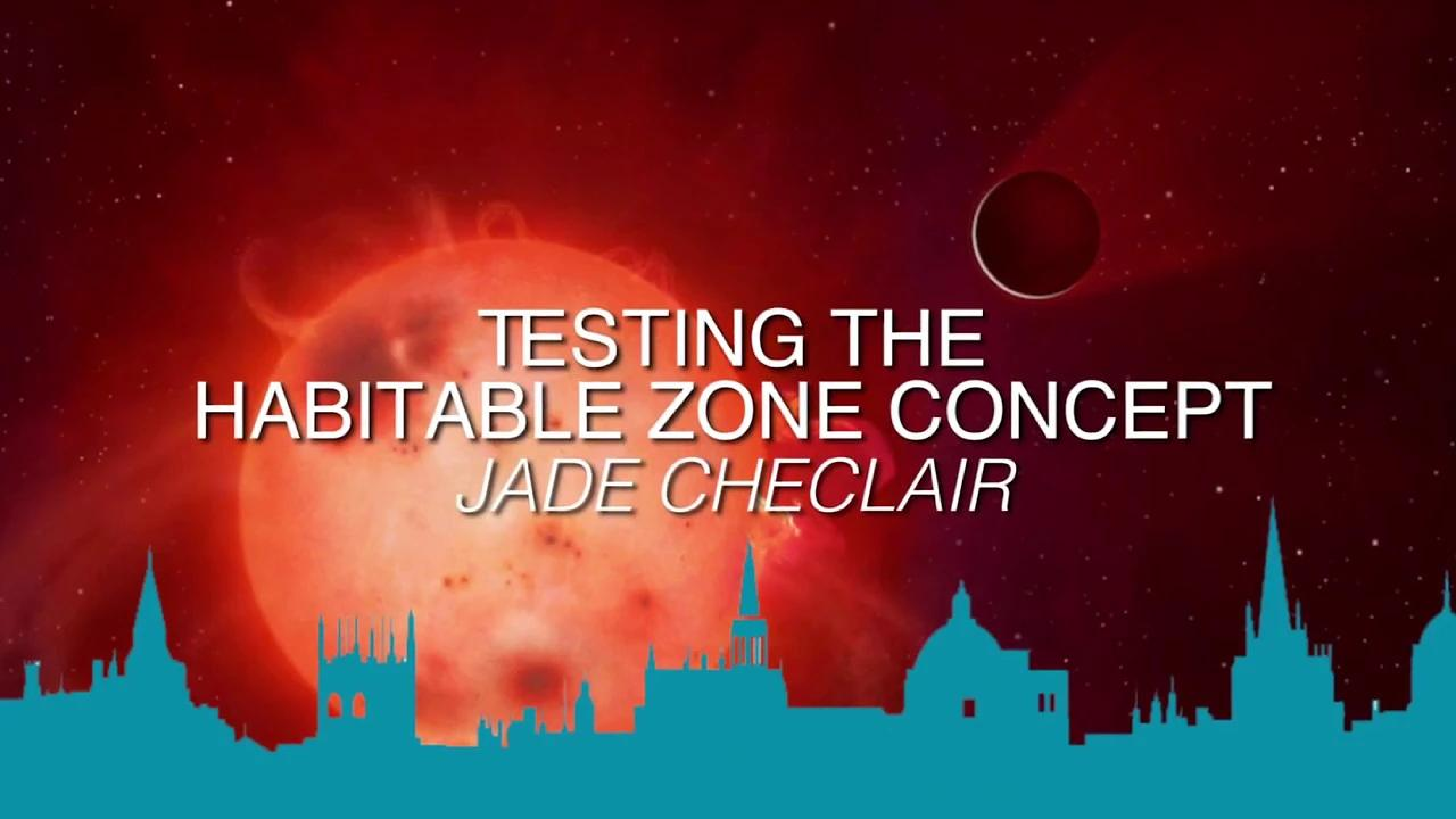

TESTING THE HABITABLE ZONE CONCEPT

JADE CHECLAIR

1
00:00:10,510 --> 00:00:04,180
[Music]

2
00:00:13,120 --> 00:00:10,520
I am Jade really happy to be closing

3
00:00:16,000 --> 00:00:13,130
this awesome meeting I'm seeing a lot of

4
00:00:17,679 --> 00:00:16,010
faces down which must means the co2 in

5
00:00:20,140 --> 00:00:17,689
this room is getting pretty high but

6
00:00:23,440 --> 00:00:20,150
let's just try to get through 15 more

7
00:00:24,999 --> 00:00:23,450
minutes and we can all go eat but today

8
00:00:27,999 --> 00:00:25,009
I'd like to discuss how we could

9
00:00:32,950 --> 00:00:28,009
potentially test the concept of the

10
00:00:34,870 --> 00:00:32,960
habitable zone so in the near future new

11
00:00:36,880 --> 00:00:34,880
and powerful instruments will allow us

12
00:00:39,220 --> 00:00:36,890
to characterize exoplanets like never

13
00:00:41,950 --> 00:00:39,230

before so what you're looking at here

14
00:00:43,900 --> 00:00:41,960
are a few instruments that are or have

15
00:00:46,150 --> 00:00:43,910
been at least partially involved in

16
00:00:49,150 --> 00:00:46,160
detecting and characterizing exoplanets

17
00:00:51,700 --> 00:00:49,160
now so far we have not yet been able to

18
00:00:54,070 --> 00:00:51,710
directly observe earth-sized habitable

19
00:00:55,840 --> 00:00:54,080
terrestrial planets however as we look

20
00:00:58,870 --> 00:00:55,850
to the future we can look forward to

21
00:01:00,730 --> 00:00:58,880
instruments dedicated to observing these

22
00:01:03,430 --> 00:01:00,740
kinds of exoplanets which we think may

23
00:01:05,170 --> 00:01:03,440
host life so in particular I'll be

24
00:01:07,450 --> 00:01:05,180
focusing on highbacks in the war right

25
00:01:10,029 --> 00:01:07,460
here which are both direct imaging

26
00:01:11,980 --> 00:01:10,039
instruments that are in the running to

27
00:01:14,709 --> 00:01:11,990
become NASA's next flagship mission and

28
00:01:16,630 --> 00:01:14,719
so they would directly image earth sized

29
00:01:18,849 --> 00:01:16,640
terrestrial exoplanets in the habitable

30
00:01:22,719 --> 00:01:18,859
zones of stars like the Sun Fuji stars

31
00:01:24,819 --> 00:01:22,729
and because for the first time in

32
00:01:27,370 --> 00:01:24,829
history we'll actually finally be able

33
00:01:30,309 --> 00:01:27,380
to observe these earth sized habitable

34
00:01:33,879 --> 00:01:30,319
exoplanets we may also be able to test

35
00:01:35,639 --> 00:01:33,889
some habitability hypothesis so to do

36
00:01:38,319 --> 00:01:35,649
that we could use a statistical

37
00:01:40,029 --> 00:01:38,329
comparative planetology approach which

38
00:01:41,919 --> 00:01:40,039

essentially just means that we'd be

39
00:01:44,559 --> 00:01:41,929
taking quick and cheap measurements on a

40
00:01:47,949 --> 00:01:44,569
large sample of exoplanets to test a

41
00:01:49,749 --> 00:01:47,959
particular hypothesis so in doing that

42
00:01:51,849 --> 00:01:49,759
we really want to take the number and

43
00:01:54,309 --> 00:01:51,859
the diversity of exoplanets as an

44
00:01:56,830 --> 00:01:54,319
advantage and a kind of real-life

45
00:01:59,349 --> 00:01:56,840
example of this is as on this cartoon

46
00:02:01,749 --> 00:01:59,359
here where we essentially just be taking

47
00:02:04,839 --> 00:02:01,759
quick and somewhat imprecise u2

48
00:02:09,820 --> 00:02:04,849
measurements on say 50 exoplanets in the

49
00:02:12,850 --> 00:02:09,830
habitable zones of their stars now a

50
00:02:17,020 --> 00:02:12,860
somewhat recent example of this approach

51
00:02:17,990 --> 00:02:17,030
is by Leslie Rogers IU Chicago and so

52
00:02:20,960 --> 00:02:18,000
this is for eggs

53
00:02:22,430 --> 00:02:20,970
and Leslie took very low precision

54
00:02:24,050 --> 00:02:22,440
measurements of match radius

55
00:02:26,570 --> 00:02:24,060
measurements for a large sample of

56
00:02:29,360 --> 00:02:26,580
planets to infer the radius at which

57
00:02:31,190 --> 00:02:29,370
planets are likely to become rocky so

58
00:02:33,230 --> 00:02:31,200
this is a really great example of this

59
00:02:35,750 --> 00:02:33,240
kind of approach because if we look at

60
00:02:38,300 --> 00:02:35,760
any individual point here the error bars

61
00:02:40,160 --> 00:02:38,310
are huge they're almost the entire size

62
00:02:43,130 --> 00:02:40,170
of the flat so it'd be really difficult

63
00:02:46,040 --> 00:02:43,140

to infer anything significant from any

64
00:02:48,350 --> 00:02:46,050
one or two of these points but by

65
00:02:49,070 --> 00:02:48,360
putting all of this low precision data

66
00:02:51,500 --> 00:02:49,080
together

67
00:02:53,449 --> 00:02:51,510
Leslie was actually able to get a

68
00:02:55,520 --> 00:02:53,459
procedure probability distribution on

69
00:02:57,320 --> 00:02:55,530
the thresholds at which planets are

70
00:03:01,540 --> 00:02:57,330
likely to become rocky so she found here

71
00:03:04,130 --> 00:03:01,550
that occurs at about 1.5 Earth radius

72
00:03:06,110 --> 00:03:04,140
now what I'd like to do with this kind

73
00:03:08,570 --> 00:03:06,120
of statistical approach is to test that

74
00:03:10,670 --> 00:03:08,580
concept of the habitable zone we've

75
00:03:12,350 --> 00:03:10,680
heard it quite a lot this week the

76
00:03:14,870 --> 00:03:12,360
habitable zone of course is defined as

77
00:03:16,850 --> 00:03:14,880
the possibility of surface we could

78
00:03:19,070 --> 00:03:16,860
water between two orbital separations

79
00:03:21,500 --> 00:03:19,080
and whenever a new planet or a new

80
00:03:23,210 --> 00:03:21,510
system of exoplanets is discovered the

81
00:03:25,490 --> 00:03:23,220
discovery usually comes with whether or

82
00:03:28,340 --> 00:03:25,500
not the orbit within the habitable zone

83
00:03:30,259 --> 00:03:28,350
however in habitable zone theory there's

84
00:03:31,729 --> 00:03:30,269
a lot of predictions and assumptions

85
00:03:37,580 --> 00:03:31,739
that we just have not yet tested

86
00:03:40,070 --> 00:03:37,590
observational now here's a slightly more

87
00:03:43,280 --> 00:03:40,080
scientific illustration of the habitable

88
00:03:45,920 --> 00:03:43,290

zone so it's distance and width varies

89
00:03:47,570 --> 00:03:45,930
as a function of cellar type and usually

90
00:03:50,000 --> 00:03:47,580
the inner edge is taken to be this

91
00:03:51,560 --> 00:03:50,010
yellow curve here which is the limits at

92
00:03:53,720 --> 00:03:51,570
which planets are likely to go into a

93
00:03:57,520 --> 00:03:53,730
moist greenhouse state so they're going

94
00:04:00,620 --> 00:03:57,530
to start using their water to space now

95
00:04:02,990 --> 00:04:00,630
within this bluish region right here we

96
00:04:04,940 --> 00:04:03,000
make an important assumption so this is

97
00:04:06,979 --> 00:04:04,950
the habitable zone we assume that the

98
00:04:09,289 --> 00:04:06,989
silicate weathering feedback functions

99
00:04:11,810 --> 00:04:09,299
to regulate the climate of this planet

100
00:04:15,080 --> 00:04:11,820
so the entire concept of the habitable

101
00:04:17,180 --> 00:04:15,090
zone relies on this climate feedback so

102
00:04:19,699 --> 00:04:17,190
what what is the silicate weathering

103
00:04:21,860 --> 00:04:19,709
feedback well it's a um negative climate

104
00:04:24,500 --> 00:04:21,870
feedback that relies on the cycling of

105
00:04:27,260 --> 00:04:24,510
co2 in and out of a planet to regulate

106
00:04:28,909 --> 00:04:27,270
its surface temperature so an easy way

107
00:04:31,180 --> 00:04:28,919
to think of it is that if we have a

108
00:04:33,190 --> 00:04:31,190
terrestrial exoplanet orbiting in the

109
00:04:35,020 --> 00:04:33,200
habitable zone but slightly further away

110
00:04:37,270 --> 00:04:35,030
from its star so closer to the outer

111
00:04:40,150 --> 00:04:37,280
edge technically its surface temperature

112
00:04:42,670 --> 00:04:40,160
could drop to below freezing now luckily

113
00:04:45,130 --> 00:04:42,680

when surface temperature decreases the

114
00:04:47,740 --> 00:04:45,140
weathering rate so the intake of co2 by

115
00:04:49,780 --> 00:04:47,750
the planets right here also starts to

116
00:04:52,450 --> 00:04:49,790
slow down and because the outgassing

117
00:04:54,370 --> 00:04:52,460
rate is usually constant co2 is going to

118
00:04:55,990 --> 00:04:54,380
be able to build it the atmosphere of

119
00:04:58,180 --> 00:04:56,000
the planet and bring the surface

120
00:05:00,670 --> 00:04:58,190
temperature back to habitable condition

121
00:05:02,410 --> 00:05:00,680
so we have pretty good geological

122
00:05:05,440 --> 00:05:02,420
evidence that this feedback has been

123
00:05:07,950 --> 00:05:05,450
functioning Earth rotates history but we

124
00:05:10,360 --> 00:05:07,960
have no idea whether or not it works on

125
00:05:14,890 --> 00:05:10,370
exoplanets we just assume it does

126
00:05:16,570 --> 00:05:14,900
because it does on earth okay so let's

127
00:05:18,550 --> 00:05:16,580
just come back to this plot right here

128
00:05:20,290 --> 00:05:18,560
what would happen if the silicate

129
00:05:22,960 --> 00:05:20,300
weathering feedback did not in fact

130
00:05:25,150 --> 00:05:22,970
function well the outer edge would be

131
00:05:28,360 --> 00:05:25,160
found much more close in so the

132
00:05:30,850 --> 00:05:28,370
habitable zone would be super tiny so

133
00:05:33,100 --> 00:05:30,860
it's clearly super important when we

134
00:05:34,960 --> 00:05:33,110
talk about the habitability of any given

135
00:05:37,690 --> 00:05:34,970
planet and whether or not it's actually

136
00:05:39,460 --> 00:05:37,700
in the habitable zone but in addition to

137
00:05:41,830 --> 00:05:39,470
bring the outer edge much more further

138
00:05:44,050 --> 00:05:41,840

out it also regulates the surface

139
00:05:45,880 --> 00:05:44,060
temperature of of planets within the

140
00:05:48,670 --> 00:05:45,890
habitable zone so instead of having

141
00:05:52,360 --> 00:05:48,680
their surface temperature go from 270

142
00:05:54,250 --> 00:05:52,370
here to 373 Kelvin here it's going to

143
00:05:56,860 --> 00:05:54,260
regulate the surface temperature to be

144
00:06:00,250 --> 00:05:56,870
more closely to that of the earth around

145
00:06:03,220 --> 00:06:00,260
290 Kelvin faster - a pretty narrow

146
00:06:05,470 --> 00:06:03,230
uncertainty range now the outer edge

147
00:06:07,000 --> 00:06:05,480
right here is usually defined by the

148
00:06:09,340 --> 00:06:07,010
point at which tier 2 is going to

149
00:06:09,880 --> 00:06:09,350
condense out of the atmosphere of the

150
00:06:11,230 --> 00:06:09,890
planet

151
00:06:13,630 --> 00:06:11,240
so therefore the silicate weathering

152
00:06:15,909 --> 00:06:13,640
feedback can no longer function and the

153
00:06:17,770 --> 00:06:15,919
planets found here are likely to be in a

154
00:06:23,110 --> 00:06:17,780
globally glaciated state so in a

155
00:06:24,700 --> 00:06:23,120
snowball state ok so we want to test

156
00:06:26,650 --> 00:06:24,710
whether or not the silicate weathering

157
00:06:30,100 --> 00:06:26,660
feedback actually functions on

158
00:06:31,780 --> 00:06:30,110
terrestrial planets and if it does and

159
00:06:33,580 --> 00:06:31,790
we observe a number of them and takes

160
00:06:35,770 --> 00:06:33,590
you to measurements on each of them at

161
00:06:38,170 --> 00:06:35,780
different orbital separation from their

162
00:06:40,659 --> 00:06:38,180
stars what we should see that there

163
00:06:43,420 --> 00:06:40,669

should be a drop of co2 with increasing

164
00:06:44,679 --> 00:06:43,430
irradiation so to illustrate why that is

165
00:06:46,959 --> 00:06:44,689
let's take this point right

166
00:06:49,209 --> 00:06:46,969
here it's a planet orbiting further away

167
00:06:51,279 --> 00:06:49,219
from its stars where they nor value of

168
00:06:53,319 --> 00:06:51,289
your radiation and because of that if

169
00:06:55,749 --> 00:06:53,329
the feedback function it should have a

170
00:06:58,149 --> 00:06:55,759
higher amount of co2 to maintain

171
00:07:00,339 --> 00:06:58,159
habitability in comparation this point

172
00:07:02,289 --> 00:07:00,349
right here is much closer to its star

173
00:07:04,719 --> 00:07:02,299
and because of that it should require

174
00:07:08,109 --> 00:07:04,729
less u2 to maintain similar surface

175
00:07:09,699 --> 00:07:08,119
conditions so if the feedback functions

176
00:07:11,469 --> 00:07:09,709
we're going to get a downward slope

177
00:07:13,899 --> 00:07:11,479
right here now of course there is going

178
00:07:16,659 --> 00:07:13,909
to be a lot of uncertainties with this

179
00:07:18,459 --> 00:07:16,669
with what exact amount of co2 we can

180
00:07:20,319 --> 00:07:18,469
expect as a function of your radiation

181
00:07:22,389 --> 00:07:20,329
so for example the exact surface

182
00:07:24,850 --> 00:07:22,399
temperature the surface pressure other

183
00:07:27,219 --> 00:07:24,860
greenhouse gases clouds and a first

184
00:07:29,979 --> 00:07:27,229
instrumental uncertainties all of these

185
00:07:33,489 --> 00:07:29,989
are going to make it more difficult for

186
00:07:35,919 --> 00:07:33,499
us to see this downward slope but the

187
00:07:37,779 --> 00:07:35,929
idea here is that the more planets we

188
00:07:40,479 --> 00:07:37,789

observe the easier it will be to

189
00:07:43,209 --> 00:07:40,489
marginalize over these uncertainties and

190
00:07:46,059 --> 00:07:43,219
so to be able to detect the downward

191
00:07:48,819 --> 00:07:46,069
slope despite our big error bars now of

192
00:07:51,249 --> 00:07:48,829
course well probably if we observe

193
00:07:52,929 --> 00:07:51,259
thousands of thousands of exoplanets we

194
00:07:55,389 --> 00:07:52,939
may detect a downward slope if the

195
00:07:57,459 --> 00:07:55,399
feedback functions but even a crazy

196
00:07:59,739 --> 00:07:57,469
expensive futuristic instruments such as

197
00:08:01,659 --> 00:07:59,749
the war won't be able to see that many

198
00:08:04,959 --> 00:08:01,669
planets so we want to know whether or

199
00:08:06,699 --> 00:08:04,969
not this test is at all feasible so the

200
00:08:08,889 --> 00:08:06,709
big question I'm asking in my work right

201
00:08:11,379 --> 00:08:08,899
now is how many planets would we have to

202
00:08:17,709 --> 00:08:11,389
observe to detect a downward slope if

203
00:08:19,989 --> 00:08:17,719
the feedback functions so to answer that

204
00:08:22,329 --> 00:08:19,999
question first at to understand how

205
00:08:25,239 --> 00:08:22,339
these downward slope changes as we vary

206
00:08:26,889 --> 00:08:25,249
our parameters so here I'm just going to

207
00:08:29,379 --> 00:08:26,899
show you some examples of the kind of

208
00:08:31,869 --> 00:08:29,389
data I get so this is using Klima

209
00:08:34,480 --> 00:08:31,879
a radiative convective model and smart a

210
00:08:37,059 --> 00:08:34,490
radiative transfer model and this is the

211
00:08:39,129 --> 00:08:37,069
same axis as you just saw YouTube versus

212
00:08:42,129 --> 00:08:39,139
irradiation and everything else is held

213
00:08:43,839 --> 00:08:42,139

fixed except surface temperature so if

214
00:08:46,269 --> 00:08:43,849
we pick a value of your radiation say

215
00:08:47,470 --> 00:08:46,279
here and we go from green to black so

216
00:08:49,720 --> 00:08:47,480
from lower to higher surface

217
00:08:52,660 --> 00:08:49,730
temperatures we see that we gradually

218
00:08:54,759 --> 00:08:52,670
need more and more co2 to maintain these

219
00:08:57,250 --> 00:08:54,769
higher surface temperatures which makes

220
00:08:59,200 --> 00:08:57,260
sense if the feedback function

221
00:09:01,120 --> 00:08:59,210
I wanted you to realize from this flood

222
00:09:02,740 --> 00:09:01,130
right here if that surface temperature

223
00:09:05,110 --> 00:09:02,750
is going to be a pretty important

224
00:09:07,210 --> 00:09:05,120
uncertainty parameter that when we vary

225
00:09:09,090 --> 00:09:07,220
it always within habitable bounds here

226
00:09:11,440 --> 00:09:09,100
we see that the shape of the curves

227
00:09:13,240 --> 00:09:11,450
changes quite a bit so this will make it

228
00:09:15,340 --> 00:09:13,250
more difficult for us to resolve over

229
00:09:18,550 --> 00:09:15,350
these error bars it adds a lot of

230
00:09:20,650 --> 00:09:18,560
uncertainty now in comparation here's

231
00:09:22,930 --> 00:09:20,660
the similar example this time for

232
00:09:25,000 --> 00:09:22,940
different amounts of methane and we see

233
00:09:27,460 --> 00:09:25,010
that this time when we go from green to

234
00:09:29,440 --> 00:09:27,470
no methane to blue so current Earth

235
00:09:31,960 --> 00:09:29,450
levels of methane and then to red torque

236
00:09:33,700 --> 00:09:31,970
in Earth levels of methane we see that

237
00:09:35,380 --> 00:09:33,710
the shape of the curve this time doesn't

238
00:09:37,630 --> 00:09:35,390

change quite that much so this is just

239
00:09:39,010 --> 00:09:37,640
to illustrate that some parameters even

240
00:09:41,470 --> 00:09:39,020
though there are certain keys they may

241
00:09:43,180 --> 00:09:41,480
not matter why that much and other thing

242
00:09:46,840 --> 00:09:43,190
such as surface pressure and temperature

243
00:09:48,820 --> 00:09:46,850
are going to really matter in this okay

244
00:09:51,220 --> 00:09:48,830
so these were just some examples of the

245
00:09:52,690 --> 00:09:51,230
kind of data we're going to be using now

246
00:09:54,670 --> 00:09:52,700
I'd like to lead you through a

247
00:09:56,920 --> 00:09:54,680
simplified explanation of the

248
00:09:58,690 --> 00:09:56,930
statistical method I used to enter the

249
00:10:00,850 --> 00:09:58,700
question of how many planets we need to

250
00:10:02,290 --> 00:10:00,860
observe to detect the downward slope and

251
00:10:04,510 --> 00:10:02,300
so prove whether or not the feedback

252
00:10:06,820 --> 00:10:04,520
function but first we had to make some

253
00:10:09,520 --> 00:10:06,830
kind of assumptions under uncertainty

254
00:10:11,650 --> 00:10:09,530
parameters we don't yet know that much

255
00:10:14,050 --> 00:10:11,660
about terrestrial exoplanets but we had

256
00:10:15,880 --> 00:10:14,060
to decide on how much we're going to for

257
00:10:18,610 --> 00:10:15,890
example at surface pressure surface

258
00:10:21,250 --> 00:10:18,620
temperature cloud opacities and so forth

259
00:10:23,140 --> 00:10:21,260
vary so here is an example for surface

260
00:10:24,970 --> 00:10:23,150
temperature here so it's a normal

261
00:10:26,770 --> 00:10:24,980
distribution centered around the value

262
00:10:29,170 --> 00:10:26,780
of the earth plus or minus is pretty

263
00:10:31,600 --> 00:10:29,180

limited range the reason we're using

264
00:10:33,970 --> 00:10:31,610
this in a bit of an optimal optimistic

265
00:10:36,340 --> 00:10:33,980
manner here is because previous work has

266
00:10:38,770 --> 00:10:36,350
shown that if a planet has a functioning

267
00:10:41,440 --> 00:10:38,780
liquid weathering feedback and it's in

268
00:10:43,360 --> 00:10:41,450
the habitable zone it should really

269
00:10:44,980 --> 00:10:43,370
maintain its surface temperature around

270
00:10:48,160 --> 00:10:44,990
that of the earth that's 4 minus about

271
00:10:50,170 --> 00:10:48,170
20 Kelvin now if you're worried if this

272
00:10:52,240 --> 00:10:50,180
is raising a red flag in your head

273
00:10:54,490 --> 00:10:52,250
already it's okay this is all really

274
00:10:56,320 --> 00:10:54,500
optimistic case for each parameter we've

275
00:10:58,720 --> 00:10:56,330
also considered a much more pessimistic

276
00:11:00,880 --> 00:10:58,730
case where for example for surface

277
00:11:04,870 --> 00:11:00,890
temperature we considered a uniform

278
00:11:06,820 --> 00:11:04,880
distribution from 270 to 373 Kelvin but

279
00:11:07,670 --> 00:11:06,830
anyway for now let's take it as it is

280
00:11:10,460 --> 00:11:07,680
and

281
00:11:13,010 --> 00:11:10,470
go through the statistical method so

282
00:11:14,930 --> 00:11:13,020
first we choose a number of model planet

283
00:11:16,880 --> 00:11:14,940
say three so were inventing we're

284
00:11:19,519 --> 00:11:16,890
creating planets that may or may not

285
00:11:21,260 --> 00:11:19,529
exist then for each of them we're going

286
00:11:23,510 --> 00:11:21,270
to draw a surface temperature values

287
00:11:25,820 --> 00:11:23,520
here from the distribution I just showed

288
00:11:28,310 --> 00:11:25,830

you so this is where these distributions

289
00:11:30,560 --> 00:11:28,320
are going to come into play they help us

290
00:11:31,970 --> 00:11:30,570
create our imaginary planet so if we

291
00:11:34,639 --> 00:11:31,980
were considering all of the parameters

292
00:11:36,860 --> 00:11:34,649
that in real life we are we'd be drawing

293
00:11:38,510 --> 00:11:36,870
values for them right here so we draw a

294
00:11:40,970 --> 00:11:38,520
surface pressure value from its

295
00:11:42,620 --> 00:11:40,980
distribution and so forth then for each

296
00:11:45,769 --> 00:11:42,630
of them we of course also draw a

297
00:11:47,510 --> 00:11:45,779
radiation values from a uniform

298
00:11:51,550 --> 00:11:47,520
distribution because the planet can be

299
00:11:54,380 --> 00:11:51,560
anywhere in the habitable zone and then

300
00:11:56,210 --> 00:11:54,390
based on these values that we've drawn

301
00:11:59,540 --> 00:11:56,220
we're going to compute the corresponding

302
00:12:01,550 --> 00:11:59,550
amount of co2 so this is where our data

303
00:12:03,820 --> 00:12:01,560
that I showed you earlier comes into

304
00:12:06,650 --> 00:12:03,830
play it's essentially a big

305
00:12:09,170 --> 00:12:06,660
multi-dimensional matrix of co2 as a

306
00:12:11,240 --> 00:12:09,180
function of a bunch of other uncertainty

307
00:12:12,949 --> 00:12:11,250
parameters okay

308
00:12:14,780 --> 00:12:12,959
so now we have co2 for all of our

309
00:12:16,370 --> 00:12:14,790
planets then we're going to add some

310
00:12:18,350 --> 00:12:16,380
instrumental noise to these values

311
00:12:21,140 --> 00:12:18,360
because we're pretending we're really

312
00:12:23,180 --> 00:12:21,150
only measuring co2 for this planet and

313
00:12:25,970 --> 00:12:23,190

then we're going to compute the

314
00:12:28,790 --> 00:12:25,980
irradiation versus co2 slope for these

315
00:12:31,460 --> 00:12:28,800
three points so here I've Illustrated

316
00:12:33,800 --> 00:12:31,470
the slope as being negative which it

317
00:12:35,900 --> 00:12:33,810
should be the feedback function but of

318
00:12:38,000 --> 00:12:35,910
course because of our uncertainties in

319
00:12:39,890 --> 00:12:38,010
here surface temperature and in

320
00:12:42,170 --> 00:12:39,900
instrumental noise in some of these

321
00:12:45,350 --> 00:12:42,180
cases the slope may end up being

322
00:12:47,210 --> 00:12:45,360
positive or very close to zero so when

323
00:12:49,250 --> 00:12:47,220
we repeat this whole process ten to the

324
00:12:51,199 --> 00:12:49,260
five times we're going to have a number

325
00:12:53,269 --> 00:12:51,209
of slopes that are negative and in

326
00:12:56,090 --> 00:12:53,279
number positive and of course the more

327
00:12:57,590 --> 00:12:56,100
planet we model the more slopes should

328
00:13:01,220 --> 00:12:57,600
be negative because we assumed the

329
00:13:03,290 --> 00:13:01,230
feedback function okay so this slide

330
00:13:05,510 --> 00:13:03,300
right here illustrates the point I just

331
00:13:07,639 --> 00:13:05,520
made so this is the distribution of

332
00:13:10,310 --> 00:13:07,649
slopes as a function of the number of

333
00:13:11,900 --> 00:13:10,320
planets that we would be observing until

334
00:13:14,540 --> 00:13:11,910
we see that for a low number of planets

335
00:13:16,550 --> 00:13:14,550
here in magenta a good fraction of the

336
00:13:18,890 --> 00:13:16,560
slopes and up being positive ratch is

337
00:13:20,490 --> 00:13:18,900
very close to zero but the more planets

338
00:13:23,170 --> 00:13:20,500

who observe the more slopes

339
00:13:24,490 --> 00:13:23,180
so this makes sense right the the more

340
00:13:26,440 --> 00:13:24,500
planets we're going to observe the

341
00:13:28,870 --> 00:13:26,450
easier it will be to detect a downward

342
00:13:30,910 --> 00:13:28,880
slope if the feedback functions but we

343
00:13:34,360 --> 00:13:30,920
had to decide on what's a good enough

344
00:13:36,699 --> 00:13:34,370
number of mother legs or planets so to

345
00:13:38,439 --> 00:13:36,709
do that we define the power as the

346
00:13:41,230 --> 00:13:38,449
fraction of slopes with a p-value less

347
00:13:44,079 --> 00:13:41,240
than zero point zero point zero five so

348
00:13:47,290 --> 00:13:44,089
this is just how many slopes are clearly

349
00:13:49,329 --> 00:13:47,300
negative enough and here to get a power

350
00:13:53,050 --> 00:13:49,339
of your point eight we see that in this

351
00:13:55,389 --> 00:13:53,060
case we need eleven model exoplanets so

352
00:13:57,879 --> 00:13:55,399
what this means in real life is that if

353
00:14:01,060 --> 00:13:57,889
the silicate weathering action feedback

354
00:14:03,579 --> 00:14:01,070
actually functions on exoplanet and we

355
00:14:05,579 --> 00:14:03,589
observed eleven of them then we'll have

356
00:14:08,410 --> 00:14:05,589
an eighty percent chance of actually

357
00:14:10,150 --> 00:14:08,420
detecting the feedback so if we want a

358
00:14:12,310 --> 00:14:10,160
higher chance of detecting it if it

359
00:14:17,290 --> 00:14:12,320
exists we'll just have to observe more

360
00:14:18,819 --> 00:14:17,300
planets now you may remember that I

361
00:14:21,759 --> 00:14:18,829
mentioned doing this for both an

362
00:14:23,620 --> 00:14:21,769
optimistic and a pessimistic case so

363
00:14:25,750 --> 00:14:23,630

this is friendly optimistic case 11

364
00:14:29,170 --> 00:14:25,760
planets and for the pessimistic case

365
00:14:31,540 --> 00:14:29,180
we'd have to after 51 exoplanet now some

366
00:14:33,610 --> 00:14:31,550
caution these are still early results in

367
00:14:35,500 --> 00:14:33,620
the sense that they're for a fixed

368
00:14:38,199 --> 00:14:35,510
amount of co2 now it's your upon five

369
00:14:40,389 --> 00:14:38,209
log unit I'm currently working with cat

370
00:14:43,300 --> 00:14:40,399
Fang from Santa Cruz right here on

371
00:14:45,970 --> 00:14:43,310
actually adding simulated habits and who

372
00:14:49,180 --> 00:14:45,980
were noise to this year to value so that

373
00:14:51,639 --> 00:14:49,190
will come later okay but are these

374
00:14:53,259 --> 00:14:51,649
values reasonable they already give us

375
00:14:56,079 --> 00:14:53,269
somewhat of an idea of what we can

376
00:14:58,660 --> 00:14:56,089
expect to ensure that we looked at some

377
00:15:00,490 --> 00:14:58,670
work from Chris dark who estimated the

378
00:15:03,250 --> 00:15:00,500
candidate field for eggs on earth using

379
00:15:06,309 --> 00:15:03,260
different future generation instruments

380
00:15:08,500 --> 00:15:06,319
so if we look here at havoc it's a

381
00:15:10,420 --> 00:15:08,510
pretty small mirror and because of that

382
00:15:13,329 --> 00:15:10,430
we likely only be able to detect about

383
00:15:15,519 --> 00:15:13,339
10-ish eggs or earth so that's not ideal

384
00:15:17,620 --> 00:15:15,529
to do any kind of statistical study in

385
00:15:19,689 --> 00:15:17,630
general which makes sense because habits

386
00:15:23,050 --> 00:15:19,699
isn't really being thought of in that

387
00:15:26,110 --> 00:15:23,060
way but in cooperation if we look at the

388
00:15:28,180 --> 00:15:26,120

war a here or even new war be we'd be

389
00:15:30,639 --> 00:15:28,190
able to observe up to about fifty five

390
00:15:31,990 --> 00:15:30,649
eggs or earth so that's really an ideal

391
00:15:33,670 --> 00:15:32,000
number two

392
00:15:36,310 --> 00:15:33,680
be able to do this kind of statistical

393
00:15:38,440 --> 00:15:36,320
study so to test the habitable zone in

394
00:15:40,300 --> 00:15:38,450
general and especially to test whether

395
00:15:44,050 --> 00:15:40,310
or not the silicate weathering feedback

396
00:15:47,260 --> 00:15:44,060
functions on exoplanets okay I'm going

397
00:16:01,920 --> 00:15:47,270
to leave my conclusions right here Thank

398
00:16:07,660 --> 00:16:05,710
Thanks so Robin Wordsworth Harvard I was

399
00:16:10,420 --> 00:16:07,670
wondering have you thought about if you

400
00:16:12,130 --> 00:16:10,430
had ancillary observations something

401
00:16:15,730 --> 00:16:12,140
like albedo that allowed you to rule out

402
00:16:18,310 --> 00:16:15,740
by the the parameter space that was

403
00:16:20,080 --> 00:16:18,320
caused you have a lot of dependence on

404
00:16:22,270 --> 00:16:20,090
certain parameters if you could if you

405
00:16:25,240 --> 00:16:22,280
could make other observations you had

406
00:16:30,340 --> 00:16:25,250
prior to your analysis with that help

407
00:16:33,460 --> 00:16:30,350
things maybe but I guess I mean if these

408
00:16:36,220 --> 00:16:33,470
observations were available sure I can't

409
00:16:37,930 --> 00:16:36,230
think of any right now in this spot but

410
00:16:39,850 --> 00:16:37,940
I think the whole point is that we

411
00:16:41,410 --> 00:16:39,860
really want it because we'd have to do

412
00:16:43,750 --> 00:16:41,420
this for a large number of planets like

413
00:16:46,810 --> 00:16:43,760

he maybe 50 we really want to make sure

414
00:16:49,810 --> 00:16:46,820
that we do this with only really quick

415
00:16:52,180 --> 00:16:49,820
and simple measurements so here in this

416
00:16:54,070 --> 00:16:52,190
case it's really advantageous because it

417
00:16:56,230 --> 00:16:54,080
would allow us to really only test for

418
00:16:58,480 --> 00:16:56,240
co2 to have an estimate of the amount of

419
00:17:00,480 --> 00:16:58,490
co2 and of course the distance to the

420
00:17:03,370 --> 00:17:00,490
star but if we want to add other

421
00:17:04,840 --> 00:17:03,380
parameters that may take longer although

422
00:17:07,569 --> 00:17:04,850
if they're available from like safe

423
00:17:10,500 --> 00:17:07,579
studies and such yeah that'd be great

424
00:17:10,510 --> 00:17:16,260
hmm Daniel here in front

425
00:17:23,710 --> 00:17:20,949
how much luar time IU is this gonna take

426
00:17:25,210 --> 00:17:23,720
overall like I'd I don't know I assume

427
00:17:27,280 --> 00:17:25,220
somebody has done some reference studies

428
00:17:29,680 --> 00:17:27,290
like to even detect like a crappy

429
00:17:31,510 --> 00:17:29,690
measurement of co2

430
00:17:36,490 --> 00:17:31,520
do you need like order of an hour or

431
00:17:38,470 --> 00:17:36,500
order weeks right I'm not sure yet I

432
00:17:40,570 --> 00:17:38,480
think we're going to take that into into

433
00:17:42,700 --> 00:17:40,580
consideration when actually computing

434
00:17:44,870 --> 00:17:42,710
the amount of co2 noise we're going to

435
00:17:48,490 --> 00:17:44,880
decide on an integration time

436
00:17:52,480 --> 00:17:48,500
we're not sure what yet yeah I don't

437
00:17:55,580 --> 00:17:52,490
probably a few hours means I don't know

438
00:17:57,020 --> 00:17:55,590

I'm not an observation there so there's

439
00:17:59,870 --> 00:17:57,030
a lot of people in this room would be

440
00:18:02,950 --> 00:17:59,880
able to say that much better than I

441
00:18:11,000 --> 00:18:08,420
secret yeah hi Sigurd ranch and MIT

442
00:18:12,680 --> 00:18:11,010
thank you for a really great talk just

443
00:18:14,930 --> 00:18:12,690
regarding the uncertainties how hard is

444
00:18:17,660 --> 00:18:14,940
it to differentiate co2 concentrations

445
00:18:20,060 --> 00:18:17,670
at very high co2 concentrations how hard

446
00:18:21,500 --> 00:18:20,070
is it to differentiate co2 concentration

447
00:18:23,210 --> 00:18:21,510
yeah I guess I'm wondering is there any

448
00:18:24,230 --> 00:18:23,220
risk of saturation of the co2 line so

449
00:18:26,390 --> 00:18:24,240
it's hard to tell if there's too much

450
00:18:28,790 --> 00:18:26,400
co2 or you always get it from the wings

451
00:18:31,310 --> 00:18:28,800
right yeah so like I'm not going to go

452
00:18:33,860 --> 00:18:31,320
back but as you saw on the plot if we're

453
00:18:36,860 --> 00:18:33,870
at lower values of irradiation

454
00:18:39,320 --> 00:18:36,870
the co2 kind of on the plot it starts

455
00:18:41,990 --> 00:18:39,330
being really straight so we definitely

456
00:18:43,550 --> 00:18:42,000
want to be able to simple enough of this

457
00:18:45,100 --> 00:18:43,560
thought that we're able to say downward

458
00:18:48,200 --> 00:18:45,110
slope because if we only looked at

459
00:18:49,850 --> 00:18:48,210
planets at which there's a lot of co2 we

460
00:18:51,560 --> 00:18:49,860
may not be able to get a slope at all

461
00:18:55,520 --> 00:18:51,570
because I don't know if you remember the

462
00:19:03,710 --> 00:18:55,530
plot kind of both like this right it's a

463
00:19:07,190 --> 00:19:03,720

good point Hannah Hannah wait good Space

464
00:19:10,160 --> 00:19:07,200
Telescope um how evenly distributed

465
00:19:12,350 --> 00:19:10,170
across the face face of stellar

466
00:19:15,530 --> 00:19:12,360
irradiance do you need these 50 planets

467
00:19:19,520 --> 00:19:15,540
to be and do we expect to be able to

468
00:19:22,270 --> 00:19:19,530
have such a distribution that's a really

469
00:19:27,260 --> 00:19:25,190
all I can say is again the same thing

470
00:19:30,890 --> 00:19:27,270
you definitely want to be able to sample

471
00:19:32,660 --> 00:19:30,900
enough of this plot that you have the

472
00:19:35,960 --> 00:19:32,670
the spot at which the downward slope is

473
00:19:39,790 --> 00:19:35,970
more obvious than rather at lower values

474
00:19:44,540 --> 00:19:39,800
of irradiation okay I'm not sure exactly

475
00:19:46,410 --> 00:19:44,550
that's a good point though all right