
AbSciCon
2017
MESA, ARIZONA

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

2
00:00:20,500 --> 00:00:18,880
[Music]

3
00:00:22,870 --> 00:00:20,510
so if we look at the planets in the

4
00:00:25,179 --> 00:00:22,880
solar system we see we have the

5
00:00:28,120 --> 00:00:25,189
terrestrial planets on the smaller side

6
00:00:29,470 --> 00:00:28,130
we have Mars and Venus and Earth and so

7
00:00:31,630 --> 00:00:29,480
on these planets the atmosphere

8
00:00:34,450 --> 00:00:31,640
represents a negligible fraction of the

9
00:00:36,310 --> 00:00:34,460
bulk mass of the planet and if we go up

10
00:00:38,470 --> 00:00:36,320
to size scale the next largest planets

11
00:00:41,140 --> 00:00:38,480
that we see are the ice giants Neptune

12
00:00:42,729 --> 00:00:41,150
and Uranus and in the solar system we

13
00:00:45,130 --> 00:00:42,739

have nothing in between these two bodies

14
00:00:46,959 --> 00:00:45,140
that's not the case around other stars

15
00:00:48,940 --> 00:00:46,969
and so we'd like to know it's how big

16
00:00:50,740 --> 00:00:48,950
can a planet like the earth be before it

17
00:00:52,600 --> 00:00:50,750
becomes something more like Uranus or

18
00:00:56,020 --> 00:00:52,610
Neptune where it has that very thick

19
00:00:59,529 --> 00:00:56,030
atmosphere that is an important factor

20
00:01:00,940 --> 00:00:59,539
in the both mass of the planet to answer

21
00:01:04,359 --> 00:01:00,950
that question we first have to consider

22
00:01:05,889 --> 00:01:04,369
how atmospheres form on planets and so

23
00:01:07,270 --> 00:01:05,899
there are three main ways you could form

24
00:01:09,460 --> 00:01:07,280
an atmosphere on a planet the first

25
00:01:10,960 --> 00:01:09,470
being volatile delivery which we see

26
00:01:13,120 --> 00:01:10,970
here where you could have comments or

27
00:01:14,830 --> 00:01:13,130
volatile richa meteorites that come in

28
00:01:16,620 --> 00:01:14,840
you impact on the surface and over time

29
00:01:19,870 --> 00:01:16,630
you can build up oceans in an atmosphere

30
00:01:21,880 --> 00:01:19,880
via these impacts the second option is

31
00:01:23,350 --> 00:01:21,890
this outgassing and if we look at the

32
00:01:25,660 --> 00:01:23,360
earth today we see that volcanoes

33
00:01:27,700 --> 00:01:25,670
outguess lots of gases like co2 and

34
00:01:29,800 --> 00:01:27,710
water vapor and on young planets this

35
00:01:31,300 --> 00:01:29,810
can be much more efficient where you can

36
00:01:33,280 --> 00:01:31,310
have magma oceans that cover the entire

37
00:01:35,620 --> 00:01:33,290
surface of these rocky planets and you

38
00:01:37,780 --> 00:01:35,630

could out get oceans and atmosphere on

39
00:01:39,760 --> 00:01:37,790
very short timescales and so this is

40
00:01:41,170 --> 00:01:39,770
probably how the earth formed its

41
00:01:43,630 --> 00:01:41,180
atmosphere of shortly after formation

42
00:01:46,120 --> 00:01:43,640
and the third option is this disk

43
00:01:47,319 --> 00:01:46,130
accretion and so this is where you have

44
00:01:49,630 --> 00:01:47,329
the disk from which the star on the

45
00:01:50,920 --> 00:01:49,640
planets are forming and you have planets

46
00:01:53,740 --> 00:01:50,930
that are able to accrete hydrogen and

47
00:01:56,080 --> 00:01:53,750
helium directly from that disk when they

48
00:01:57,670 --> 00:01:56,090
form so Jupiter and Saturn likely formed

49
00:02:00,069 --> 00:01:57,680
via this process and were able to

50
00:02:01,749 --> 00:02:00,079
accrete large quantities of hydrogen and

51
00:02:03,460 --> 00:02:01,759
helium from the disk before it

52
00:02:05,399 --> 00:02:03,470
dissipated even Neptune and Uranus

53
00:02:08,560 --> 00:02:05,409
likely accreted a fairly substantial

54
00:02:11,289 --> 00:02:08,570
amount of this gas but it turns out that

55
00:02:12,940 --> 00:02:11,299
even the smallest planets can accrete

56
00:02:14,380 --> 00:02:12,950
this hydrogen and helium from the disk

57
00:02:15,970 --> 00:02:14,390
before it dissipates and you only need

58
00:02:17,590 --> 00:02:15,980
to be about one-tenth the mass of the

59
00:02:19,600 --> 00:02:17,600
earth which is about the mass of Mars

60
00:02:21,100 --> 00:02:19,610
and you can start a creating hydrogen

61
00:02:21,880 --> 00:02:21,110
and helium directly from the disk before

62
00:02:23,890 --> 00:02:21,890
it dissipates

63
00:02:24,770 --> 00:02:23,900

and so we call these atmospheres proto

64
00:02:27,350 --> 00:02:24,780
atmospheres

65
00:02:29,059 --> 00:02:27,360
on rocky planet and they could be

66
00:02:30,590 --> 00:02:29,069
thousands of bars at the surface so

67
00:02:32,630 --> 00:02:30,600
these would be very hot atmospheres

68
00:02:34,670 --> 00:02:32,640
which could be very puffy and and light

69
00:02:36,410 --> 00:02:34,680
and extended and if you think about the

70
00:02:38,990 --> 00:02:36,420
modern earth as being the size of an

71
00:02:40,520 --> 00:02:39,000
apple the Earth's atmosphere would be as

72
00:02:42,500 --> 00:02:40,530
thick as just the skin on that Apple so

73
00:02:43,820 --> 00:02:42,510
very small but if you think about an

74
00:02:45,290 --> 00:02:43,830
earth-like planet with a proto

75
00:02:47,330 --> 00:02:45,300
atmosphere like this the atmosphere

76
00:02:49,340 --> 00:02:47,340
could extend many times the radius of

77
00:02:50,840 --> 00:02:49,350
the planet outwards so if you were an

78
00:02:52,010 --> 00:02:50,850
observer of one of these planets and you

79
00:02:54,229 --> 00:02:52,020
were to look at say an earth-like planet

80
00:02:56,090 --> 00:02:54,239
with a proto atmosphere you wouldn't see

81
00:02:57,380 --> 00:02:56,100
a rocky planet what you would see is

82
00:02:59,300 --> 00:02:57,390
something that looked more like Jupiter

83
00:03:01,670 --> 00:02:59,310
in terms of density but it would just be

84
00:03:04,340 --> 00:03:01,680
much less massive and since we're

85
00:03:06,920 --> 00:03:04,350
focused on habitability these planets

86
00:03:08,570 --> 00:03:06,930
are not habitable and any way that I

87
00:03:10,070 --> 00:03:08,580
could imagine the temperature at the

88
00:03:15,080 --> 00:03:10,080

surface would be much too hot for liquid

89
00:03:17,720 --> 00:03:15,090
water to exist in to exist and so if we

90
00:03:19,820 --> 00:03:17,730
look at the available exoplanet data if

91
00:03:21,229 --> 00:03:19,830
we if we look at these these planets

92
00:03:24,229 --> 00:03:21,239
these small mass planets that we see

93
00:03:25,759 --> 00:03:24,239
down here on the lower portion what

94
00:03:27,500 --> 00:03:25,769
we're seeing in this plot is mass versus

95
00:03:29,690 --> 00:03:27,510
radius so each of these dots represents

96
00:03:31,280 --> 00:03:29,700
an exoplanet and if we make the

97
00:03:32,840 --> 00:03:31,290
assumption that all planets initially

98
00:03:34,370 --> 00:03:32,850
formed with proto atmospheres and we

99
00:03:36,440 --> 00:03:34,380
said there's no real barrier for them to

100
00:03:38,539 --> 00:03:36,450
form so if we assume that all planets

101
00:03:40,160 --> 00:03:38,549
form with those atmospheres then we

102
00:03:42,229 --> 00:03:40,170
would expect all planets to form along

103
00:03:44,330 --> 00:03:42,239
this hydrogen line here or close to it

104
00:03:46,220 --> 00:03:44,340
and each of these lines you can think of

105
00:03:48,500 --> 00:03:46,230
as a contour of constant density so

106
00:03:49,850 --> 00:03:48,510
planets that are on this hydrogen line

107
00:03:52,100 --> 00:03:49,860
have a lot of hydrogen and helium in

108
00:03:53,420 --> 00:03:52,110
them water is the blue line and planets

109
00:03:56,000 --> 00:03:53,430
which you see right here is the earth

110
00:03:58,640 --> 00:03:56,010
and Venus on this rocky line right here

111
00:04:00,590 --> 00:03:58,650
those are the rocky planets and so we

112
00:04:02,750 --> 00:04:00,600
see here is that we only have these

113
00:04:04,400 --> 00:04:02,760

low-mass planets that are falling off of

114
00:04:06,620 --> 00:04:04,410
this hydrogen line towards this rocky

115
00:04:08,660 --> 00:04:06,630
composition and if we look at the zoomed

116
00:04:10,370 --> 00:04:08,670
in version which is just a low match the

117
00:04:12,860 --> 00:04:10,380
low mass region of this same plot down

118
00:04:15,500 --> 00:04:12,870
here the largest rocky planet that we

119
00:04:17,960 --> 00:04:15,510
see is this 55 Cancri E and that's about

120
00:04:20,449 --> 00:04:17,970
eight to ten Earth masses and the radius

121
00:04:22,430 --> 00:04:20,459
on that planet is in a 1.6 1.7 Earth

122
00:04:24,200 --> 00:04:22,440
radii and this plot is a little bit

123
00:04:26,060 --> 00:04:24,210
dated but even if you were to put the

124
00:04:28,640 --> 00:04:26,070
latest exoplanet data on here the same

125
00:04:31,340 --> 00:04:28,650
trend is visible or this entire portion

126
00:04:33,890 --> 00:04:31,350
of this plot is empty we don't see these

127
00:04:36,200 --> 00:04:33,900
large mass rocky planets that just don't

128
00:04:38,050 --> 00:04:36,210
exist so then why is it that these small

129
00:04:39,550 --> 00:04:38,060
planets don't have atmospheres

130
00:04:41,020 --> 00:04:39,560
these stick proto atmospheres while

131
00:04:43,870 --> 00:04:41,030
these larger mass planets are able to

132
00:04:45,550 --> 00:04:43,880
retain those and so one way that that

133
00:04:47,680 --> 00:04:45,560
we've found that can explain that is

134
00:04:50,170 --> 00:04:47,690
through atmospheric escape via

135
00:04:52,000 --> 00:04:50,180
hydrodynamic escape and so hydrodynamic

136
00:04:53,680 --> 00:04:52,010
escape is a pressure driven thermal loss

137
00:04:55,090 --> 00:04:53,690
process where your atmosphere becomes

138
00:04:57,700 --> 00:04:55,100

heated and in this case we're

139
00:04:59,950 --> 00:04:57,710
considering heating by XUV where the XUV

140
00:05:01,690 --> 00:04:59,960
is x-ray and UV photons from the host

141
00:05:03,400 --> 00:05:01,700
star so that comes in and heats the

142
00:05:05,350 --> 00:05:03,410
atmosphere of your planet the atmosphere

143
00:05:06,790 --> 00:05:05,360
starts to expand and it expands so

144
00:05:09,010 --> 00:05:06,800
rapidly that the atmosphere just sort of

145
00:05:10,900 --> 00:05:09,020
puffs off into space so you can remove

146
00:05:13,480 --> 00:05:10,910
the entire proto atmosphere from small

147
00:05:15,400 --> 00:05:13,490
planets very quickly via this process on

148
00:05:17,860 --> 00:05:15,410
timescales of just a few million years I

149
00:05:19,990 --> 00:05:17,870
borrowed a an animation of this from the

150
00:05:22,240 --> 00:05:20,000
LPO where you can see this hydrodynamic

151
00:05:23,920 --> 00:05:22,250
escape happening to a planet orbiting a

152
00:05:25,720 --> 00:05:23,930
sun-like star and what you're seeing

153
00:05:27,910 --> 00:05:25,730
with that light blue that's atmosphere

154
00:05:29,380 --> 00:05:27,920
being blown off from the star and this

155
00:05:31,150 --> 00:05:29,390
is similar to what happens on comets

156
00:05:32,860 --> 00:05:31,160
that enter the inner solar system where

157
00:05:35,050 --> 00:05:32,870
they shed mass to remain an energy

158
00:05:38,140 --> 00:05:35,060
balance so we took the equations that

159
00:05:40,720 --> 00:05:38,150
describe this hydrodynamic escape and we

160
00:05:42,880 --> 00:05:40,730
put together a simple energy limited

161
00:05:44,320 --> 00:05:42,890
hydrodynamic escape model where we

162
00:05:45,520 --> 00:05:44,330
assumed that all these rocky planets are

163
00:05:47,530 --> 00:05:45,530

forming with those stick proto

164
00:05:50,050 --> 00:05:47,540
atmospheres and we put them very close

165
00:05:51,280 --> 00:05:50,060
to a sun-like star at point 1 au and

166
00:05:52,660 --> 00:05:51,290
we're putting them close in since the

167
00:05:56,320 --> 00:05:52,670
goal is to figure out how big a rocky

168
00:05:57,520 --> 00:05:56,330
planet can be and sort of what will what

169
00:05:59,260 --> 00:05:57,530
will it take to evolve it to a rocky

170
00:06:00,910 --> 00:05:59,270
planet status and so putting them close

171
00:06:03,040 --> 00:06:00,920
in will make them very hot and expose

172
00:06:05,080 --> 00:06:03,050
them to a lot of that UV radiation which

173
00:06:07,180 --> 00:06:05,090
will drive off their atmosphere then to

174
00:06:08,860 --> 00:06:07,190
calculate the loss rate from the planet

175
00:06:10,690 --> 00:06:08,870
we have to specify 7 model parameters

176
00:06:14,260 --> 00:06:10,700
which are shown in this table which

177
00:06:16,540 --> 00:06:14,270
specify the temperature the XUV flux the

178
00:06:18,370 --> 00:06:16,550
initial atmospheric mass fraction we

179
00:06:19,630 --> 00:06:18,380
need to know the escape efficiency which

180
00:06:21,850 --> 00:06:19,640
you can think of as just being the

181
00:06:23,800 --> 00:06:21,860
fraction of that incoming x UV radiation

182
00:06:26,080 --> 00:06:23,810
that goes into driving the atmospheric

183
00:06:28,360 --> 00:06:26,090
escape then the pressure at the base of

184
00:06:29,680 --> 00:06:28,370
the thermosphere is where that X UV

185
00:06:31,750 --> 00:06:29,690
radiation is absorbed in the atmosphere

186
00:06:33,340 --> 00:06:31,760
you need to know the specific gas

187
00:06:34,690 --> 00:06:33,350
constant for the atmosphere which you

188
00:06:37,270 --> 00:06:34,700

can think of as just telling you how

189
00:06:39,550 --> 00:06:37,280
light the atmosphere is and then the XUV

190
00:06:41,170 --> 00:06:39,560
saturation time and so the XUV

191
00:06:43,810 --> 00:06:41,180
saturation time is the period during

192
00:06:46,030 --> 00:06:43,820
which the host star remains at a peak

193
00:06:47,710 --> 00:06:46,040
XUV emissions and so forth unlike stars

194
00:06:50,620 --> 00:06:47,720
this is about a hundred million years

195
00:06:52,250 --> 00:06:50,630
and so during that time the XUV flux is

196
00:06:54,410 --> 00:06:52,260
maximal and then after

197
00:06:56,510 --> 00:06:54,420
of that period it dips off exponentially

198
00:07:00,080 --> 00:06:56,520
so most of the mass loss is going to

199
00:07:01,550 --> 00:07:00,090
occur during this time so we can select

200
00:07:03,110 --> 00:07:01,560
from the you know these seven parameters

201
00:07:04,460 --> 00:07:03,120
for our model and if we run it we

202
00:07:06,230 --> 00:07:04,470
generate something that looks like this

203
00:07:08,810 --> 00:07:06,240
so we're seeing here again as the mass

204
00:07:11,120 --> 00:07:08,820
versus radius and this - contour here

205
00:07:13,040 --> 00:07:11,130
represents an earthlike density so any

206
00:07:16,010 --> 00:07:13,050
planet that falls below that is a rocky

207
00:07:17,450 --> 00:07:16,020
planet and any planet above it is a low

208
00:07:20,240 --> 00:07:17,460
density planet that we would consider

209
00:07:21,860 --> 00:07:20,250
guest enveloped and so we see here is

210
00:07:23,780 --> 00:07:21,870
that the small mass planets very quickly

211
00:07:25,880 --> 00:07:23,790
lose their atmospheres and fall below

212
00:07:27,620 --> 00:07:25,890
this line well the larger mass planets

213
00:07:30,500 --> 00:07:27,630

are able to retain them for extended

214
00:07:32,600 --> 00:07:30,510
periods and this is dependent on what

215
00:07:34,640 --> 00:07:32,610
parameters we select from that table so

216
00:07:36,410 --> 00:07:34,650
we took our model and we ran it for

217
00:07:38,240 --> 00:07:36,420
10000 parameter combinations and

218
00:07:39,980 --> 00:07:38,250
calculated where that cutoff between

219
00:07:41,690 --> 00:07:39,990
those rocky and gas envelope planets

220
00:07:44,300 --> 00:07:41,700
occurred and so that's what we see in

221
00:07:47,480 --> 00:07:44,310
this histogram here and so the mean for

222
00:07:50,630 --> 00:07:47,490
our model is that this 1.6 1.7 Earth

223
00:07:52,370 --> 00:07:50,640
radii with the error bar showing the 1

224
00:07:54,590 --> 00:07:52,380
sigma confidence interval on that

225
00:07:56,660 --> 00:07:54,600
calculation the red dot is from the

226
00:07:59,750 --> 00:07:56,670
Rogers at all 2015 paper where they

227
00:08:01,460 --> 00:07:59,760
looked at exoplanet data and found that

228
00:08:03,860 --> 00:08:01,470
there was a transition between rocky and

229
00:08:06,530 --> 00:08:03,870
gas and below planets at about 1.6 Earth

230
00:08:08,600 --> 00:08:06,540
radii was there 95% confidence interval

231
00:08:10,070 --> 00:08:08,610
on that measurement so what we see here

232
00:08:11,300 --> 00:08:10,080
is that there's this strong agreement

233
00:08:12,560 --> 00:08:11,310
between what our simple model would

234
00:08:14,720 --> 00:08:12,570
predict for the cutoff between rocky

235
00:08:18,230 --> 00:08:14,730
planets and what actually observed in

236
00:08:20,840 --> 00:08:18,240
the exoplanet data and just if we look

237
00:08:22,520 --> 00:08:20,850
back in at the end of data here again we

238
00:08:26,090 --> 00:08:22,530

can see that it does agree right around

239
00:08:27,350 --> 00:08:26,100
that 1.6 1.7 cutoff and just to give

240
00:08:28,700 --> 00:08:27,360
this a little bit of context of why this

241
00:08:30,590 --> 00:08:28,710
is important and why we should care

242
00:08:32,000 --> 00:08:30,600
about these rocky planet sizes well

243
00:08:33,469 --> 00:08:32,010
rocky planets can be habitable so it's

244
00:08:35,690 --> 00:08:33,479
interesting just to know how big they

245
00:08:37,610 --> 00:08:35,700
could possibly be and it's also helpful

246
00:08:39,200 --> 00:08:37,620
for future observations since we often

247
00:08:41,810 --> 00:08:39,210
detect exoplanets through a transit

248
00:08:43,100 --> 00:08:41,820
which is shown on this cartoon here and

249
00:08:44,660 --> 00:08:43,110
the thing that you measure in that is

250
00:08:46,100 --> 00:08:44,670
often the dip in the planet the

251
00:08:48,410 --> 00:08:46,110
Starlight as the planet passes in front

252
00:08:51,050 --> 00:08:48,420
and the amount of solid that's blocked

253
00:08:52,460 --> 00:08:51,060
tells you of the radius of the planet so

254
00:08:53,750 --> 00:08:52,470
often that's all you'll know is just the

255
00:08:54,890 --> 00:08:53,760
radius so being able to determine

256
00:08:57,380 --> 00:08:54,900
whether or not a planet is worthy of

257
00:08:58,610 --> 00:08:57,390
follow-up studies could be helped in

258
00:09:01,580 --> 00:08:58,620
this manner of looking for earth-like

259
00:09:03,430 --> 00:09:01,590
planets so put up a summary and take any

260
00:09:10,180 --> 00:09:03,440
questions thank you

261
00:09:11,530 --> 00:09:10,190
I think we have lots of time for

262
00:09:15,249 --> 00:09:11,540
questions so please come up to the

263
00:09:17,259 --> 00:09:15,259

microphone if you have questions thanks

264
00:09:19,540 --> 00:09:17,269
that I talk that are really interesting

265
00:09:21,429 --> 00:09:19,550
I'm going to ask you the question that

266
00:09:25,329 --> 00:09:21,439
is not supposed to be asked which is

267
00:09:28,240 --> 00:09:25,339
what about magnetic fields because what

268
00:09:30,519 --> 00:09:28,250
I mean is that they're the atmospheric

269
00:09:32,110 --> 00:09:30,529
loss from pressure because I noticed a

270
00:09:34,689 --> 00:09:32,120
lot of your plots are as a function of

271
00:09:37,720 --> 00:09:34,699
radius mass but not there's a function

272
00:09:39,790 --> 00:09:37,730
of distance or insulation flux and I

273
00:09:41,949 --> 00:09:39,800
would imagine that under many

274
00:09:46,480 --> 00:09:41,959
circumstances the the atmospheric loss

275
00:09:51,809 --> 00:09:46,490
from from the from the stellar winds

276
00:09:53,949 --> 00:09:51,819
will be larger than that from the XUV

277
00:09:56,139 --> 00:09:53,959
processes if the stellar wind could be

278
00:09:58,150 --> 00:09:56,149
could be very effective especially these

279
00:09:59,230 --> 00:09:58,160
close distances distances and that's not

280
00:10:01,749 --> 00:09:59,240
something that we've put into the model

281
00:10:03,519 --> 00:10:01,759
although if it became sufficiently rapid

282
00:10:04,509 --> 00:10:03,529
than you'd be removing materials so

283
00:10:06,939 --> 00:10:04,519
quickly that it would actually be a

284
00:10:08,220 --> 00:10:06,949
hydrodynamic eventually you sort of

285
00:10:11,230 --> 00:10:08,230
reach that cutoff if you were removing

286
00:10:13,360 --> 00:10:11,240
material so quickly so I'm not sure how

287
00:10:15,309 --> 00:10:13,370
exactly adding magnetic fields in would

288
00:10:16,509 --> 00:10:15,319

impact our model I imagine you may slow

289
00:10:18,160 --> 00:10:16,519
down a little bit and that's definitely

290
00:10:19,689 --> 00:10:18,170
an area for future research but it's not

291
00:10:21,240 --> 00:10:19,699
included at all in this model which

292
00:10:24,460 --> 00:10:21,250
we're just looking at the energy limited

293
00:10:25,749 --> 00:10:24,470
for thermally driven escape but that

294
00:10:27,759 --> 00:10:25,759
it's very of an excellent point and we

295
00:10:29,800 --> 00:10:27,769
did only look at one orbital distance we

296
00:10:31,210 --> 00:10:29,810
put them at that point one au which is

297
00:10:32,800 --> 00:10:31,220
sort of an inner limit where you can

298
00:10:35,019 --> 00:10:32,810
have a hydrostatic rebound lower

299
00:10:38,920 --> 00:10:35,029
atmosphere for these planets around

300
00:10:40,990 --> 00:10:38,930
sun-like stars okay thanks yeah there

301
00:10:43,329 --> 00:10:41,000
you go in a nice talk I was just

302
00:10:46,480 --> 00:10:43,339
wondering if you've tested how sensitive

303
00:10:48,639 --> 00:10:46,490
your results are at the exact escape

304
00:10:50,139 --> 00:10:48,649
efficiency that you assumed and if you

305
00:10:52,150 --> 00:10:50,149
assume some kind of prior and notice the

306
00:10:55,240 --> 00:10:52,160
range is like point one to point six for

307
00:10:56,980 --> 00:10:55,250
a de to do something like a flat prior

308
00:10:59,439 --> 00:10:56,990
did you play around with it I'm just

309
00:11:03,009 --> 00:10:59,449
wondering aside what we just significant

310
00:11:04,600 --> 00:11:03,019
it is a linear dependence on what we

311
00:11:05,860 --> 00:11:04,610
assumed for that escape efficiency and

312
00:11:08,559 --> 00:11:05,870
so we just looked at a uniform

313
00:11:09,759 --> 00:11:08,569

distribution across that which there's

314
00:11:11,829 --> 00:11:09,769
probably a better distribution to

315
00:11:13,809 --> 00:11:11,839
consider when looking at escape but for

316
00:11:16,319 --> 00:11:13,819
this model it was just uniform and so

317
00:11:19,590 --> 00:11:16,329
the linear dependence on that with

318
00:11:22,280 --> 00:11:19,600
and yeah I think that there are papers

319
00:11:25,850 --> 00:11:22,290
showing that for the Kepler population

320
00:11:27,780 --> 00:11:25,860
something like point one matches the

321
00:11:29,729 --> 00:11:27,790
population at the population level

322
00:11:31,859 --> 00:11:29,739
median Valley point one matches it so I

323
00:11:34,769 --> 00:11:31,869
wonder if that would make your histogram

324
00:11:36,629 --> 00:11:34,779
even more consistent with the Rogers

325
00:11:42,239 --> 00:11:36,639
video when I play around with that thank

326
00:11:45,509 --> 00:11:42,249
you what about impacts knocking off the

327
00:11:48,329 --> 00:11:45,519
atmosphere climate ID hits the planet

328
00:11:49,889 --> 00:11:48,339
and blows the whole atmosphere away yes

329
00:11:51,239 --> 00:11:49,899
so that it could definitely happen if

330
00:11:52,829 --> 00:11:51,249
you had two planets collide you could

331
00:11:54,780 --> 00:11:52,839
probably remove an atmosphere very

332
00:11:56,759 --> 00:11:54,790
quickly impacts do tend to be less

333
00:11:58,889 --> 00:11:56,769
important for the larger mass planet so

334
00:12:01,769 --> 00:11:58,899
by the time you reach six to seven Earth

335
00:12:03,030 --> 00:12:01,779
masses it seems less likely that you

336
00:12:05,220 --> 00:12:03,040
could have impacts that are removing the

337
00:12:06,720 --> 00:12:05,230
entire atmosphere so then this

338
00:12:08,039 --> 00:12:06,730

hydrodynamic escape becomes more

339
00:12:09,809 --> 00:12:08,049
important which is where we see sort of

340
00:12:11,669 --> 00:12:09,819
that final cut off but for those lower

341
00:12:12,989 --> 00:12:11,679
mass planets especially then having

342
00:12:19,079 --> 00:12:12,999
impacts could remove your atmosphere

343
00:12:22,109 --> 00:12:19,089
very quickly thanks great awk I think

344
00:12:24,239 --> 00:12:22,119
there it seems parent that this is sort

345
00:12:26,549 --> 00:12:24,249
of an upper limit as in there are many

346
00:12:27,989 --> 00:12:26,559
other ways to remove atmospheres but I'm

347
00:12:30,419 --> 00:12:27,999
actually more interested in the other

348
00:12:33,359 --> 00:12:30,429
question is a number of the planets that

349
00:12:35,159 --> 00:12:33,369
are quite low mass seem to have very

350
00:12:36,840 --> 00:12:35,169
puffy atmospheres I mean a number of

351
00:12:39,090 --> 00:12:36,850
them that have been detected clearly

352
00:12:41,369 --> 00:12:39,100
within the error bars fit above that

353
00:12:42,809 --> 00:12:41,379
range not all I mean it's only a few but

354
00:12:45,329 --> 00:12:42,819
I guess have you guys thought about ways

355
00:12:48,900 --> 00:12:45,339
to actually preserve even for low-mass

356
00:12:50,579 --> 00:12:48,910
planets that puffy atmosphere actually

357
00:12:52,229 --> 00:12:50,589
we haven't looked at how to preserve

358
00:12:53,669 --> 00:12:52,239
those atmospheres at this point and what

359
00:12:54,749 --> 00:12:53,679
actually motivated this work was looking

360
00:12:56,460 --> 00:12:54,759
at some of those very low-mass planets

361
00:12:58,319 --> 00:12:56,470
and trying to figure out why they still

362
00:13:00,109 --> 00:12:58,329
had atmospheres since some of them have

363
00:13:02,340 --> 00:13:00,119

densities you know that are less than

364
00:13:04,019 --> 00:13:02,350
point zero five grams per cubic

365
00:13:05,939 --> 00:13:04,029
centimeter or something I'm from these

366
00:13:07,829 --> 00:13:05,949
planets so we're trying to model

367
00:13:09,749 --> 00:13:07,839
initially how those plans could have

368
00:13:11,009 --> 00:13:09,759
atmospheres and that's what we ended up

369
00:13:12,600 --> 00:13:11,019
with these escape models that are

370
00:13:14,369 --> 00:13:12,610
showing this cutoff between the rocky

371
00:13:15,239 --> 00:13:14,379
and gas envelope worlds but that's a

372
00:13:16,769 --> 00:13:15,249
really good question that I think

373
00:13:18,659 --> 00:13:16,779
definitely deserves future study is how

374
00:13:19,919 --> 00:13:18,669
you can have these really low density

375
00:13:21,770 --> 00:13:19,929
low-mass planets that are retaining

376
00:13:26,760 --> 00:13:21,780
their thick atmospheres

377
00:13:29,070 --> 00:13:26,770
do we have so following up on obvious

378
00:13:32,160 --> 00:13:29,080
question does that preservation of

379
00:13:34,530 --> 00:13:32,170
atmosphere depend upon the age of the

380
00:13:36,030 --> 00:13:34,540
star or radio system because it takes up

381
00:13:38,670 --> 00:13:36,040
100 million years for you to remove

382
00:13:40,200 --> 00:13:38,680
atmosphere right right so it does depend

383
00:13:42,540 --> 00:13:40,210
on the age of the stars so we're using

384
00:13:45,390 --> 00:13:42,550
the XUV flux which on these sun-like

385
00:13:46,950 --> 00:13:45,400
stars is really in that peak for about a

386
00:13:48,870 --> 00:13:46,960
hundred million years and after that

387
00:13:50,640 --> 00:13:48,880
it's going to drop off exponentially so

388
00:13:52,470 --> 00:13:50,650

your your mass whilst driven by that

389
00:13:53,910 --> 00:13:52,480
flux is going to drop off with it so if

390
00:13:55,530 --> 00:13:53,920
a planet were to form further out and

391
00:13:57,270 --> 00:13:55,540
migrated inwards after that that

392
00:13:59,070 --> 00:13:57,280
actually be saturation then it would

393
00:14:01,290 --> 00:13:59,080
definitely not be subjected to the same

394
00:14:03,300 --> 00:14:01,300
level of mass loss and that's something

395
00:14:04,710 --> 00:14:03,310
that we could consider in this model as

396
00:14:07,920 --> 00:14:04,720
well in the future