AbSciCon 2017

MESA, ARIZONA

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

2
00:00:16,800 --> 00:00:14,190
[Music]

3
00:00:19,090 --> 00:00:16,810
hi okay so I'm not going to talk about

4
00:00:22,570 --> 00:00:19,100
stars really at all what I want to talk

5
00:00:26,620 --> 00:00:22,580
about is the sort of the idea that rocky

6
00:00:28,630 --> 00:00:26,630
planets might have elemental ratios that

7
00:00:32,170 --> 00:00:28,640
are basically the same as their stars

8
00:00:33,880 --> 00:00:32,180
but maybe those can be post processed

9
00:00:35,680 --> 00:00:33,890
through atmospheric escape and so I

10
00:00:37,509 --> 00:00:35,690
wanted to examine sort of the idea that

11
00:00:40,540 --> 00:00:37,519
you could lose enough rocky elements

12
00:00:42,540 --> 00:00:40,550
from the planet's atmosphere to to sort

13
00:00:46,630 --> 00:00:42,550

of fractioning its actual solid

14
00:00:48,459 --> 00:00:46,640
abundances so the the idea of

15
00:00:51,880 --> 00:00:48,469
atmospheric escape from M dwarf planets

16
00:00:53,530 --> 00:00:51,890
are from really any rocky planets is

17
00:00:55,810 --> 00:00:53,540
pretty popular in the exit planet

18
00:00:57,970 --> 00:00:55,820
literature especially this idea that you

19
00:01:00,639 --> 00:00:57,980
can take a gas giant or a mini Neptune

20
00:01:02,290 --> 00:01:00,649
and just to rode the entire volatile

21
00:01:04,630 --> 00:01:02,300
envelope and be left over with a rocky

22
00:01:06,940 --> 00:01:04,640
planet so I just want to highlight a

23
00:01:09,430 --> 00:01:06,950
couple of studies here so this is a

24
00:01:12,820 --> 00:01:09,440
paper from Eric Lopez that was looking

25
00:01:14,950 --> 00:01:12,830
at the Kepler 36 system and the idea

26
00:01:17,230 --> 00:01:14,960
that they're exploring is that you have

27
00:01:20,710 --> 00:01:17,240
a certain amount of rocky material as a

28
00:01:23,679 --> 00:01:20,720
core and you have of 20% hydrogen or

29
00:01:25,750 --> 00:01:23,689
helium envelope on top and that the size

30
00:01:27,880 --> 00:01:25,760
of the rocky core is going to dictate

31
00:01:30,310 --> 00:01:27,890
how much of that envelope you can Road

32
00:01:32,980 --> 00:01:30,320
over time so these two planets are

33
00:01:34,480 --> 00:01:32,990
observed to have they're very close in

34
00:01:37,630 --> 00:01:34,490
orbital period but they have very

35
00:01:39,940 --> 00:01:37,640
different observe radii but in his

36
00:01:42,569 --> 00:01:39,950
models you can take basically the same

37
00:01:45,039 --> 00:01:42,579
initial envelope abundance and the

38
00:01:47,950 --> 00:01:45,049

planet with a smaller core you can erode

39
00:01:49,510 --> 00:01:47,960
all of that envelope whereas the planet

40
00:01:54,580 --> 00:01:49,520
with a larger core you can only Rhodes

41
00:01:56,530 --> 00:01:54,590
about 10% of that envelope and then this

42
00:01:59,380 --> 00:01:56,540
is work from Rodrigo Luthor who we heard

43
00:02:02,440 --> 00:01:59,390
from earlier looking at also evaporated

44
00:02:04,690 --> 00:02:02,450
cores this is looking at the level of

45
00:02:07,389 --> 00:02:04,700
zone for M dwarf planets so this is

46
00:02:09,340 --> 00:02:07,399
stellar mass and orbital distance in

47
00:02:11,590 --> 00:02:09,350
this shaded region is the Hubble's own

48
00:02:13,569 --> 00:02:11,600
of these stars and these contours are

49
00:02:16,259 --> 00:02:13,579
showing where you have evaporated cores

50
00:02:18,250 --> 00:02:16,269
so to the left of these lines you have

51
00:02:22,150 --> 00:02:18,260
planets who have lost their entire

52
00:02:23,550 --> 00:02:22,160
volatile envelope of about 50% or about

53
00:02:26,220 --> 00:02:23,560
half of their mass

54
00:02:28,470 --> 00:02:26,230
as hydrogen so if you have energy

55
00:02:30,180 --> 00:02:28,480
limited escapes in the planets that

56
00:02:32,280 --> 00:02:30,190
you're seeing in the handle zone could

57
00:02:34,500 --> 00:02:32,290
have started off with 50% of their mass

58
00:02:37,110 --> 00:02:34,510
in hydrogen okay so that's a lot of

59
00:02:38,820 --> 00:02:37,120
atmosphere that you could lose you can

60
00:02:40,830 --> 00:02:38,830
play the same game with steam

61
00:02:45,150 --> 00:02:40,840
atmospheres this is more work from

62
00:02:48,600 --> 00:02:45,160
Roderigo Luger looking at water loss so

63
00:02:50,340 --> 00:02:48,610

this is again indoor pool zones and

64
00:02:53,809 --> 00:02:50,350
looking at the amount of water you can

65
00:02:58,020 --> 00:02:53,819
lose from a planet due to this extended

66
00:03:00,120 --> 00:02:58,030
phase and in Dorf evolution where these

67
00:03:02,699 --> 00:03:00,130
planets are actually in interior to the

68
00:03:04,199 --> 00:03:02,709
to the initial levels own so the red

69
00:03:06,330 --> 00:03:04,209
here is just indicating that you have

70
00:03:08,610 --> 00:03:06,340
lost all of your water your initial

71
00:03:11,490 --> 00:03:08,620
water envelope I'm and if your stripping

72
00:03:14,550 --> 00:03:11,500
hydrogen off of of water than you can

73
00:03:16,920 --> 00:03:14,560
get oxygen build-up so over here they're

74
00:03:18,900 --> 00:03:16,930
showing the oxygen buildup red is

75
00:03:21,240 --> 00:03:18,910
basically all of the water has been

76
00:03:23,370 --> 00:03:21,250
converted into oxygen but over here

77
00:03:25,320 --> 00:03:23,380
you've actually lost some of your oxygen

78
00:03:27,630 --> 00:03:25,330
right so you haven't been able to hold

79
00:03:30,000 --> 00:03:27,640
on to all that oxygen because it's being

80
00:03:33,330 --> 00:03:30,010
lost along with the hydrogen through

81
00:03:35,940 --> 00:03:33,340
hydrodynamic drag so if you're losing

82
00:03:39,090 --> 00:03:35,950
oxygen maybe you can also lose other

83
00:03:41,100 --> 00:03:39,100
elements as well and this is important

84
00:03:42,960 --> 00:03:41,110
because magma ocean atmospheres are not

85
00:03:45,140 --> 00:03:42,970
pure steam and they're not pure hydrogen

86
00:03:47,640 --> 00:03:45,150
this is work from Bruce vaguely

87
00:03:50,190 --> 00:03:47,650
published last year looking at the

88
00:03:52,050 --> 00:03:50,200

compositions of steam atmospheres as a

89
00:03:54,870 --> 00:03:52,060
function of surface temperature here on

90
00:03:57,690 --> 00:03:54,880
the x-axis and this is the mole fraction

91
00:03:59,250 --> 00:03:57,700
of gases in the atmosphere on the y-axis

92
00:04:01,349 --> 00:03:59,260
so you can see the atmosphere is

93
00:04:03,599 --> 00:04:01,359
dominated by steam it's got a lot of

94
00:04:06,270 --> 00:04:03,609
hydrogen but the third most abundant

95
00:04:10,050 --> 00:04:06,280
hydrogen bearing gas is silicon tetra

96
00:04:12,030 --> 00:04:10,060
hydroxide at 2000 Kelvin if you go up to

97
00:04:15,509 --> 00:04:12,040
higher temperatures you get magnesium

98
00:04:18,029 --> 00:04:15,519
iron sodium hydroxides right so you have

99
00:04:20,699 --> 00:04:18,039
a reasonably abundant lissa file

100
00:04:22,860 --> 00:04:20,709
elements in your atmosphere so if you're

101
00:04:24,960 --> 00:04:22,870
losing hydrogen from the atmosphere then

102
00:04:28,950 --> 00:04:24,970
you might be dragging these elements

103
00:04:31,200 --> 00:04:28,960
along for the ride so a lot of this is

104
00:04:32,909 --> 00:04:31,210
you know based on the idea that you can

105
00:04:35,130 --> 00:04:32,919
do this and that people have looked at

106
00:04:36,839 --> 00:04:35,140
this in the solar system for noble gases

107
00:04:37,380 --> 00:04:36,849
as you can fractionate doe noble gas

108
00:04:40,470 --> 00:04:37,390
isotope

109
00:04:43,010 --> 00:04:40,480
through hydrodynamic drag so maybe you

110
00:04:45,360 --> 00:04:43,020
can do this for rocky elements as well

111
00:04:46,980 --> 00:04:45,370
and there's at least two ways you can

112
00:04:48,420 --> 00:04:46,990
fractionate the elements in these

113
00:04:51,000 --> 00:04:48,430

atmospheres the first is through

114
00:04:52,830 --> 00:04:51,010
fractional vaporization and then the

115
00:04:54,900 --> 00:04:52,840
second is is through the dynamical

116
00:04:57,510 --> 00:04:54,910
effects given that these elements have

117
00:05:00,200 --> 00:04:57,520
different masses so I'll talk a little

118
00:05:03,000 --> 00:05:00,210
bit about both of those

119
00:05:05,370 --> 00:05:03,010
okay so first a fractional vaporization

120
00:05:07,350 --> 00:05:05,380
is just that the gas composition is not

121
00:05:09,420 --> 00:05:07,360
the same as the solid material right

122
00:05:11,430 --> 00:05:09,430
these elements have different

123
00:05:13,110 --> 00:05:11,440
volatilities and so they're going to go

124
00:05:14,400 --> 00:05:13,120
into the gas phase at different rates

125
00:05:17,730 --> 00:05:14,410
depending on the temperature and the

126
00:05:19,440 --> 00:05:17,740
pressure of your envelope this is

127
00:05:21,240 --> 00:05:19,450
another figure from Bruce vaguely who

128
00:05:25,170 --> 00:05:21,250
sort of came up with this idea that you

129
00:05:28,920 --> 00:05:25,180
could lose silicate elements from from

130
00:05:30,660 --> 00:05:28,930
these steam atmospheres the X scale here

131
00:05:32,520 --> 00:05:30,670
is inverse temperature so higher

132
00:05:35,010 --> 00:05:32,530
temperatures on the left here lower

133
00:05:38,130 --> 00:05:35,020
temperature on the right and the y-axis

134
00:05:42,090 --> 00:05:38,140
is the silicon to magnesium ratio in the

135
00:05:43,560 --> 00:05:42,100
atmosphere and then the two colors here

136
00:05:45,860 --> 00:05:43,570
are two different pressures so a

137
00:05:48,120 --> 00:05:45,870
different atmospheric mask basically

138
00:05:51,000 --> 00:05:48,130

this is lower pressure this is higher

139
00:05:53,100 --> 00:05:51,010
pressure so what happens is the silicon

140
00:05:55,080 --> 00:05:53,110
abundance in the atmosphere is very

141
00:05:56,370 --> 00:05:55,090
strongly pressure dependent but it

142
00:05:59,150 --> 00:05:56,380
doesn't depend very strongly on

143
00:06:01,380 --> 00:05:59,160
temperature so as you go up and pressure

144
00:06:02,820 --> 00:06:01,390
the silicon abundance is going to

145
00:06:04,650 --> 00:06:02,830
increase in so you're going to increase

146
00:06:07,080 --> 00:06:04,660
the silicon to magnesium ratio in the

147
00:06:08,820 --> 00:06:07,090
atmosphere you're also just overall

148
00:06:11,850 --> 00:06:08,830
increasing the silicon abundance in the

149
00:06:14,760 --> 00:06:11,860
atmosphere at really high pressures

150
00:06:16,740 --> 00:06:14,770
silicon tetra hydroxide can actually be

151
00:06:18,450 --> 00:06:16,750
the second most abundant gas in the

152
00:06:21,450 --> 00:06:18,460
entire atmosphere so it can make up a

153
00:06:22,530 --> 00:06:21,460
significant portion magnesium on the

154
00:06:23,970 --> 00:06:22,540
other hand is not very pressure

155
00:06:26,790 --> 00:06:23,980
dependent but it is very strongly

156
00:06:29,100 --> 00:06:26,800
temperature-dependent the abundance of

157
00:06:31,170 --> 00:06:29,110
magnesium increases as you go to higher

158
00:06:33,810 --> 00:06:31,180
temperatures and so our silicon and

159
00:06:37,320 --> 00:06:33,820
magnesium ratio is decreasing over here

160
00:06:39,810 --> 00:06:37,330
at at high temperatures so if we just

161
00:06:41,850 --> 00:06:39,820
take this atmosphere and just blow it

162
00:06:44,550 --> 00:06:41,860
off assume there's no dynamical effects

163
00:06:47,430 --> 00:06:44,560

at all in order to make a significant

164
00:06:49,140 --> 00:06:47,440
effect on the rocky body itself you need

165
00:06:49,490 --> 00:06:49,150
to lose about two weight percent of the

166
00:06:51,770 --> 00:06:49,500
plan

167
00:06:54,800 --> 00:06:51,780
it in terms of esteem atmosphere in

168
00:06:57,800 --> 00:06:54,810
order to lose about 1% of your total

169
00:07:00,080 --> 00:06:57,810
silicon that's in your mantle and the

170
00:07:02,270 --> 00:07:00,090
magnesium lost given this you're losing

171
00:07:03,740 --> 00:07:02,280
a massive atmosphere there's very little

172
00:07:05,840 --> 00:07:03,750
magnesium in the atmosphere so you're

173
00:07:07,730 --> 00:07:05,850
actually not losing very much of it so

174
00:07:12,010 --> 00:07:07,740
then that effect is to decrease the

175
00:07:14,540 --> 00:07:12,020
silicon magnesium ratio of your mantle

176
00:07:16,940 --> 00:07:14,550
but what about those dynamical effects

177
00:07:18,680 --> 00:07:16,950
okay so and that should be that's a

178
00:07:21,020 --> 00:07:18,690
decided upper limit right so there's no

179
00:07:23,000 --> 00:07:21,030
dynamical effects in here so what if we

180
00:07:25,370 --> 00:07:23,010
do take those into account if we're

181
00:07:29,000 --> 00:07:25,380
looking just at the simple energy

182
00:07:31,250 --> 00:07:29,010
limited escape we can put a limit on the

183
00:07:33,440 --> 00:07:31,260
mass of the particles that can be drug

184
00:07:36,170 --> 00:07:33,450
along with the hydrogen okay so this is

185
00:07:38,300 --> 00:07:36,180
the crossover mass and basically if the

186
00:07:41,090 --> 00:07:38,310
mass of your particle is lower than the

187
00:07:43,430 --> 00:07:41,100
crossover mass then it can escape along

188
00:07:46,430 --> 00:07:43,440

with the hydrogen then you can convert

189
00:07:49,790 --> 00:07:46,440
this crossover mass into an effective

190
00:07:52,280 --> 00:07:49,800
XUV flux so if your planet receives more

191
00:07:54,320 --> 00:07:52,290
XUV flux than this critical value then

192
00:07:58,070 --> 00:07:54,330
you can strip off that element from the

193
00:07:59,870 --> 00:07:58,080
atmosphere an important caveat here is

194
00:08:01,280 --> 00:07:59,880
of course that the little pile Elmas in

195
00:08:03,320 --> 00:08:01,290
order to be stripped actually have to be

196
00:08:04,909 --> 00:08:03,330
in the atmosphere and so that means you

197
00:08:06,469 --> 00:08:04,919
actually have to be not just in the

198
00:08:08,480 --> 00:08:06,479
runaway greenhouse effect but you have

199
00:08:10,190 --> 00:08:08,490
to be in the magma ocean stage where

200
00:08:12,350 --> 00:08:10,200
you've melted the surface and your

201
00:08:17,420 --> 00:08:12,360
temperature is at least about 1500

202
00:08:20,330 --> 00:08:17,430
Kelvin or hotter okay so here I'm

203
00:08:22,130 --> 00:08:20,340
showing the XUV fluxes of the Hallows

204
00:08:25,130 --> 00:08:22,140
own planet so these are planets that are

205
00:08:28,130 --> 00:08:25,140
in the have ozone at five Giga years for

206
00:08:31,340 --> 00:08:28,140
different stellar masses as a function

207
00:08:33,860 --> 00:08:31,350
of time this is for a point one solar

208
00:08:36,829 --> 00:08:33,870
mass star and I'm taking the inner and

209
00:08:39,500 --> 00:08:36,839
outer habitable zone edges from Ravi

210
00:08:42,680 --> 00:08:39,510
Cooper operatives work this is a recent

211
00:08:46,010 --> 00:08:42,690
Venus in the early Mars okay and here's

212
00:08:48,530 --> 00:08:46,020
a 0.5 solar masses and point nine solar

213
00:08:52,700 --> 00:08:48,540

masses and here's the runaway greenhouse

214
00:08:54,410 --> 00:08:52,710
women okay so for the K dwarf here the

215
00:08:56,540 --> 00:08:54,420
Quinta's don't spend a whole lot of time

216
00:08:58,370 --> 00:08:56,550
in the runaway greenhouse limit but for

217
00:09:00,800 --> 00:08:58,380
the in dwarf stars they stay in the

218
00:09:02,210 --> 00:09:00,810
runaway greenhouse limit for for quite a

219
00:09:04,740 --> 00:09:02,220
long time

220
00:09:06,630 --> 00:09:04,750
and then I'm going to compare this xev

221
00:09:08,700 --> 00:09:06,640
flex that these planets are receiving to

222
00:09:12,330 --> 00:09:08,710
the critical xev flux for the different

223
00:09:15,710 --> 00:09:12,340
with a file elements so this depends on

224
00:09:18,450 --> 00:09:15,720
the atomic masses of hydrogen and MV

225
00:09:19,950 --> 00:09:18,460
with a file element the planet mass

226
00:09:21,900 --> 00:09:19,960
which here I'm just taking one earth

227
00:09:25,170 --> 00:09:21,910
mass and this binary diffusion

228
00:09:27,060 --> 00:09:25,180
coefficient which is usually measured

229
00:09:28,890 --> 00:09:27,070
empirically but we don't have those

230
00:09:31,260 --> 00:09:28,900
measurements for rocky elements so I've

231
00:09:35,510 --> 00:09:31,270
approached mated them using this that's

232
00:09:38,850 --> 00:09:35,520
hard spheres formula so here's the

233
00:09:42,150 --> 00:09:38,860
critical xev flux for silicon for

234
00:09:44,310 --> 00:09:42,160
magnesium and then for iron you can see

235
00:09:46,890 --> 00:09:44,320
there's a mass dependence here magnesium

236
00:09:49,260 --> 00:09:46,900
is the lightest heaviest but these are

237
00:09:51,780 --> 00:09:49,270
all below the runaway greenhouse limit

238
00:09:53,760 --> 00:09:51,790

which means that the limiting factor

239
00:09:56,820 --> 00:09:53,770
here is how long you have a steam

240
00:09:58,800 --> 00:09:56,830
atmosphere not the the XUV flux that

241
00:10:00,240 --> 00:09:58,810
you're receiving so if you have a steam

242
00:10:03,210 --> 00:10:00,250
atmosphere you should be losing these

243
00:10:06,840 --> 00:10:03,220
elements here's a very preliminary

244
00:10:07,800 --> 00:10:06,850
calculation for silicon math class I

245
00:10:10,230 --> 00:10:07,810
haven't really gotten around to the

246
00:10:12,690 --> 00:10:10,240
other elements yet looking at the

247
00:10:15,330 --> 00:10:12,700
fraction of silicon that has lost four

248
00:10:19,410 --> 00:10:15,340
different envelope masses as a function

249
00:10:22,290 --> 00:10:19,420
of time so starting from one earth ocean

250
00:10:24,180 --> 00:10:22,300
up to about 400 Earth oceans which for

251
00:10:26,430 --> 00:10:24,190
reference is about nine weight percent

252
00:10:29,490 --> 00:10:26,440
of an earth-mass planet so you can see

253
00:10:34,080 --> 00:10:29,500
this is a log scale down here we have

254
00:10:36,360 --> 00:10:34,090
very minimal loss of silicon and we only

255
00:10:38,970 --> 00:10:36,370
really get significant loss of silicon

256
00:10:41,660 --> 00:10:38,980
up here for about 400 ocean masses so

257
00:10:45,030 --> 00:10:41,670
this is a very very water rich planet

258
00:10:47,310 --> 00:10:45,040
and and these curves I should say are

259
00:10:49,410 --> 00:10:47,320
being cut off where you are reaching a

260
00:10:51,810 --> 00:10:49,420
surface temperature of about 1400 Kelvin

261
00:10:53,370 --> 00:10:51,820
so below that the lid to file elements

262
00:10:57,270 --> 00:10:53,380
drop you might so get a little bit more

263
00:11:00,420 --> 00:10:57,280

escape but not significant amount so

264
00:11:03,540 --> 00:11:00,430
just to sum up if you have significant

265
00:11:05,010 --> 00:11:03,550
envelope stripping of a planet it's

266
00:11:07,080 --> 00:11:05,020
possible that you could fraction eight

267
00:11:09,360 --> 00:11:07,090
the little file elements it seems that

268
00:11:11,519 --> 00:11:09,370
this is only going to be important

269
00:11:13,530 --> 00:11:11,529
forward very extreme cases of

270
00:11:15,629 --> 00:11:13,540
of envelope stripping for have alone

271
00:11:19,710 --> 00:11:15,639
cleanest but it's likely to be much more

272
00:11:21,150 --> 00:11:19,720
important for planets that are closer to

273
00:11:23,610 --> 00:11:21,160
the star than they have the ozone I

274
00:11:26,579 --> 00:11:23,620
didn't really talk about alkali elements

275
00:11:28,739 --> 00:11:26,589
at all but sodium is both lighter than

276
00:11:31,139 --> 00:11:28,749
silicon and also more volatile so you

277
00:11:32,460 --> 00:11:31,149
can imagine that there might be planets

278
00:11:36,600 --> 00:11:32,470
where you have stripped off most of your

279
00:11:38,910 --> 00:11:36,610
sodium so next steps we need to look

280
00:11:41,160 --> 00:11:38,920
also at loss from hydrogen envelopes

281
00:11:44,009 --> 00:11:41,170
where the volatilities of these elements

282
00:11:46,019 --> 00:11:44,019
are going to be different gas and mantle

283
00:11:48,329 --> 00:11:46,029
composition should co-evolve which is

284
00:11:51,420 --> 00:11:48,339
not happening right now I'm just taking

285
00:11:53,519 --> 00:11:51,430
a fixed sort of gas composition cloud

286
00:11:55,889 --> 00:11:53,529
formation might actually hinder this

287
00:11:57,809 --> 00:11:55,899
kind of loss again for closer in planets

288
00:12:00,170 --> 00:11:57,819

this is probably not going to matter too

289
00:12:03,780 --> 00:12:00,180
much but for have ozone planets it could

290
00:12:05,549 --> 00:12:03,790
could definitely a halt loss and then of

291
00:12:07,829 --> 00:12:05,559
course there are other loss processes so

292
00:12:09,270 --> 00:12:07,839
I'll stop there thanks my funding

293
00:12:20,720 --> 00:12:09,280
sources and take any questions

294
00:12:26,100 --> 00:12:23,340
Laura this is really cool stuff I was

295
00:12:29,310 --> 00:12:26,110
curious if you were sort of taking into

296
00:12:31,860 --> 00:12:29,320
account how much of those ocean masses

297
00:12:33,480 --> 00:12:31,870
you're losing so could you drive escape

298
00:12:35,220 --> 00:12:33,490
of those lighter elements and then

299
00:12:37,100 --> 00:12:35,230
basically at the end you're just

300
00:12:40,050 --> 00:12:37,110
dragging off silicon because it's

301
00:12:44,250 --> 00:12:40,060
basically have a silicon atmosphere of

302
00:12:46,199 --> 00:12:44,260
some kind or silica atmospheres um so

303
00:12:49,710 --> 00:12:46,209
you mean if so if we have a smaller

304
00:12:51,449 --> 00:12:49,720
volatile envelope and maybe it's just so

305
00:12:53,160 --> 00:12:51,459
you really need the water in order to

306
00:12:55,019 --> 00:12:53,170
get the surface hot enough right to

307
00:12:56,610 --> 00:12:55,029
vaporize the silicon unless you're much

308
00:12:58,620 --> 00:12:56,620
closer to the star so you can imagine

309
00:13:02,490 --> 00:12:58,630
there there are definitely planets like

310
00:13:04,910 --> 00:13:02,500
55 Cancri E or Colorado 7b or Kepler 10b

311
00:13:07,310 --> 00:13:04,920
where they're just vaporizing silicon

312
00:13:11,970 --> 00:13:07,320
without having any kind of atmosphere

313
00:13:14,160 --> 00:13:11,980

for the the have ozone planets you do

314
00:13:16,560 --> 00:13:14,170
need some kind of greenhouse warming in

315
00:13:20,579 --> 00:13:16,570
order to get hot enough to vaporize them

316
00:13:22,620 --> 00:13:20,589
so at once you lose enough envelope

317
00:13:24,510 --> 00:13:22,630
you're going to probably condense

318
00:13:28,900 --> 00:13:24,520
everything back onto the surface yeah