
AbSciCon
2017
MESA, ARIZONA

1
00:00:12,250 --> 00:00:06,150
you

2
00:00:20,190 --> 00:00:14,160
[Music]

3
00:00:23,740 --> 00:00:20,200
hey I'm Jade this is my first talk and

4
00:00:26,410 --> 00:00:23,750
today I'd like to talk to you about the

5
00:00:29,109 --> 00:00:26,420
possibility of snowball bifurcations on

6
00:00:34,180 --> 00:00:29,119
tightly locked exoplanet so orbiting and

7
00:00:36,100 --> 00:00:34,190
stars okay so as everyone in the room

8
00:00:38,290 --> 00:00:36,110
here knows by now we found many ago

9
00:00:40,330 --> 00:00:38,300
planets and much of the fields focus is

10
00:00:42,340 --> 00:00:40,340
on trying to figure out which one's of

11
00:00:43,780 --> 00:00:42,350
those could be habitable now to know

12
00:00:45,760 --> 00:00:43,790
that we need to know which ones can

13
00:00:55,600 --> 00:00:45,770

support surface liquid water because

14
00:00:57,850 --> 00:00:55,610
habitability is a surface property okay

15
00:01:00,790 --> 00:00:57,860
now a major factor that can affect a

16
00:01:02,970 --> 00:01:00,800
planet's habitability is the ice albedo

17
00:01:06,400 --> 00:01:02,980
feedback so here on the left is very

18
00:01:08,560 --> 00:01:06,410
simple cartoon illustrates the effect so

19
00:01:10,990 --> 00:01:08,570
we know that the ocean absorbs much more

20
00:01:13,300 --> 00:01:11,000
solar radiation than ice which is very

21
00:01:16,210 --> 00:01:13,310
reflective so if we were to increase the

22
00:01:17,800 --> 00:01:16,220
insulation on the planet we would have a

23
00:01:20,410 --> 00:01:17,810
melting of sea ice which will decrease

24
00:01:22,240 --> 00:01:20,420
the albedo and induce more melting but

25
00:01:24,969 --> 00:01:22,250
if we were to lower the inspiration we

26
00:01:26,859 --> 00:01:24,979
would have some sea ice on forming which

27
00:01:28,630 --> 00:01:26,869
will increase the albedo and induce more

28
00:01:30,820 --> 00:01:28,640
freezing so because of this

29
00:01:33,340 --> 00:01:30,830
non-linearity a planet like the earth

30
00:01:36,399 --> 00:01:33,350
can have two stable States for a range

31
00:01:38,950 --> 00:01:36,409
of installations so we can look here at

32
00:01:41,920 --> 00:01:38,960
the plot on the right here the vertical

33
00:01:43,990 --> 00:01:41,930
axis is the sign of the ice latitude so

34
00:01:46,990 --> 00:01:44,000
the ice latitude is the latitudinal

35
00:01:50,050 --> 00:01:47,000
extent of ice on the planet and the

36
00:01:52,090 --> 00:01:50,060
horizontal axis is the insulation the

37
00:01:54,370 --> 00:01:52,100
solid lines represent stable States and

38
00:01:56,080 --> 00:01:54,380

the dashed line unstable sticks so if we

39
00:01:58,149 --> 00:01:56,090
start at the top right with a planet

40
00:01:59,530 --> 00:01:58,159
like the earth like modern earth in its

41
00:02:04,600 --> 00:01:59,540
warm state and we decrease the

42
00:02:06,670 --> 00:02:04,610
insulation eventually it will jump into

43
00:02:08,770 --> 00:02:06,680
a snowball state right there now to get

44
00:02:10,630 --> 00:02:08,780
out of this noble state we would need to

45
00:02:13,090 --> 00:02:10,640
increase the insulation but much more

46
00:02:14,920 --> 00:02:13,100
than the glaciation insulation so a

47
00:02:17,080 --> 00:02:14,930
planet might have a hard time to escape

48
00:02:19,690 --> 00:02:17,090
that snuggle state and this could have

49
00:02:21,490 --> 00:02:19,700
bad implications for habitability but at

50
00:02:24,340 --> 00:02:21,500
the same time although I'm not an expert

51
00:02:26,780 --> 00:02:24,350
on this for Earth

52
00:02:28,610 --> 00:02:26,790
like going through a snowball stage has

53
00:02:31,010 --> 00:02:28,620
been associated with the rise in oxygen

54
00:02:34,960 --> 00:02:31,020
and in complex life so it could be a

55
00:02:38,870 --> 00:02:34,970
good thing but still up for debate so

56
00:02:40,970 --> 00:02:38,880
okay now on this beautiful figure again

57
00:02:42,950 --> 00:02:40,980
by funny we see that the boundaries of

58
00:02:45,770 --> 00:02:42,960
the habitable zone strongly depend on

59
00:02:47,810 --> 00:02:45,780
the stellar type so for an M dwarf here

60
00:02:49,910 --> 00:02:47,820
which is much smaller and dimmer than a

61
00:02:54,530 --> 00:02:49,920
G sorry the habitable zone is much more

62
00:02:56,210 --> 00:02:54,540
close in so in fact it's so close in

63
00:02:58,520 --> 00:02:56,220

that a planet that's orbiting in the

64
00:03:00,710 --> 00:02:58,530
habitable zone of those M stars are

65
00:03:04,220 --> 00:03:00,720
close enough to likely become tightly

66
00:03:06,470 --> 00:03:04,230
locked as we see here so this means that

67
00:03:08,660 --> 00:03:06,480
one side of the planet will always be

68
00:03:11,360 --> 00:03:08,670
facing the star and the other side will

69
00:03:13,640 --> 00:03:11,370
always be facing away so because those

70
00:03:15,949 --> 00:03:13,650
planets orbit their stars in such a

71
00:03:18,260 --> 00:03:15,959
different manner than rapidly rotating

72
00:03:19,790 --> 00:03:18,270
planets like the earth we want to know

73
00:03:21,740 --> 00:03:19,800
whether they could still go through a

74
00:03:26,720 --> 00:03:21,750
snowboard bifurcation like we know the

75
00:03:29,240 --> 00:03:26,730
earth can now there's already been some

76
00:03:32,390 --> 00:03:29,250
work done on the subject first let's

77
00:03:35,690 --> 00:03:32,400
look here at those two plots by Joshi in

78
00:03:38,030 --> 00:03:35,700
2012 the top panel shows that the peak

79
00:03:39,860 --> 00:03:38,040
of the third spectrum of an M star is

80
00:03:41,990 --> 00:03:39,870
that a higher wavelength than that of a

81
00:03:44,600 --> 00:03:42,000
G star and because of this the Eifel

82
00:03:46,759 --> 00:03:44,610
video of a planet orbiting those M stars

83
00:03:48,979 --> 00:03:46,769
will be much lower so the non-linearity

84
00:03:51,080 --> 00:03:48,989
of the Eifel video effect will be

85
00:03:53,000 --> 00:03:51,090
reduced and we can imagine that a planet

86
00:03:55,370 --> 00:03:53,010
orbiting an M sir might have a more

87
00:03:58,640 --> 00:03:55,380
difficult time going through a snowball

88
00:04:01,970 --> 00:03:58,650

bifurcation because of that and also

89
00:04:04,850 --> 00:04:01,980
more recently here shields in 2014

90
00:04:08,210 --> 00:04:04,860
showed that for an M star compared to a

91
00:04:11,390 --> 00:04:08,220
G star the range of information at which

92
00:04:12,890 --> 00:04:11,400
there is by stability is much smaller so

93
00:04:14,990 --> 00:04:12,900
again the planet might have a more

94
00:04:17,479 --> 00:04:15,000
difficult time going through its network

95
00:04:20,090 --> 00:04:17,489
bifurcation now both of those works were

96
00:04:22,460 --> 00:04:20,100
about comparing the different solar

97
00:04:25,610 --> 00:04:22,470
spectra of an M star energy star and

98
00:04:27,680 --> 00:04:25,620
seeing how going like orbiting an M star

99
00:04:29,960 --> 00:04:27,690
might make it more difficult for the

100
00:04:31,909 --> 00:04:29,970
planet to go through the bifurcation but

101
00:04:34,159 --> 00:04:31,919
what we want to know is whether or not

102
00:04:36,260 --> 00:04:34,169
the fact itself that the planet

103
00:04:38,749 --> 00:04:36,270
My Luck whether it's orbiting an M star

104
00:04:40,489 --> 00:04:38,759
or a G star or whatever could make it

105
00:04:44,480 --> 00:04:40,499
more difficult to go through the

106
00:04:46,939 --> 00:04:44,490
bifurcation okay so we use a global

107
00:04:50,420 --> 00:04:46,949
climate model called blessing so it's a

108
00:04:52,010 --> 00:04:50,430
3d GCM of medium complexity we set it up

109
00:04:54,350 --> 00:04:52,020
in a modern earth continual

110
00:04:58,399 --> 00:04:54,360
configuration computed clouds and kept

111
00:05:00,980 --> 00:04:58,409
this here to fix a 360 ppm and here's

112
00:05:02,420 --> 00:05:00,990
what we see first for the earth so I'm

113
00:05:04,339 --> 00:05:02,430

here the top panels the surface

114
00:05:06,649 --> 00:05:04,349
temperature the bottom the sea ice cover

115
00:05:10,279 --> 00:05:06,659
and again the horizontal axis is always

116
00:05:12,529 --> 00:05:10,289
insulation the red stars here correspond

117
00:05:15,110 --> 00:05:12,539
to a warm start so where the planet is

118
00:05:17,089 --> 00:05:15,120
completely ice-free and the blue stars

119
00:05:19,279 --> 00:05:17,099
correspond to a cold start or it's

120
00:05:22,730 --> 00:05:19,289
completely ice covered on both of those

121
00:05:25,219 --> 00:05:22,740
initially and we see that we retrieve

122
00:05:27,860 --> 00:05:25,229
the expected snowboard bifurcation here

123
00:05:29,719 --> 00:05:27,870
and we have by stability so great the

124
00:05:32,570 --> 00:05:29,729
GPM reproduces the very well-known

125
00:05:35,179 --> 00:05:32,580
result for the earth but now using it in

126
00:05:37,670 --> 00:05:35,189
a tightly locked configuration we see

127
00:05:40,459 --> 00:05:37,680
something quite different right here on

128
00:05:42,740 --> 00:05:40,469
the left so whether we start cold or

129
00:05:44,209 --> 00:05:42,750
warm the surface temperature increases

130
00:05:46,339 --> 00:05:44,219
or decreases linearly with the

131
00:05:49,159 --> 00:05:46,349
insulation we don't see a snowboard

132
00:05:51,860 --> 00:05:49,169
bifurcation now you might be wondering

133
00:05:53,659 --> 00:05:51,870
about the small gap right here in

134
00:05:56,329 --> 00:05:53,669
surface temperature for those

135
00:05:58,399 --> 00:05:56,339
intermediate ranges of installations but

136
00:06:00,769 --> 00:05:58,409
this is not real hysteresis it's

137
00:06:02,959 --> 00:06:00,779
actually just a model artifact due to

138
00:06:05,389 --> 00:06:02,969

the simple CI scheme of the GPM we're

139
00:06:06,950 --> 00:06:05,399
using I don't want to get more into it

140
00:06:09,139 --> 00:06:06,960
now but if you'd like to know you can

141
00:06:10,969 --> 00:06:09,149
always ask me later but what's really

142
00:06:12,649 --> 00:06:10,979
important is just setting up the planet

143
00:06:15,170 --> 00:06:12,659
in the GCM in a tightly locked

144
00:06:17,420 --> 00:06:15,180
configuration gets rid of the snowboard

145
00:06:19,040 --> 00:06:17,430
by vacation and this is with a GSR

146
00:06:21,469 --> 00:06:19,050
spectrum all right so we can imagine

147
00:06:23,269 --> 00:06:21,479
that if we had used an answer spectrum

148
00:06:26,689 --> 00:06:23,279
it would be even less likely to go

149
00:06:28,909 --> 00:06:26,699
through a bifurcation okay now how can

150
00:06:31,279 --> 00:06:28,919
we understand this well we can use a

151
00:06:34,219 --> 00:06:31,289
simple energy balance model right here

152
00:06:36,290 --> 00:06:34,229
where the absorb solar radiation is

153
00:06:39,019 --> 00:06:36,300
equal to the outgoing long-wave plus the

154
00:06:40,969 --> 00:06:39,029
heat transport both on parametrize so

155
00:06:43,339 --> 00:06:40,979
first for the earth here's an example

156
00:06:46,159 --> 00:06:43,349
state for the planet and what's

157
00:06:47,570 --> 00:06:46,169
important to note right here is so this

158
00:06:49,580 --> 00:06:47,580
is the equator in the middle

159
00:06:51,560 --> 00:06:49,590
it's that the installation shape is

160
00:06:53,720 --> 00:06:51,570
flatter on the equator right we don't

161
00:06:56,630 --> 00:06:53,730
see a super sharp increase in insulation

162
00:06:59,270 --> 00:06:56,640
from the pole to the equator now solving

163
00:07:01,610 --> 00:06:59,280

this IBM for the ice latitude so again

164
00:07:04,130 --> 00:07:01,620
the isolated is the latitudinal extent

165
00:07:06,020 --> 00:07:04,140
of the ice on the planet we retrieve the

166
00:07:08,150 --> 00:07:06,030
bifurcation diagram that I showed and

167
00:07:09,920 --> 00:07:08,160
explained at the beginning so where the

168
00:07:15,290 --> 00:07:09,930
planet can jump into a snowball stage

169
00:07:17,300 --> 00:07:15,300
here okay now setting up the EVM in a

170
00:07:18,910 --> 00:07:17,310
tightly locked configuration what's

171
00:07:21,320 --> 00:07:18,920
important is that the insulation

172
00:07:23,930 --> 00:07:21,330
increases really sharply from the

173
00:07:25,850 --> 00:07:23,940
Terminator which is here to the sub-zero

174
00:07:28,700 --> 00:07:25,860
point which is here right compared to

175
00:07:31,130 --> 00:07:28,710
the earth which was much more flat now

176
00:07:33,770 --> 00:07:31,140
solving the EBM again for the ice

177
00:07:35,960 --> 00:07:33,780
latitude the bifurcation diagram here

178
00:07:37,820 --> 00:07:35,970
shows no bifurcation so it looks like

179
00:07:41,000 --> 00:07:37,830
the EBM is able to explain what's

180
00:07:43,460 --> 00:07:41,010
happening in our GCM now I just note

181
00:07:45,530 --> 00:07:43,470
that we are able to retrieve the

182
00:07:47,930 --> 00:07:45,540
bifurcation in this slightly large

183
00:07:49,580 --> 00:07:47,940
configuration in our ABM if we just

184
00:07:52,130 --> 00:07:49,590
greatly increase the heat transport

185
00:07:57,110 --> 00:07:52,140
let's just keep this in mind for the

186
00:07:58,940 --> 00:07:57,120
next slide ok so this slide explain

187
00:08:00,740 --> 00:07:58,950
what's happening in DBM but before

188
00:08:02,630 --> 00:08:00,750

looking at it ultimately what you need

189
00:08:04,610 --> 00:08:02,640
to know is that whether or not the

190
00:08:07,820 --> 00:08:04,620
planet goes through on the bifurcation

191
00:08:10,430 --> 00:08:07,830
depends on the insulation shape so let's

192
00:08:12,080 --> 00:08:10,440
first look at on the right here for the

193
00:08:14,990 --> 00:08:12,090
case where the planet does go through

194
00:08:16,730 --> 00:08:15,000
the bifurcation so we have the ice line

195
00:08:19,850 --> 00:08:16,740
somewhere between the pole and equator

196
00:08:22,100 --> 00:08:19,860
and we perturb it slightly towards the

197
00:08:24,140 --> 00:08:22,110
equator now there the insulation and the

198
00:08:26,210 --> 00:08:24,150
hay transport will be greater but

199
00:08:28,700 --> 00:08:26,220
because as we saw for the earth the

200
00:08:30,860 --> 00:08:28,710
insulation ship is not so sharp or on

201
00:08:32,570 --> 00:08:30,870
the equator at that point the hay

202
00:08:34,820 --> 00:08:32,580
transport will actually have increased

203
00:08:37,340 --> 00:08:34,830
more than the insulation increased and

204
00:08:39,650 --> 00:08:37,350
because of this di slang we continue all

205
00:08:42,950 --> 00:08:39,660
the way to the equator for the planet is

206
00:08:44,570 --> 00:08:42,960
in a snowball state now on the left for

207
00:08:46,970 --> 00:08:44,580
the stable case for example for a

208
00:08:48,440 --> 00:08:46,980
tightly locked planet again we have a

209
00:08:50,240 --> 00:08:48,450
nice line somewhere between the

210
00:08:53,150 --> 00:08:50,250
Terminator and the substellar point and

211
00:08:55,460 --> 00:08:53,160
we again perturb it slightly so towards

212
00:08:57,980 --> 00:08:55,470
the sub-zero point this time but because

213
00:09:00,110 --> 00:08:57,990

as we saw for HIV locked a net the rise

214
00:09:02,450 --> 00:09:00,120
in insulation is so sharp from the term

215
00:09:04,010 --> 00:09:02,460
later to the substernal point this time

216
00:09:06,530 --> 00:09:04,020
the installation will have increased

217
00:09:08,480 --> 00:09:06,540
more than the heat transport and because

218
00:09:11,060 --> 00:09:08,490
of this the ice line will return to its

219
00:09:13,870 --> 00:09:11,070
original position so the planet doesn't

220
00:09:16,519 --> 00:09:13,880
go through a snowball bifurcation so

221
00:09:18,800 --> 00:09:16,529
this is my conclusion that tightly

222
00:09:20,780 --> 00:09:18,810
locked exoplanets are unlikely to go

223
00:09:23,030 --> 00:09:20,790
through a snowball bifurcation because

224
00:09:25,130 --> 00:09:23,040
of the sharp increase in insulation from

225
00:09:27,860 --> 00:09:25,140
the Terminator to the sub-zero point and

226
00:09:29,120 --> 00:09:27,870
we have a paper in prep on this that

227
00:09:41,510 --> 00:09:29,130
will be submitted soon if you're

228
00:09:43,160 --> 00:09:41,520
interested thank you hi my name is

229
00:09:44,870 --> 00:09:43,170
Richard Archer from University Colorado

230
00:09:48,380 --> 00:09:44,880
Boulder I thought it was really great

231
00:09:50,420 --> 00:09:48,390
presentation so congratulations I have a

232
00:09:53,090 --> 00:09:50,430
question regarding volcanism so in terms

233
00:09:55,519 --> 00:09:53,100
of snowball earth it was there are

234
00:09:57,079 --> 00:09:55,529
people that suggested that the release

235
00:09:59,930 --> 00:09:57,089
of some all births condition was driven

236
00:10:01,610 --> 00:09:59,940
by volcanic co2 so after it's still all

237
00:10:03,350 --> 00:10:01,620
earth you actually have very large

238
00:10:06,620 --> 00:10:03,360

greenhouse effect and I just wonder what

239
00:10:09,500 --> 00:10:06,630
you think that might apply to to your

240
00:10:10,880 --> 00:10:09,510
model so that's to get out of the snow

241
00:10:13,690 --> 00:10:10,890
board once you're already in it

242
00:10:17,390 --> 00:10:13,700
volcanoes could out gas a lot of co2

243
00:10:19,010 --> 00:10:17,400
right I mean we just saw that tightly

244
00:10:21,019 --> 00:10:19,020
locked planet don't go through the solar

245
00:10:22,370 --> 00:10:21,029
bifurcation but yes they can be in a

246
00:10:25,160 --> 00:10:22,380
snowboard state if you decrease the

247
00:10:26,810 --> 00:10:25,170
insulation enough however to get out of

248
00:10:28,880 --> 00:10:26,820
this noble state it would be much easier

249
00:10:30,650 --> 00:10:28,890
than for the earth because it's not a

250
00:10:38,820 --> 00:10:30,660
bifurcation so you would just need to

251
00:10:48,300 --> 00:10:46,380
oh so you mean for example if we had

252
00:10:55,650 --> 00:10:48,310
tried using the GCM with a much higher

253
00:10:57,900 --> 00:10:55,660
co2 level sure okay yeah I was just

254
00:10:59,130 --> 00:10:57,910
wondering the the result eeeh tightly

255
00:11:02,490 --> 00:10:59,140
locked exoplanets are unlikely to go

256
00:11:04,769 --> 00:11:02,500
through its Noble is that conditional on

257
00:11:07,440 --> 00:11:04,779
assuming that there is not any heat

258
00:11:08,670 --> 00:11:07,450
transport from the insulated side to the

259
00:11:13,319 --> 00:11:08,680
shadow side of a tidally locked planet

260
00:11:15,360 --> 00:11:13,329
ah no no there is heat transport so you

261
00:11:16,710 --> 00:11:15,370
have a basic model of default this is

262
00:11:18,210 --> 00:11:16,720
how much heat transport you have and

263
00:11:20,850 --> 00:11:18,220

then you still get tight and you just

264
00:11:22,440 --> 00:11:20,860
and you still get a what - you do not go

265
00:11:25,050 --> 00:11:22,450
through the bifurcation but if you

266
00:11:27,150 --> 00:11:25,060
increase that above what you expect then

267
00:11:30,420 --> 00:11:27,160
you do go through them the heat

268
00:11:33,269 --> 00:11:30,430
transport yes yes yeah you are actually

269
00:11:36,389 --> 00:11:33,279
yeah actually it's interesting that in

270
00:11:38,519 --> 00:11:36,399
the GCM I didn't present it in the talk

271
00:11:40,170 --> 00:11:38,529
but we found that the heat transport on

272
00:11:42,449 --> 00:11:40,180
the tightly locked planet is much

273
00:11:44,430 --> 00:11:42,459
greater than for the earth and it's

274
00:11:47,250 --> 00:11:44,440
great enough that on the IBM we should

275
00:11:49,980 --> 00:11:47,260
be able to get the bifurcation back but

276
00:11:52,500 --> 00:11:49,990
the difference in albedo it's smaller

277
00:11:54,540 --> 00:11:52,510
than for the earth because of so many

278
00:11:56,340 --> 00:11:54,550
clouds at the Sub Zero point and they

279
00:11:58,170 --> 00:11:56,350
still get the tidally locked planet to

280
00:11:59,730 --> 00:11:58,180
not go through the bifurcation so as

281
00:12:02,130 --> 00:11:59,740
heat transport is really important it's

282
00:12:03,810 --> 00:12:02,140
definitely happening and it's enough to

283
00:12:07,430 --> 00:12:03,820
normally go through a bifurcation if

284
00:12:11,850 --> 00:12:07,440
that albedo range wasn't smaller please

285
00:12:13,740 --> 00:12:11,860
any more questions if not we can give

286
00:12:14,250 --> 00:12:13,750
Jada round of applause thank you very