more easier senses is by trying to

396

00:14:56,120 --> 00:14:54,360

measure when mid transit is moon's orbit

397

00:14:57,260 --> 00:14:56,130

around a planet and so you don't know if

398

00:14:58,400 --> 00:14:57,270

it's going to be on the left side or the

399

00:15:00,470 --> 00:14:58,410

right side of the planet when it

400

00:15:02,240 --> 00:15:00,480

transits and so it could kind of drag

401
00:15:03,710 --> 00:15:02,250
your light curve down early or late

402
00:15:06,320 --> 00:15:03,720
depending on which side of the planets

403
00:15:08,780 --> 00:15:06,330
it's on so that would show up as a bump

404
00:15:10,880 --> 00:15:08,790
near our ingress or egress here or a

405
00:15:12,770 --> 00:15:10,890
widening of the ingress and egress

406
00:15:15,620 --> 00:15:12,780
because this is integrated over many

407
00:15:17,180 --> 00:15:15,630
years so you just see it wider so there

408
00:15:20,690 --> 00:15:17,190
would be ways to confirm that via

409
00:15:22,190 --> 00:15:20,700
spectroscopy of this planet later but we

410
00:15:25,340 --> 00:15:22,200
don't see any evidence for that here and

411
00:15:27,470 --> 00:15:25,350
chances are you can imagine the hill

412
00:15:28,670 --> 00:15:27,480
sphere the radius around the planet at

413
00:15:31,550 --> 00:15:28,680

which things could orbit the planet

414

00:15:33,950 --> 00:15:31,560

stabilis is very very small because this

415

00:15:35,450 --> 00:15:33,960

planet is nearly on top of its star so

416

00:15:37,190 --> 00:15:35,460

anything that could have been there one

417

00:15:39,290 --> 00:15:37,200

day is probably dynamically stripped

418

00:15:39,290 --> 00:15:39,300

away