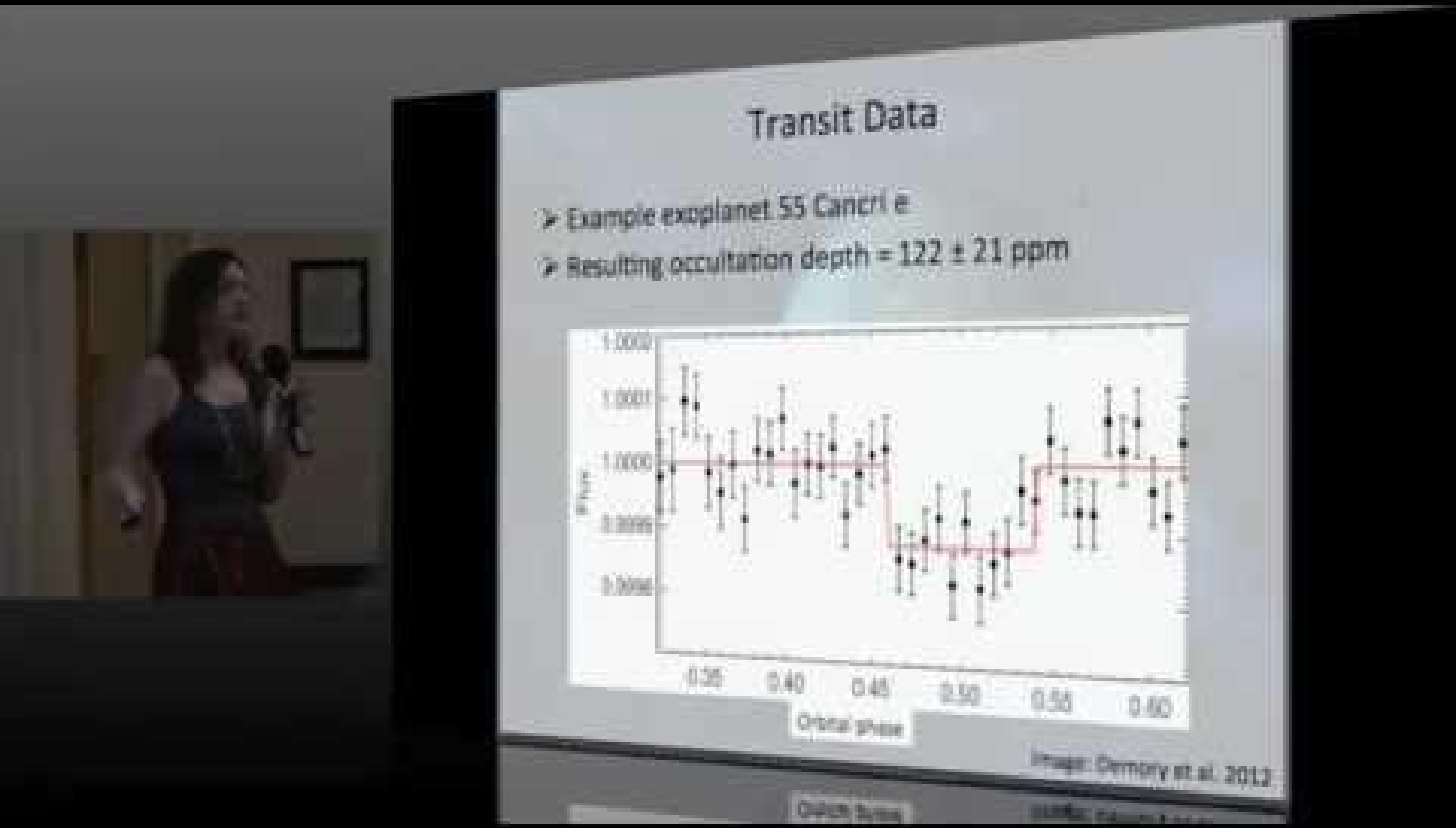
Transit Data
Example exoplanet 55 Cancri e
Resulting occultation depth = 122 ± 21 ppm
1.0002
1.0001
1.0000
0.9999
0.9998
0.35
0.40
0.45
0.50
0.55
0.60
Orbital phase
Image: Demory et al. 2012

1
00:00:10,280 --> 00:00:08,630
so when Mike and I are doing the warm up

2
00:00:12,049 --> 00:00:10,290
top for today anyone who do hear my name

3
00:00:17,000 --> 00:00:12,059
is Alissa I'm also one of the organizers

4
00:00:18,980 --> 00:00:17,010
for this conference I am slightly under

5
00:00:20,540 --> 00:00:18,990
prepared and I feel highly under

6
00:00:23,630 --> 00:00:20,550
qualified to be giving this warm-up talk

7
00:00:26,930 --> 00:00:23,640
but apparently I'm doing it anyway it is

8
00:00:29,240 --> 00:00:26,940
a very general and also a very

9
00:00:30,860 --> 00:00:29,250
abbreviated introduction into astronomy

10
00:00:32,799 --> 00:00:30,870
and planetary science just because we

11
00:00:36,170 --> 00:00:32,809
don't have enough time to do everything

12
00:00:38,090 --> 00:00:36,180
so I'm trying to cover on touch on some

13
00:00:39,410 --> 00:00:38,100

of the topics that will be discussed for

14
00:00:42,619 --> 00:00:39,420
this morning's talks so anything

15
00:00:46,099 --> 00:00:42,629
astronomy in planetary science based so

16
00:00:48,939 --> 00:00:46,109
I guess we'll just get started so

17
00:00:50,599 --> 00:00:48,949
introduction to planetary habitability

18
00:00:52,579 --> 00:00:50,609
habitability is one of the biggest

19
00:00:55,279 --> 00:00:52,589
things in my opinion in astrobiology

20
00:00:56,689 --> 00:00:55,289
right now because we're you know we have

21
00:00:58,219 --> 00:00:56,699
Kepler space telescope and lots of other

22
00:00:59,989 --> 00:00:58,229
things that are helping us to find these

23
00:01:02,000 --> 00:00:59,999
exoplanets so a big thing is how would

24
00:01:03,649 --> 00:01:02,010
we be able to tell whether or not these

25
00:01:06,289 --> 00:01:03,659
exoplanets that we're discovering if

26
00:01:08,120 --> 00:01:06,299
they're habitable or not there are a

27
00:01:10,400 --> 00:01:08,130
variety of characteristics that affect

28
00:01:12,410 --> 00:01:10,410
planetary habitability including

29
00:01:14,870 --> 00:01:12,420
composition of the exoplanet any

30
00:01:16,730 --> 00:01:14,880
atmosphere stellar radiation title

31
00:01:18,680 --> 00:01:16,740
evolution I'm not going to get to all of

32
00:01:20,600 --> 00:01:18,690
those but just so you know that they do

33
00:01:22,820 --> 00:01:20,610
exist and they are a factor in planetary

34
00:01:24,650 --> 00:01:22,830
habitability but so the first thing in

35
00:01:26,000 --> 00:01:24,660
exoplanets that I wanted to introduce is

36
00:01:28,190 --> 00:01:26,010
how we detect them how do we actually

37
00:01:29,420 --> 00:01:28,200
find these exoplanets and now that I'm

38
00:01:30,800 --> 00:01:29,430

involved in my talk I'd like to point

39
00:01:32,120 --> 00:01:30,810
out that you guys are welcome to get up

40
00:01:33,260 --> 00:01:32,130
and wander around during the time if you

41
00:01:34,580 --> 00:01:33,270
want to go get more coffee or more food

42
00:01:37,540 --> 00:01:34,590
it's supposed to be informal so you

43
00:01:41,090 --> 00:01:37,550
don't have to stay put sorry moving on

44
00:01:43,670 --> 00:01:41,100
okay two primary ways to detect

45
00:01:45,680 --> 00:01:43,680
exoplanets first way is called the

46
00:01:49,610 --> 00:01:45,690
radial velocity method or alternatively

47
00:01:53,630 --> 00:01:49,620
Doppler wobble how this works I need my

48
00:01:55,820 --> 00:01:53,640
hands that's okay when you have ok if

49
00:01:57,950 --> 00:01:55,830
this hand is the Sun and this is you

50
00:01:59,660 --> 00:01:57,960
know a planet or something when two

51
00:02:02,000 --> 00:01:59,670
objects are orbiting around each other

52
00:02:03,410 --> 00:02:02,010
you know the smaller body stays in orbit

53
00:02:06,440 --> 00:02:03,420
due to the gravitational tug of the

54
00:02:08,270 --> 00:02:06,450
larger body but in that same vein the

55
00:02:10,040 --> 00:02:08,280
smaller body will also exert a

56
00:02:11,690 --> 00:02:10,050
gravitational pull on the larger body it

57
00:02:14,230 --> 00:02:11,700
happens you know so the two things or

58
00:02:18,500 --> 00:02:14,240
orbit their common center of mass so

59
00:02:19,820 --> 00:02:18,510
it's an imperfect image because it's

60
00:02:22,160 --> 00:02:19,830
it's exaggerating

61
00:02:24,050 --> 00:02:22,170
evett ational poll all right people keep

62
00:02:27,050 --> 00:02:24,060
crossing in front that's right so in

63
00:02:28,490 --> 00:02:27,060

this case we have one son that's in the

64
00:02:30,620 --> 00:02:28,500
center and then an exoplanet orbiting

65
00:02:32,540 --> 00:02:30,630
the outside the point to take away from

66
00:02:35,630 --> 00:02:32,550
this image is that as the exoplanet

67
00:02:37,610 --> 00:02:35,640
orbits around the star there's a slight

68
00:02:44,810 --> 00:02:37,620
wobble a slight shift in the radial

69
00:02:48,080 --> 00:02:44,820
velocity of the Sun and you can you can

70
00:02:51,380 --> 00:02:48,090
measure the slight velocity wobble based

71
00:02:53,330 --> 00:02:51,390
on the red shifting of the color that we

72
00:02:55,340 --> 00:02:53,340
receive from the star so when a star is

73
00:02:57,470 --> 00:02:55,350
moving away from us the color will be

74
00:02:58,850 --> 00:02:57,480
slightly red shifted and when a star is

75
00:03:01,490 --> 00:02:58,860
moving towards us it will be slightly

76
00:03:03,380 --> 00:03:01,500
blue shifted so in this you know in this

77
00:03:05,150 --> 00:03:03,390
way we can look at a star and we watch

78
00:03:06,590 --> 00:03:05,160
over time and we see the light become

79
00:03:07,850 --> 00:03:06,600
red shifted and then blue shifted and

80
00:03:11,449 --> 00:03:07,860
then red shifted and then blue shifted

81
00:03:13,790 --> 00:03:11,459
and you can infer the presence of an

82
00:03:16,400 --> 00:03:13,800
exoplanet because there has to be some

83
00:03:20,360 --> 00:03:16,410
body that's orbiting that Sun that is

84
00:03:22,900 --> 00:03:20,370
causing the the shifting of the light so

85
00:03:25,699 --> 00:03:22,910
this is one way to detect exoplanets

86
00:03:29,020 --> 00:03:25,709
second way is using transit using

87
00:03:32,000 --> 00:03:29,030
transits sorry I keep combining hands

88
00:03:34,310 --> 00:03:32,010

transits are not quite as complicated as

89
00:03:36,410 --> 00:03:34,320
Doppler shift the whole point the big

90
00:03:39,470 --> 00:03:36,420
circle have a pointer the big circle in

91
00:03:41,000 --> 00:03:39,480
the background this is a star right when

92
00:03:42,830 --> 00:03:41,010
you are just looking at a star you

93
00:03:45,140 --> 00:03:42,840
measure some amount of light coming from

94
00:03:47,300 --> 00:03:45,150
the star which is what we see is this

95
00:03:49,340 --> 00:03:47,310
solid line right here but periodically

96
00:03:50,420 --> 00:03:49,350
you're going to have a plant or well you

97
00:03:52,490 --> 00:03:50,430
wouldn't know it's a planet there's

98
00:03:55,130 --> 00:03:52,500
something that passes in front of the

99
00:03:56,330 --> 00:03:55,140
star and causes you know it blocks some

100
00:03:58,250 --> 00:03:56,340
of the light that we receive from the

101
00:03:59,300 --> 00:03:58,260
star so this is this is just a dip in

102
00:04:01,009 --> 00:03:59,310
the light levels that we're observing

103
00:04:03,500 --> 00:04:01,019
because there's something obscuring the

104
00:04:05,090 --> 00:04:03,510
view of the star so we can actually we

105
00:04:08,479 --> 00:04:05,100
can't see this this is the part that we

106
00:04:10,820 --> 00:04:08,489
can't see very rough analogy if that

107
00:04:12,530 --> 00:04:10,830
doesn't make a lot of sense if you

108
00:04:14,240 --> 00:04:12,540
imagine the car at night if you're

109
00:04:16,219 --> 00:04:14,250
standing right up close next to the car

110
00:04:18,110 --> 00:04:16,229
you can see both the car headlight and

111
00:04:20,030 --> 00:04:18,120
any insects that are flying around the

112
00:04:21,229 --> 00:04:20,040
car headlight but if you turn around and

113
00:04:23,270 --> 00:04:21,239

walk away from the car and then look

114
00:04:25,520 --> 00:04:23,280
back you can still see the car headlight

115
00:04:27,830 --> 00:04:25,530
the Sun but you can no longer make out

116
00:04:29,270 --> 00:04:27,840
the individual insects it's just it's

117
00:04:30,590 --> 00:04:29,280
just because you're too far away and you

118
00:04:32,090 --> 00:04:30,600
can't see the size of the insects so

119
00:04:33,050 --> 00:04:32,100
it's the same thing with exoplanets and

120
00:04:35,360 --> 00:04:33,060
sons we

121
00:04:37,040 --> 00:04:35,370
can't actually see this but we can

122
00:04:39,200 --> 00:04:37,050
detect the change in the light levels

123
00:04:43,280 --> 00:04:39,210
when it when a planet transits in front

124
00:04:45,500 --> 00:04:43,290
in front of a star and just in terms of

125
00:04:48,140 --> 00:04:45,510
vocabulary you'll hear transit and

126
00:04:50,840 --> 00:04:48,150
occultation a transit is what happens

127
00:04:53,270 --> 00:04:50,850
when a planet passes in front of a star

128
00:04:54,980 --> 00:04:53,280
and the occultation is the same thing

129
00:04:57,740 --> 00:04:54,990
but when the planet passes behind the

130
00:04:58,970 --> 00:04:57,750
star so it's it means the same thing it

131
00:05:00,290 --> 00:04:58,980
means you're blocking out light it's

132
00:05:04,190 --> 00:05:00,300
just whether it's in front of or behind

133
00:05:06,560 --> 00:05:04,200
the star I had someone asked me

134
00:05:08,719 --> 00:05:06,570
yesterday about uncertainties so I just

135
00:05:12,020 --> 00:05:08,729
wanted to throw up a set of example data

136
00:05:14,180 --> 00:05:12,030
so you know what real data looks like so

137
00:05:15,350 --> 00:05:14,190
all of these these dots with their with

138
00:05:17,420 --> 00:05:15,360

their error bars on them this is an

139
00:05:18,890 --> 00:05:17,430
example set of data here you know our

140
00:05:20,719 --> 00:05:18,900
average amount of light that we're

141
00:05:22,670 --> 00:05:20,729
receiving from a star is here and then

142
00:05:24,950 --> 00:05:22,680
periodically you'll have this dip in the

143
00:05:27,290 --> 00:05:24,960
light level and just to see this dip

144
00:05:29,150 --> 00:05:27,300
once is not enough but if you observe

145
00:05:31,490 --> 00:05:29,160
this over time and you see that dip

146
00:05:34,550 --> 00:05:31,500
repeated numerous times again the

147
00:05:35,600 --> 00:05:34,560
implication is that there has to be a

148
00:05:37,490 --> 00:05:35,610
planet there there has to be something

149
00:05:41,779 --> 00:05:37,500
orbiting the star that is causing this

150
00:05:44,450 --> 00:05:41,789
dip in light levels which is Kepler

151
00:05:46,490 --> 00:05:44,460
everyone hope has heard of Kepler and

152
00:05:48,200 --> 00:05:46,500
you one who does planetary science is

153
00:05:51,380 --> 00:05:48,210
really really excited about Kepler space

154
00:05:52,880 --> 00:05:51,390
telescope this is a Space Telescope and

155
00:05:54,740 --> 00:05:52,890
not a ground telescope that means that

156
00:05:57,469 --> 00:05:54,750
it's in space and not on the ground it's

157
00:05:59,810 --> 00:05:57,479
the only distinction the benefit there

158
00:06:01,250 --> 00:05:59,820
are a variety of benefits for that an

159
00:06:02,420 --> 00:06:01,260
example being that if you're in space

160
00:06:04,790 --> 00:06:02,430
rather than on the ground you don't have

161
00:06:06,620 --> 00:06:04,800
to deal with them you know light like

162
00:06:08,840 --> 00:06:06,630
light to light pollution coming in and

163
00:06:12,310 --> 00:06:08,850

affecting the mirrors and stuff so this

164
00:06:15,860 --> 00:06:12,320
is just a artistic rendering of Kepler

165
00:06:17,570 --> 00:06:15,870
what do we have yeah Kepler the sole

166
00:06:19,640 --> 00:06:17,580
point of the kepler space telescope is

167
00:06:22,219 --> 00:06:19,650
to find exoplanets that's kind of its

168
00:06:24,469 --> 00:06:22,229
whole job which is why it's exciting at

169
00:06:26,900 --> 00:06:24,479
any one time it simultaneously looks at

170
00:06:28,550 --> 00:06:26,910
over 150,000 stars so it's not just

171
00:06:30,320 --> 00:06:28,560
looking at one little spot of light in

172
00:06:33,500 --> 00:06:30,330
finding planets it can do it for a wide

173
00:06:35,240 --> 00:06:33,510
variety of stars all at the same time it

174
00:06:36,620 --> 00:06:35,250
has that photometers the the thing that

175
00:06:39,050 --> 00:06:36,630
measures the light level and you see the

176
00:06:41,810 --> 00:06:39,060
dip in it that's the photometer Kepler

177
00:06:44,330 --> 00:06:41,820
was launched in 2009 anyone who's heard

178
00:06:45,620 --> 00:06:44,340
the news we sadly just lost a second

179
00:06:46,760 --> 00:06:45,630
wheel on Kepler which means we can't

180
00:06:48,710 --> 00:06:46,770
really steer it

181
00:06:49,999 --> 00:06:48,720
anymore so we can't actually aim it at

182
00:06:51,110 --> 00:06:50,009
one point in the sky we're not sure

183
00:06:54,680 --> 00:06:51,120
what's going to happen with Kepler but

184
00:06:56,540 --> 00:06:54,690
it's very sad um last numbers I was

185
00:07:00,200 --> 00:06:56,550
aware of that Kepler has discovered

186
00:07:02,659 --> 00:07:00,210
almost 3,000 candidate exoplanets and as

187
00:07:04,369 --> 00:07:02,669
of right now there's only 114 that have

188
00:07:06,409 --> 00:07:04,379

been confirmed as exoplanets but that's

189
00:07:08,600 --> 00:07:06,419
still a pretty impressive number now

190
00:07:12,110 --> 00:07:08,610
that we do know that there are real

191
00:07:13,760 --> 00:07:12,120
exoplanets orbiting distant stars and if

192
00:07:16,430 --> 00:07:13,770
you extrapolate the data from the part

193
00:07:19,070 --> 00:07:16,440
of the sky that we've looked at you know

194
00:07:20,779 --> 00:07:19,080
scientists other other scientists

195
00:07:22,969 --> 00:07:20,789
estimate that at about 17 billion

196
00:07:27,649 --> 00:07:22,979
earth-sized exoplanet in the Milky Way

197
00:07:29,809 --> 00:07:27,659
alone so impressive this is just an

198
00:07:32,270 --> 00:07:29,819
example set of data so these are the 114

199
00:07:34,010 --> 00:07:32,280
confirmed exoplanets that we have from

200
00:07:36,860 --> 00:07:34,020
Kepler we're looking at here this is

201
00:07:39,680 --> 00:07:36,870
planet mass on the y axis and semi major

202
00:07:41,839 --> 00:07:39,690
axis on the x axis semi-major axis is

203
00:07:45,409 --> 00:07:41,849
just orbital radius that's how far a

204
00:07:47,719 --> 00:07:45,419
planet orbits from its star also note

205
00:07:50,149 --> 00:07:47,729
this is on log scale so we are right

206
00:07:52,309 --> 00:07:50,159
here where it 1-1 where it's you know

207
00:07:55,850 --> 00:07:52,319
one earth mass and one astronomical unit

208
00:07:57,080 --> 00:07:55,860
from the Sun you can see two so they're

209
00:07:58,730 --> 00:07:57,090
rough groupings and I'm not going to get

210
00:08:00,050 --> 00:07:58,740
into the groupings what I am

211
00:08:01,100 --> 00:08:00,060
particularly interested in and I'm going

212
00:08:03,170 --> 00:08:01,110
to talk about in just a second are the

213
00:08:05,420 --> 00:08:03,180

super Earths which are in this range

214
00:08:09,469 --> 00:08:05,430
right here they're kind of this oval

215
00:08:10,879 --> 00:08:09,479
collection of planets and just to

216
00:08:13,610 --> 00:08:10,889
illustrate a point these are the hundred

217
00:08:16,100 --> 00:08:13,620
and fifty confirmed exoplanets these are

218
00:08:17,420 --> 00:08:16,110
the almost 3000 candidate exoplanets so

219
00:08:19,519 --> 00:08:17,430
they have not been confirmed yet but you

220
00:08:20,779 --> 00:08:19,529
can see they do follow the same trend so

221
00:08:22,390 --> 00:08:20,789
hopefully you know when we get enough

222
00:08:24,709 --> 00:08:22,400
data we can confirm more of those

223
00:08:28,820 --> 00:08:24,719
candidate planets as confirmed

224
00:08:30,529 --> 00:08:28,830
exoplanets so that was an introduction

225
00:08:31,969 --> 00:08:30,539
to detection and how we do that stuff I

226
00:08:34,399 --> 00:08:31,979
want to take just a minute and go into

227
00:08:37,870 --> 00:08:34,409
some theory behind super Earths because

228
00:08:40,639 --> 00:08:37,880
that's kind of my thing super Earths

229
00:08:42,469 --> 00:08:40,649
what is the super earth a super earth is

230
00:08:46,550 --> 00:08:42,479
a class of exoplanet with a mass between

231
00:08:48,110 --> 00:08:46,560
one and ten earth masses so we're at one

232
00:08:50,900 --> 00:08:48,120
astronomical unit the distance from the

233
00:08:53,660 --> 00:08:50,910
earth to the Sun is one AU super Earths

234
00:08:55,400 --> 00:08:53,670
are less than point to a you so they

235
00:08:58,189 --> 00:08:55,410
orbit very very closely to their parent

236
00:08:59,569 --> 00:08:58,199
stars they do have some a centricity and

237
00:09:00,260 --> 00:08:59,579
I'll talk about that in just a second

238
00:09:03,980 --> 00:09:00,270

that just means

239
00:09:05,480 --> 00:09:03,990
how how oval your orbit is if you're not

240
00:09:08,680 --> 00:09:05,490
traveling in a perfect circle around

241
00:09:11,240 --> 00:09:08,690
your star you're in an eccentric orbit

242
00:09:13,130 --> 00:09:11,250
super-earths are primarily terrestrial

243
00:09:14,540 --> 00:09:13,140
which is exciting when we come back to

244
00:09:18,410 --> 00:09:14,550
astrobiology because the assumption

245
00:09:20,750 --> 00:09:18,420
right now is that to find sorry to find

246
00:09:26,060 --> 00:09:20,760
a habitable planet it would have to be

247
00:09:29,360 --> 00:09:26,070
terrestrial like the earth all right

248
00:09:31,280 --> 00:09:29,370
it's too early to talk this much so

249
00:09:34,220 --> 00:09:31,290
primarily their terrestrial secondarily

250
00:09:35,600 --> 00:09:34,230
they are ocean worlds they have no solar

251
00:09:37,040 --> 00:09:35,610
system counterpart like I said you know

252
00:09:39,860 --> 00:09:37,050
they're up to ten times the size of the

253
00:09:41,870 --> 00:09:39,870
earth and they orbit even closer to our

254
00:09:44,300 --> 00:09:41,880
son then like we're mercury orbits

255
00:09:45,680 --> 00:09:44,310
roughly there's a variety of

256
00:09:46,820 --> 00:09:45,690
characteristics about these again I'm

257
00:09:47,990 --> 00:09:46,830
not going to have time to go into all of

258
00:09:49,820 --> 00:09:48,000
them but just so you know that they

259
00:09:52,070 --> 00:09:49,830
exist I'm going to talk briefly about

260
00:09:54,050 --> 00:09:52,080
the composition the interior of the

261
00:09:55,460 --> 00:09:54,060
super Earths any tectonic activity that

262
00:09:58,010 --> 00:09:55,470
goes on because that's a pretty key

263
00:10:00,290 --> 00:09:58,020

thing and also how atmosphere and how

264
00:10:04,070 --> 00:10:00,300
all those things affect out ability how

265
00:10:06,140 --> 00:10:04,080
are we on time okay we're okay so this

266
00:10:07,370 --> 00:10:06,150
just in case I lost anyone with a little

267
00:10:09,530 --> 00:10:07,380
bit more terminology for anyone who

268
00:10:11,150 --> 00:10:09,540
doesn't do planets in this case the

269
00:10:14,060 --> 00:10:11,160
yellow blob in the middle that's a son

270
00:10:16,370 --> 00:10:14,070
and the blue planet here is on a perfect

271
00:10:18,560 --> 00:10:16,380
circular orbit and in that case the

272
00:10:20,570 --> 00:10:18,570
eccentricity we say is zero it's just

273
00:10:22,160 --> 00:10:20,580
it's a perfect circle in the case with

274
00:10:24,230 --> 00:10:22,170
the red planet you kind of have this

275
00:10:26,570 --> 00:10:24,240
fried egg picture right here the fried

276
00:10:28,850 --> 00:10:26,580
egg image with with an oval orbit means

277
00:10:30,800 --> 00:10:28,860
that you have a centricity it the Easton

278
00:10:32,900 --> 00:10:30,810
tricity is not zero and again semi-major

279
00:10:37,090 --> 00:10:32,910
axis is just the orbital radius the

280
00:10:41,330 --> 00:10:40,370
so composition I'm trying to try it

281
00:10:43,760 --> 00:10:41,340
going to try to not make it too

282
00:10:45,710 --> 00:10:43,770
scientific when you model soup the

283
00:10:47,810 --> 00:10:45,720
interior of super Earths you have three

284
00:10:50,300 --> 00:10:47,820
different things you have an ice mass

285
00:10:53,180 --> 00:10:50,310
fraction a mantle mass fraction and

286
00:10:55,040 --> 00:10:53,190
decor mass fraction and you just model

287
00:10:58,580 --> 00:10:55,050
those three different homogeneous

288
00:11:00,350 --> 00:10:58,590

concentric shells the outer layer is all

289
00:11:02,720 --> 00:11:00,360
water it can be either liquid or frozen

290
00:11:04,910 --> 00:11:02,730
but it's a water outer shell you have a

291
00:11:06,770 --> 00:11:04,920
silikal in the middle and you have an

292
00:11:10,250 --> 00:11:06,780
inner core of either solid or liquid

293
00:11:12,470 --> 00:11:10,260
iron so these are these three basic

294
00:11:13,820 --> 00:11:12,480
assumptions about bulk composition for

295
00:11:14,150 --> 00:11:13,830
super Earths but given what i was

296
00:11:16,550 --> 00:11:14,160
talking

297
00:11:18,410 --> 00:11:16,560
with detection when you have radial

298
00:11:20,540 --> 00:11:18,420
velocity data when you can feel that

299
00:11:23,480 --> 00:11:20,550
Doppler wobble the Doppler wobble tells

300
00:11:25,519 --> 00:11:23,490
you the mass of an exoplanet and with

301
00:11:27,619 --> 00:11:25,529
the transit transit data that gives you

302
00:11:28,819 --> 00:11:27,629
the radius so if you have basic

303
00:11:30,619 --> 00:11:28,829
information about the mass and the

304
00:11:31,850 --> 00:11:30,629
radius of a planet you can infer

305
00:11:33,559 --> 00:11:31,860
something about its bulk composition

306
00:11:38,179 --> 00:11:33,569
which is what leads us to this theory

307
00:11:39,410 --> 00:11:38,189
for super earth interiors this is the

308
00:11:42,110 --> 00:11:39,420
most scientific slide I'm going to show

309
00:11:43,819 --> 00:11:42,120
but don't be too frightened again it's

310
00:11:45,710 --> 00:11:43,829
just those three mass fractions so we

311
00:11:47,470 --> 00:11:45,720
have ice mantle and core mass fractions

312
00:11:51,050 --> 00:11:47,480
eat this is called a ternary diagram

313
00:11:52,819 --> 00:11:51,060

each of these different sides is just

314
00:11:56,420 --> 00:11:52,829
measures a different fractional amount

315
00:11:57,980 --> 00:11:56,430
of the ice the mantle and the core so

316
00:12:00,439 --> 00:11:57,990
the best example because we were just

317
00:12:01,970 --> 00:12:00,449
saying you know to to be habitable we're

318
00:12:03,350 --> 00:12:01,980
assuming that an exoplanet is going to

319
00:12:05,300 --> 00:12:03,360
have to be terrestrial there has to be

320
00:12:06,710 --> 00:12:05,310
you know something to stand on like we

321
00:12:10,040 --> 00:12:06,720
can't stand on a Jupiter so that would

322
00:12:13,220 --> 00:12:10,050
be pointless so in this case water is

323
00:12:15,110 --> 00:12:13,230
measured here it's this anyway hold on

324
00:12:17,389 --> 00:12:15,120
so right here this is when water is 100

325
00:12:19,160 --> 00:12:17,399
and this side is when water is zero so

326
00:12:21,110 --> 00:12:19,170
we call this side the terrestrial side

327
00:12:24,319 --> 00:12:21,120
there's no significant water presence on

328
00:12:26,329 --> 00:12:24,329
a planet and the whole point of a

329
00:12:28,129 --> 00:12:26,339
ternary diagram is because it's a grid

330
00:12:30,530 --> 00:12:28,139
representation of the relationship

331
00:12:32,090 --> 00:12:30,540
between the water the mantle in the core

332
00:12:34,370 --> 00:12:32,100
mass fractions so we can actually throw

333
00:12:36,110 --> 00:12:34,380
some some science and some theory and

334
00:12:38,569 --> 00:12:36,120
some other stuff in here and get a

335
00:12:40,340 --> 00:12:38,579
working equation for the relationship

336
00:12:42,889 --> 00:12:40,350
between these three mass fractions when

337
00:12:45,079 --> 00:12:42,899
you model super Earths so to be

338
00:12:46,970 --> 00:12:45,089

habitable right now we're looking at

339
00:12:57,660 --> 00:12:46,980
anything that falls on the terrestrial

340
00:13:03,150 --> 00:13:01,230
um very briefly plate tectonics for

341
00:13:04,530 --> 00:13:03,160
anyone who is unfamiliar I know jess is

342
00:13:05,490 --> 00:13:04,540
doing the Geo talk tomorrow so I'm not

343
00:13:07,770 --> 00:13:05,500
going to spend a lot of time on this

344
00:13:09,180 --> 00:13:07,780
there are two main ways to transport

345
00:13:10,590 --> 00:13:09,190
heat and we have to transport heat in an

346
00:13:13,050 --> 00:13:10,600
exoplanet you have conduction and

347
00:13:14,580 --> 00:13:13,060
convection rock is a really sucky

348
00:13:16,530 --> 00:13:14,590
conductor so we're not going to work

349
00:13:19,170 --> 00:13:16,540
with conduction there are two main ways

350
00:13:22,710 --> 00:13:19,180
of having convective cycles in a planet

351
00:13:26,910 --> 00:13:22,720
we have either stagnant tectonics or I'm

352
00:13:29,130 --> 00:13:26,920
sorry stagnant lid stuff or actual plate

353
00:13:31,440 --> 00:13:29,140
tectonics like on earth so stagnant lid

354
00:13:33,720 --> 00:13:31,450
is when you have no plate tectonic

355
00:13:35,670 --> 00:13:33,730
activity it's just an outer crust of a

356
00:13:38,100 --> 00:13:35,680
planet that has cooled off more than the

357
00:13:40,140 --> 00:13:38,110
interior so the heat burst its way

358
00:13:41,640 --> 00:13:40,150
through the crust like these little like

359
00:13:44,640 --> 00:13:41,650
all the volcanoes that are on Io that's

360
00:13:46,380 --> 00:13:44,650
an example of stagnant lid as opposed to

361
00:13:48,960 --> 00:13:46,390
something like earth which does have

362
00:13:50,040 --> 00:13:48,970
plate tectonics and in that case this is

363
00:13:51,690 --> 00:13:50,050

this image here so you have these

364
00:13:53,700 --> 00:13:51,700
convection cells that are carrying the

365
00:13:55,350 --> 00:13:53,710
heat material is created if the

366
00:13:56,940 --> 00:13:55,360
mid-ocean ridges here and then the

367
00:13:59,940 --> 00:13:56,950
plates slide apart and then they're

368
00:14:02,280 --> 00:13:59,950
recycled down in subduction zones so

369
00:14:04,140 --> 00:14:02,290
there these are the two big arguments

370
00:14:06,890 --> 00:14:04,150
and theories for for which super-earth

371
00:14:10,400 --> 00:14:06,900
do the arguments being that super Earths

372
00:14:12,930 --> 00:14:10,410
because there's so much more massive

373
00:14:13,860 --> 00:14:12,940
their their gravity has increased which

374
00:14:16,140 --> 00:14:13,870
is going to cause an increase in

375
00:14:17,400 --> 00:14:16,150
pressure and this these people say that

376
00:14:19,170 --> 00:14:17,410
the pressure is going to be so great

377
00:14:21,030 --> 00:14:19,180
that it's going to actually cause fault

378
00:14:22,500 --> 00:14:21,040
blocking and the plates are not going to

379
00:14:24,750 --> 00:14:22,510
be able to deform at all so you're going

380
00:14:26,130 --> 00:14:24,760
to have a stagnant lid system the other

381
00:14:28,410 --> 00:14:26,140
side of the argument say that the

382
00:14:29,790 --> 00:14:28,420
greater the increased mass of the super

383
00:14:31,650 --> 00:14:29,800
Earths is going to cause an increase in

384
00:14:33,420 --> 00:14:31,660
stress and when you have an increase in

385
00:14:35,760 --> 00:14:33,430
stress the plates will be more easily

386
00:14:37,470 --> 00:14:35,770
deformed so we you know we haven't

387
00:14:38,400 --> 00:14:37,480
actually confirmed this one way or the

388
00:14:42,720 --> 00:14:38,410

other but just so you know there are

389
00:14:44,190 --> 00:14:42,730
arguments out there basic introduction

390
00:14:46,380 --> 00:14:44,200
to atmosphere I do not work in

391
00:14:47,550 --> 00:14:46,390
atmospheres so again under qualified to

392
00:14:52,080 --> 00:14:47,560
give this talk we have a couple people

393
00:14:53,430 --> 00:14:52,090
doing atmospheric things the point I

394
00:14:56,460 --> 00:14:53,440
want just wanted to make without being

395
00:14:59,220 --> 00:14:56,470
too scientific is that we can measure

396
00:15:01,890 --> 00:14:59,230
the we can detect the atmospheres of

397
00:15:03,690 --> 00:15:01,900
some of these exoplanets and if we find

398
00:15:05,910 --> 00:15:03,700
things in the atmosphere like carbon

399
00:15:07,320 --> 00:15:05,920
dioxide or water vapor you know some

400
00:15:08,760 --> 00:15:07,330
other things those are what we call bio

401
00:15:10,710 --> 00:15:08,770
signatures and they indicate the

402
00:15:11,519 --> 00:15:10,720
presence of life on a planet so for

403
00:15:14,610 --> 00:15:11,529
example something like

404
00:15:16,739 --> 00:15:14,620
oxygen oxygen is unstable on its own so

405
00:15:18,300 --> 00:15:16,749
when we have oxygen in the atmosphere on

406
00:15:20,300 --> 00:15:18,310
earth we know oxygen is only there

407
00:15:22,619 --> 00:15:20,310
because there's life on this planet so

408
00:15:24,869 --> 00:15:22,629
kind of a rough assumption but we'll go

409
00:15:27,540 --> 00:15:24,879
with it if we found something like that

410
00:15:29,460 --> 00:15:27,550
on a you know in an exoplanet atmosphere

411
00:15:30,780 --> 00:15:29,470
it would not necessarily guarantee the

412
00:15:32,910 --> 00:15:30,790
presence of life but it would be like

413
00:15:36,269 --> 00:15:32,920

hey that's something to look at because

414
00:15:38,249 --> 00:15:36,279
there's some bio signature there and how

415
00:15:40,160 --> 00:15:38,259
that happens is something like this so

416
00:15:43,139 --> 00:15:40,170
this is again so here you have oh god

417
00:15:45,119 --> 00:15:43,149
you have sorry here you have the transit

418
00:15:47,790 --> 00:15:45,129
in front in the occupation in back and

419
00:15:50,460 --> 00:15:47,800
when the planet passes in front you take

420
00:15:52,470 --> 00:15:50,470
an image of the star by itself and you

421
00:15:54,900 --> 00:15:52,480
take an image of the star with the

422
00:15:56,069 --> 00:15:54,910
planet in front and you do I don't know

423
00:15:57,420 --> 00:15:56,079
what's called it's like a negative you

424
00:15:59,489 --> 00:15:57,430
take the difference of the two images

425
00:16:01,679 --> 00:15:59,499
and what you're left with like if you

426
00:16:03,360 --> 00:16:01,689
you know if you subtract I don't know

427
00:16:04,949 --> 00:16:03,370
how to explain this cuz I don't do it if

428
00:16:06,329 --> 00:16:04,959
you take an image of just the star and

429
00:16:08,100 --> 00:16:06,339
then an image of the star and the planet

430
00:16:09,210 --> 00:16:08,110
if you subtract them you're left with

431
00:16:12,780 --> 00:16:09,220
the image of the planet or something

432
00:16:14,670 --> 00:16:12,790
like that and you can magically you know

433
00:16:16,079 --> 00:16:14,680
you can see this little blue shell you

434
00:16:17,699 --> 00:16:16,089
see the atmosphere and you can get a

435
00:16:20,069 --> 00:16:17,709
spectrum and when you have a spectrum

436
00:16:22,139 --> 00:16:20,079
you can infer based on where the peaks

437
00:16:24,150 --> 00:16:22,149
are what the the chemical makeup is of

438
00:16:30,689 --> 00:16:24,160

that atmosphere so it's possible was my

439
00:16:32,910 --> 00:16:30,699
point you can do that habitability short

440
00:16:35,579 --> 00:16:32,920
thing for habitability again earth is

441
00:16:37,889 --> 00:16:35,589
currently the only planet that we know

442
00:16:39,780 --> 00:16:37,899
to be inhabited and because of that fact

443
00:16:41,429 --> 00:16:39,790
it's kind of the only thing that we're

444
00:16:43,230 --> 00:16:41,439
left with when we talk about habitable

445
00:16:44,460 --> 00:16:43,240
zones and what it means to be a

446
00:16:46,590 --> 00:16:44,470
habitable planet just because it's the

447
00:16:49,189 --> 00:16:46,600
only thing we know so we define

448
00:16:51,420 --> 00:16:49,199
something called a habitable zone a

449
00:16:54,540 --> 00:16:51,430
habitable zone is the distance from a

450
00:16:57,389 --> 00:16:54,550
star for which a planet can support

451
00:16:58,499 --> 00:16:57,399
liquid water on its surface so you're

452
00:17:00,360 --> 00:16:58,509
going to have an inner edge in an outer

453
00:17:02,369 --> 00:17:00,370
edge of the habitable zone if you're in

454
00:17:04,380 --> 00:17:02,379
this nice band going around your star if

455
00:17:05,880 --> 00:17:04,390
you're on the inner edge of the

456
00:17:07,439 --> 00:17:05,890
habitable zone if you're too close to

457
00:17:08,730 --> 00:17:07,449
the star you're going to get a runaway

458
00:17:09,960 --> 00:17:08,740
greenhouse effect because everything's

459
00:17:11,789 --> 00:17:09,970
going to be evaporated which is kind of

460
00:17:13,439 --> 00:17:11,799
what we see on Venus if you're on the

461
00:17:15,090 --> 00:17:13,449
outer edge of the habitable zone you're

462
00:17:16,710 --> 00:17:15,100
too far away from the star and

463
00:17:17,429 --> 00:17:16,720

everything's going to get too cold and

464
00:17:19,260 --> 00:17:17,439
you're going to have a runaway

465
00:17:21,779 --> 00:17:19,270
glaciation effect everything's going to

466
00:17:24,569 --> 00:17:21,789
freeze which is not really what we see

467
00:17:27,189 --> 00:17:24,579
on Mars but work with me here

468
00:17:29,289 --> 00:17:27,199
call this the Goldilocks zone Goldilocks

469
00:17:32,799 --> 00:17:29,299
principle too hot too cold right in the

470
00:17:35,140 --> 00:17:32,809
middle I like this one just because it

471
00:17:36,669 --> 00:17:35,150
this image just because it kind of shows

472
00:17:39,549 --> 00:17:36,679
you what I mean with the whole habitable

473
00:17:41,289 --> 00:17:39,559
zone thing so here we have a our Sun on

474
00:17:43,510 --> 00:17:41,299
the top and these are our planets going

475
00:17:45,909 --> 00:17:43,520
across the top line here you see mercury

476
00:17:47,710 --> 00:17:45,919
mercury is very very far within the

477
00:17:49,240 --> 00:17:47,720
habitable zone sorry the blue band is

478
00:17:51,340 --> 00:17:49,250
our habitable zone Mercury's not

479
00:17:52,600 --> 00:17:51,350
habitable all here's Venus it's kind of

480
00:17:53,919 --> 00:17:52,610
on the inner edge of the habitable zone

481
00:17:56,140 --> 00:17:53,929
it has that runaway greenhouse effect

482
00:17:59,890 --> 00:17:56,150
here's the earth right in the middle of

483
00:18:02,590 --> 00:17:59,900
this blue habitable zone we exist happy

484
00:18:04,240 --> 00:18:02,600
us and here's Mars and again it's not an

485
00:18:07,270 --> 00:18:04,250
exact science this image it's just kind

486
00:18:08,529 --> 00:18:07,280
of illustrative so we have Mars that's

487
00:18:11,169 --> 00:18:08,539
close to the outer edge of the habitable

488
00:18:14,350 --> 00:18:11,179

zone and we do have someone talking

489
00:18:17,590 --> 00:18:14,360
about em Dorf today I believe Gliese 581

490
00:18:20,440 --> 00:18:17,600
is an m-dwarf yes good Gliese 581 is an

491
00:18:21,610 --> 00:18:20,450
m-dwarf excellent and Gliese 581 has a

492
00:18:25,899 --> 00:18:21,620
whole bunch of planets which is really

493
00:18:27,549 --> 00:18:25,909
exciting G the planet Gliese 581g is

494
00:18:29,380 --> 00:18:27,559
right in the middle of its habitable

495
00:18:32,010 --> 00:18:29,390
zone too sad part about Gliese 581g s

496
00:18:35,440 --> 00:18:32,020
that we think it doesn't actually exist

497
00:18:37,779 --> 00:18:35,450
but ignoring Gliese 581g let's look at

498
00:18:39,610 --> 00:18:37,789
Gliese 581d which is still at least kind

499
00:18:41,560 --> 00:18:39,620
of sort of borderline in the habitable

500
00:18:43,480 --> 00:18:41,570
zone so that just means that look we

501
00:18:45,190 --> 00:18:43,490
found an exoplanet and it's kind of sort

502
00:18:49,360 --> 00:18:45,200
of almost in the habitable zone so maybe

503
00:18:51,549 --> 00:18:49,370
there could be life there type stuff the

504
00:18:53,649 --> 00:18:51,559
other thing to note all of this talk

505
00:18:55,090 --> 00:18:53,659
about habitable zone is based solely on

506
00:18:56,230 --> 00:18:55,100
the assumption of having liquid water

507
00:18:58,330 --> 00:18:56,240
present on the surface of the planet

508
00:19:00,190 --> 00:18:58,340
there are lots of other characteristics

509
00:19:01,750 --> 00:19:00,200
that come into play when you really want

510
00:19:06,130 --> 00:19:01,760
to consider whether or not the planet is

511
00:19:07,750 --> 00:19:06,140
habitable for example tidal locking this

512
00:19:15,220 --> 00:19:07,760
in no way takes into account tidal

513
00:19:18,190 --> 00:19:15,230

locking so tidal locking is when two

514
00:19:20,770 --> 00:19:18,200
orbiting bodies show the same face to

515
00:19:21,850 --> 00:19:20,780
each other all the time so I'm easiest

516
00:19:26,560 --> 00:19:21,860
analog again would be like the

517
00:19:28,419 --> 00:19:26,570
earth-moon system ah sorry um the moon

518
00:19:30,460 --> 00:19:28,429
is tidally locked to the earth which is

519
00:19:31,510 --> 00:19:30,470
why we we always see the same face of

520
00:19:36,580 --> 00:19:31,520
the moon the moon does not seem to

521
00:19:43,090 --> 00:19:36,590
rotate but not explaining that very well

522
00:19:45,730 --> 00:19:43,100
if we had two things like this that

523
00:19:47,200 --> 00:19:45,740
orbit like this at each other they are

524
00:19:49,690 --> 00:19:47,210
tightly locked because you always see

525
00:19:54,190 --> 00:19:49,700
the same face that's my point those were

526
00:19:55,960 --> 00:19:54,200
moons um sorry so yes tightly locked

527
00:19:58,330 --> 00:19:55,970
moon is tidally locked to the earth

528
00:20:00,810 --> 00:19:58,340
which is just another another factor I

529
00:20:03,010 --> 00:20:00,820
don't have an image of that sorry

530
00:20:04,120 --> 00:20:03,020
exomoons I just wanted to touch on

531
00:20:06,010 --> 00:20:04,130
briefly I think we have a couple talks

532
00:20:07,570 --> 00:20:06,020
about excellence as well oh and a note

533
00:20:09,430 --> 00:20:07,580
that i forgot to put a layer the

534
00:20:11,710 --> 00:20:09,440
habitable zone does shrink when you

535
00:20:15,760 --> 00:20:11,720
consider smaller stars this is on a log

536
00:20:17,320 --> 00:20:15,770
scale so back back here the habitable

537
00:20:20,260 --> 00:20:17,330
zone is actually wider than it is up

538
00:20:22,810 --> 00:20:20,270

here when you have a smaller star that

539
00:20:23,980 --> 00:20:22,820
is you know less there's less heat and

540
00:20:25,720 --> 00:20:23,990
less energy and stuff coming off of

541
00:20:28,299 --> 00:20:25,730
something like an M Dorf so the

542
00:20:30,700 --> 00:20:28,309
habitable zone both moves inward closer

543
00:20:32,529 --> 00:20:30,710
to the star and also becomes narrower so

544
00:20:36,039 --> 00:20:32,539
it's a narrower band of habitable zone

545
00:20:38,710 --> 00:20:36,049
pneus moons I just wanted to mention

546
00:20:40,480 --> 00:20:38,720
real quick like an exoplanet so an

547
00:20:42,519 --> 00:20:40,490
exoplanet is an extrasolar planet and

548
00:20:44,580 --> 00:20:42,529
EXO moon is an extrasolar moon it's just

549
00:20:46,840 --> 00:20:44,590
a moon that orbits an extrasolar planet

550
00:20:48,340 --> 00:20:46,850
if they exist it would be really really

551
00:20:50,409 --> 00:20:48,350
nice if we could find them to be roughly

552
00:20:52,060 --> 00:20:50,419
earth-sized because there is you know

553
00:20:55,330 --> 00:20:52,070
possibility to have a habitable exomoons

554
00:20:57,549 --> 00:20:55,340
besides just a habitable exoplanet and

555
00:20:59,590 --> 00:20:57,559
the the upside of looking at exomoons

556
00:21:03,070 --> 00:20:59,600
this time is is this thing's too long

557
00:21:04,450 --> 00:21:03,080
good side of looking at exomoons this

558
00:21:06,370 --> 00:21:04,460
time is because they're gonna be

559
00:21:08,980 --> 00:21:06,380
hopefully a lot more numerous than the

560
00:21:10,510 --> 00:21:08,990
exoplanets if you consider planets that

561
00:21:14,139 --> 00:21:10,520
are the size of Jupiter and Saturn right

562
00:21:15,279 --> 00:21:14,149
now they have a whole lot of moons so

563
00:21:16,750 --> 00:21:15,289

we're hoping that if we can find these

564
00:21:18,090 --> 00:21:16,760
huge super Earths that are really really

565
00:21:21,639 --> 00:21:18,100
large maybe they would have a similar

566
00:21:24,430 --> 00:21:21,649
increase and you know what am I think if

567
00:21:27,700 --> 00:21:24,440
you have 100 exoplanets and each one has

568
00:21:29,680 --> 00:21:27,710
ten moons even you've already increased

569
00:21:31,299 --> 00:21:29,690
the number of potentially habitable

570
00:21:34,750 --> 00:21:31,309
bodies so we're looking at exomoons as

571
00:21:38,320 --> 00:21:34,760
well this is just an image from Renee

572
00:21:40,899 --> 00:21:38,330
Heller as an example XO moon system so

573
00:21:43,840 --> 00:21:40,909
here we have a hypothetical earth-sized

574
00:21:45,399 --> 00:21:43,850
moon that is orbiting this orange

575
00:21:47,980 --> 00:21:45,409
exoplanet in the background and there

576
00:21:49,920 --> 00:21:47,990
its star is it star in the background so

577
00:21:54,010 --> 00:21:49,930
just an example system

578
00:21:56,410 --> 00:21:54,020
um I also wanted to mention Triton this

579
00:21:57,940 --> 00:21:56,420
x11 stuff I'm not going to do a lot

580
00:21:59,920 --> 00:21:57,950
about the capturing but just so you know

581
00:22:02,020 --> 00:21:59,930
Triton is one of the coolest moons is

582
00:22:04,000 --> 00:22:02,030
our system it is a moon of Neptune and

583
00:22:06,190 --> 00:22:04,010
we think it might be captured because it

584
00:22:08,680 --> 00:22:06,200
actually travels I don't know what the

585
00:22:10,270 --> 00:22:08,690
word is it Rhett visit retrograde thank

586
00:22:11,800 --> 00:22:10,280
you it travels backwards like all the

587
00:22:15,070 --> 00:22:11,810
other moons are going this way Triton

588
00:22:17,230 --> 00:22:15,080

swimming upstream so trite in school and

589
00:22:19,360 --> 00:22:17,240
it has it has an atmosphere and it has

590
00:22:21,130 --> 00:22:19,370
some nitrogen sublimation stuff going on

591
00:22:25,270 --> 00:22:21,140
so it's cool someone's talking about

592
00:22:27,490 --> 00:22:25,280
Triton there it is good so that's mostly

593
00:22:29,170 --> 00:22:27,500
the end for me what was the point the

594
00:22:32,050 --> 00:22:29,180
point was that there are a lot of

595
00:22:33,280 --> 00:22:32,060
factors that that you have to consider

596
00:22:35,320 --> 00:22:33,290
when you're talking about planetary

597
00:22:38,230 --> 00:22:35,330
habitability especially with this new

598
00:22:39,250 --> 00:22:38,240
science of exoplanets super Earths are

599
00:22:41,980 --> 00:22:39,260
going to be the big thing in XO

600
00:22:45,150 --> 00:22:41,990
planetary science went with related with

601
00:22:47,710 --> 00:22:45,160
relation to habitability in astrobiology

602
00:22:49,990 --> 00:22:47,720
exomoons are really a new thing so

603
00:22:52,450 --> 00:22:50,000
exoplanets started relatively recently

604
00:22:55,360 --> 00:22:52,460
moons or even really really more

605
00:22:56,740 --> 00:22:55,370
recently good job the largest moon in

606
00:22:58,900 --> 00:22:56,750
our system is Ganymede which is still

607
00:23:01,270 --> 00:22:58,910
only a quarter of a percent Earth's size

608
00:23:02,740 --> 00:23:01,280
thanks to Kepler we have a whole lot of

609
00:23:04,780 --> 00:23:02,750
planets that we're discovering and we

610
00:23:06,400 --> 00:23:04,790
have all these great ways to detect

611
00:23:08,860 --> 00:23:06,410
exoplanets right now so we have dr.

612
00:23:11,770 --> 00:23:08,870
wobble we have transit data all this

613
00:23:13,630 --> 00:23:11,780

sort of stuff and hopefully science will

614
00:23:17,410 --> 00:23:13,640
keep going and we will eventually find a

615
00:23:18,940 --> 00:23:17,420
habitable exoplanet or eczema um and if

616
00:23:21,190 --> 00:23:18,950
we have just a couple minutes I can do

617
00:23:22,620 --> 00:23:21,200
questions otherwise we will carry on to

618
00:23:25,810 --> 00:23:22,630
Mike who is going to introduce the

619
00:23:27,490 --> 00:23:25,820
second half of today's talks but I think

620
00:23:28,990 --> 00:23:27,500
we have I have like three minutes if

621
00:23:30,400 --> 00:23:29,000
anyone has a quick question before Mike