

The background features a large, glowing red star with surface activity, a smaller black circle in the upper right, and a dark red city skyline silhouette at the bottom. The text is centered in white.

**RADIUS VALLEY VIA CORE-POWERED
MASS-LOSS MECHANISM**
HILKE SCHLICHTING

1
00:00:09,209 --> 00:00:06,680

[Music]

2
00:00:10,500 --> 00:00:09,219

thank you very much thank you very much

3
00:00:13,260 --> 00:00:10,510

for the organizers for putting together

4
00:00:14,640 --> 00:00:13,270

this very interesting program and for

5
00:00:15,990 --> 00:00:14,650

giving me the opportunity to tell you a

6
00:00:19,109 --> 00:00:16,000

little bit about some of the research

7
00:00:21,599 --> 00:00:19,119

we've been doing in my group I had

8
00:00:25,290 --> 00:00:21,609

submitted a much longer title more

9
00:00:27,150 --> 00:00:25,300

detailed maybe more complicated and when

10
00:00:28,679 --> 00:00:27,160

I looked at the program I found it

11
00:00:30,599 --> 00:00:28,689

shortened to this and I thought just

12
00:00:31,679 --> 00:00:30,609

like you don't argue with an editor of

13
00:00:33,330 --> 00:00:31,689

nature when they're willing to accept

14

00:00:35,700 --> 00:00:33,340

your paper and want to change your title

15

00:00:39,090 --> 00:00:35,710

I thought I'm not gonna argue with the

16

00:00:41,310 --> 00:00:39,100

organizers and basically this is my talk

17

00:00:46,020 --> 00:00:41,320

summarized and in a smaller number of

18

00:00:48,420 --> 00:00:46,030

words yes I will tell you about some

19

00:00:50,700 --> 00:00:48,430

work in which we discovered that you can

20

00:00:52,920 --> 00:00:50,710

sort of reproduce the observed radius

21

00:00:55,320 --> 00:00:52,930

valley that separates the super earth

22

00:01:00,800 --> 00:00:55,330

and the subducting population just from

23

00:01:04,079 --> 00:01:00,810

a plan information point of view so

24

00:01:05,310 --> 00:01:04,089

thanks to the - very nice previous talks

25

00:01:07,560 --> 00:01:05,320

I don't really have to do much

26

00:01:09,060 --> 00:01:07,570

introduction so the population that I'll

27

00:01:11,310 --> 00:01:09,070

be talking about are these super Earths

28

00:01:13,140 --> 00:01:11,320

and sub Neptune's these planets that as

29

00:01:15,240 --> 00:01:13,150

up to date are the most common planets

30

00:01:16,860 --> 00:01:15,250

that we have been discovered and they're

31

00:01:20,100 --> 00:01:16,870

almost everywhere as I'm sure you know

32

00:01:22,260 --> 00:01:20,110

and they're intriguing they were

33

00:01:24,000 --> 00:01:22,270

entering for me for a long time somebody

34

00:01:27,210 --> 00:01:24,010

who's been studying transformation for

35

00:01:28,590 --> 00:01:27,220

many years because these planets are so

36

00:01:30,930 --> 00:01:28,600

different for what we have in our solar

37

00:01:34,520 --> 00:01:30,940

system right typically they are in

38

00:01:37,020 --> 00:01:34,530

between the size of Earth and Neptune on

39

00:01:39,540 --> 00:01:37,030

orbital periods that are built in the

40

00:01:41,550 --> 00:01:39,550

orbit of mercury um in addition we know

41

00:01:42,870 --> 00:01:41,560

for several of those planets that the

42

00:01:44,820 --> 00:01:42,880

radii are so large

43

00:01:47,100 --> 00:01:44,830

given their masses that they must have

44

00:01:49,440 --> 00:01:47,110

about a few percent of the total mass

45

00:01:52,050 --> 00:01:49,450

budget is sort of a hydrogen helium

46

00:01:53,520 --> 00:01:52,060

envelope and so we were just curious to

47

00:01:56,280 --> 00:01:53,530

see whether we can understand the

48

00:01:58,560 --> 00:01:56,290

formation of these planets by sort of

49

00:02:01,080 --> 00:01:58,570

self consistently treating the gas

50

00:02:05,580 --> 00:02:01,090

accretion and the subsequent evolution

51
00:02:05,910 --> 00:02:05,590
and laughs from those planets so here we

52
00:02:08,190 --> 00:02:05,920
go

53
00:02:11,550 --> 00:02:08,200
so when you form a planet you start

54
00:02:13,019 --> 00:02:11,560
accreting a core in the disk one of the

55
00:02:15,059 --> 00:02:13,029
key things you need to do is right you

56
00:02:17,980 --> 00:02:15,069
need to basically you're converting

57
00:02:21,070 --> 00:02:17,990
loads of gravitational binding energy

58
00:02:24,850 --> 00:02:21,080
into heat as you're accusing your rocky

59
00:02:27,190 --> 00:02:24,860
core and the seat can very effectively

60
00:02:28,780 --> 00:02:27,200
be transported away if you're doing this

61
00:02:31,570 --> 00:02:28,790
in a disc when you initially have a very

62
00:02:34,450 --> 00:02:31,580
small body if that body is smaller then

63
00:02:36,730 --> 00:02:34,460

basically the Bondi radius or the radius

64

00:02:39,130 --> 00:02:36,740

where the thermal speed equals escape

65

00:02:40,450 --> 00:02:39,140

speed of your planet if that's inside

66

00:02:42,760 --> 00:02:40,460

the physical rays of the planet your gas

67

00:02:45,070 --> 00:02:42,770

will just flow by carry away the heat

68

00:02:48,580 --> 00:02:45,080

and you can affect very efficiently cool

69

00:02:50,920 --> 00:02:48,590

you're growing embryo however once you

70

00:02:52,800 --> 00:02:50,930

grow a core we're basically the physical

71

00:02:58,480 --> 00:02:52,810

size of your planet becomes comparable

72

00:03:01,060 --> 00:02:58,490

or smaller than the spondee radius then

73

00:03:02,890 --> 00:03:01,070

you start holding on to the gas because

74

00:03:05,950 --> 00:03:02,900

now there is a region outside the

75

00:03:07,840 --> 00:03:05,960

physical core radius of your planet up

76

00:03:11,890 --> 00:03:07,850

to which the gas will be gravitationally

77

00:03:14,920 --> 00:03:11,900

bound to you and once this happened any

78

00:03:17,620 --> 00:03:14,930

in you know you're still accreting your

79

00:03:19,480 --> 00:03:17,630

core so you're still heating your core

80

00:03:21,190 --> 00:03:19,490

but any of that heat can no longer

81

00:03:23,950 --> 00:03:21,200

easily be carried away by the gas

82

00:03:26,260 --> 00:03:23,960

flowing by but no the gas that you're

83

00:03:27,910 --> 00:03:26,270

creating and holding on to starts to act

84

00:03:30,430 --> 00:03:27,920

like a thermal blanket and now you have

85

00:03:33,430 --> 00:03:30,440

to think of your planet as a couple

86

00:03:36,760 --> 00:03:33,440

system your atmosphere in your core and

87

00:03:38,080 --> 00:03:36,770

so as a consequence the course that are

88

00:03:40,150 --> 00:03:38,090

underlying these hydrogen helium

89

00:03:43,240 --> 00:03:40,160

envelopes sort of have the maximum

90

00:03:44,710 --> 00:03:43,250

temperature that can have and still hold

91

00:03:46,630 --> 00:03:44,720

on to hydrogen Amandla because there

92

00:03:49,000 --> 00:03:46,640

would be any hotter the envelope will be

93

00:03:51,850 --> 00:03:49,010

unbound and then you could cool until

94

00:03:54,040 --> 00:03:51,860

you find that envelope to you again and

95

00:03:57,190 --> 00:03:54,050

so you know that the temperature of

96

00:03:58,840 --> 00:03:57,200

these course it's between 10 to the 4

97

00:04:01,270 --> 00:03:58,850

and 10 to the 5 Kelvin not depends on

98

00:04:04,060 --> 00:04:01,280

whether you are in earth or 10 times the

99

00:04:09,190 --> 00:04:04,070

earth mass and then on top you have

100

00:04:10,810 --> 00:04:09,200

sitting this hydrogen helium envelope so

101

00:04:12,160 --> 00:04:10,820

what's the structure of this envelope

102

00:04:14,320 --> 00:04:12,170

and how do you create this envelope so

103

00:04:17,500 --> 00:04:14,330

initially you just have whatever is

104

00:04:19,180 --> 00:04:17,510

found within your Bondi radius and you

105

00:04:20,979 --> 00:04:19,190

can do some simple math and count up how

106

00:04:23,560 --> 00:04:20,989

much mass that is and you find but

107

00:04:26,050 --> 00:04:23,570

typically less than point one percent of

108

00:04:27,640 --> 00:04:26,060

the total planet mass so it's cute if

109

00:04:30,820 --> 00:04:27,650

you just want some envelope but it's not

110

00:04:31,750 --> 00:04:30,830

enough right to form these sub Neptune's

111

00:04:33,190 --> 00:04:31,760

which have like

112

00:04:35,770 --> 00:04:33,200

few percent of the total mass in

113

00:04:36,160 --> 00:04:35,780

hydrogen helium you have to do something

114

00:04:38,350 --> 00:04:36,170

else

115

00:04:39,760 --> 00:04:38,360

to accrete more gas so what is the

116

00:04:40,930 --> 00:04:39,770

something else but something else is

117

00:04:43,750 --> 00:04:40,940

that you just have to wait a little bit

118

00:04:46,000 --> 00:04:43,760

for your envelope to cool and contract

119

00:04:48,760 --> 00:04:46,010

as your envelopes that's the cookin

120

00:04:51,400 --> 00:04:48,770

contract you can pile on more gas on the

121

00:04:54,340 --> 00:04:51,410

outside and see your planet keep Kim

122

00:04:56,680 --> 00:04:54,350

keep growing its envelope mass so in

123

00:04:58,570 --> 00:04:56,690

detail what you have is your envelope

124

00:05:00,880 --> 00:04:58,580

structure is mostly at about eight

125

00:05:02,530 --> 00:05:00,890

because the energy is being transported

126

00:05:04,480 --> 00:05:02,540

by convection but then you start

127

00:05:06,580 --> 00:05:04,490

developing a small outer range of layer

128

00:05:09,220 --> 00:05:06,590

that basically is where your envelope

129

00:05:12,580 --> 00:05:09,230

shrinks and contracts such that you can

130

00:05:15,600 --> 00:05:12,590

accrete more material and so interesting

131

00:05:17,860 --> 00:05:15,610

enough in this face of graphic creations

132

00:05:19,180 --> 00:05:17,870

you're a creationist basically just

133

00:05:21,190 --> 00:05:19,190

limited by cooling because if you can

134

00:05:24,940 --> 00:05:21,200

cool faster you just can create more gas

135

00:05:26,170 --> 00:05:24,950

faster and so what is nice it is was

136

00:05:27,940 --> 00:05:26,180

this understanding you can write down

137

00:05:31,150 --> 00:05:27,950

what the typical envelope mass that you

138

00:05:32,710 --> 00:05:31,160

can it create is given other parameters

139

00:05:35,110 --> 00:05:32,720

of your system so that's what I've shown

140

00:05:37,210 --> 00:05:35,120

here F is just a fraction of the total

141

00:05:39,610 --> 00:05:37,220

atmospheric mass to the core math and

142

00:05:41,440 --> 00:05:39,620

you can see not surprisingly it skills

143

00:05:43,210 --> 00:05:41,450

as the mouth of a planet because of you

144

00:05:45,370 --> 00:05:43,220

xx radius right if you're bigger your

145

00:05:47,460 --> 00:05:45,380

body radius is figure and so you have

146

00:05:50,110 --> 00:05:47,470

more region to hold on to an atmosphere

147

00:05:51,550 --> 00:05:50,120

it scale to the disk lifetime because it

148

00:05:55,510 --> 00:05:51,560

sets the timescale you have for a

149

00:05:57,880 --> 00:05:55,520

creation rate and the opacity because

150

00:05:59,440 --> 00:05:57,890

and specifically the opacity at the rate

151
00:06:01,690 --> 00:05:59,450
of convective boundary where you connect

152
00:06:07,840 --> 00:06:01,700
the rate of region of your envelope to

153
00:06:09,400 --> 00:06:07,850
the isothermal radiative region because

154
00:06:11,590 --> 00:06:09,410
that's the bottleneck for cooling right

155
00:06:13,630 --> 00:06:11,600
any heat that wants to escape from the

156
00:06:16,270 --> 00:06:13,640
envelope and your core needs to

157
00:06:17,830 --> 00:06:16,280
basically go from the optic thick to the

158
00:06:20,260 --> 00:06:17,840
thin part at this rate of convective

159
00:06:22,570 --> 00:06:20,270
battery so those two 0 order you can

160
00:06:24,640 --> 00:06:22,580
understand this and the good news is

161
00:06:27,130 --> 00:06:24,650
typical this lifetimes on our planet

162
00:06:29,200 --> 00:06:27,140
masses you can indeed create several

163
00:06:34,000 --> 00:06:29,210

percents of the planets total mass as

164

00:06:36,280 --> 00:06:34,010

hydrogen so that's great one cute site

165

00:06:38,350 --> 00:06:36,290

note because the outer layer of your

166

00:06:40,660 --> 00:06:38,360

planet and these they are almost

167

00:06:43,210 --> 00:06:40,670

isothermal and therefore they have an

168

00:06:44,290 --> 00:06:43,220

close to exponential density profile so

169

00:06:46,300 --> 00:06:44,300

the

170

00:06:48,700 --> 00:06:46,310

atmospheric reed is actually only

171

00:06:51,700 --> 00:06:48,710

logarithmically dependent on the gas

172

00:06:55,059 --> 00:06:51,710

disc density that you have because

173

00:06:57,279 --> 00:06:55,069

that's only how it enters basically into

174

00:07:01,480 --> 00:06:57,289

the equation so it's not super sensitive

175

00:07:04,240 --> 00:07:01,490

to to those details so that's sort of a

176

00:07:06,180 --> 00:07:04,250

nice thing but okay so we should be

177

00:07:09,189 --> 00:07:06,190

happy we can accrete our atmospheres

178

00:07:11,499 --> 00:07:09,199

turns out we don't get to keep all of

179

00:07:13,360 --> 00:07:11,509

the stuff we have accreted the first

180

00:07:16,869 --> 00:07:13,370

thing that's going to happen to us is

181

00:07:19,899 --> 00:07:16,879

the falling the gaskets will go away

182

00:07:22,510 --> 00:07:19,909

eventually and if that happens basically

183

00:07:24,279 --> 00:07:22,520

you lose the pressure support in the

184

00:07:26,830 --> 00:07:24,289

disk and so basically if you know look

185

00:07:29,350 --> 00:07:26,840

at your planet the outer regions of your

186

00:07:31,540 --> 00:07:29,360

atmosphere and because you remove the

187

00:07:35,320 --> 00:07:31,550

gases from the outside will want to

188

00:07:38,680 --> 00:07:35,330

expand into vacuum just because they can

189

00:07:40,450 --> 00:07:38,690

and because of that and because there's

190

00:07:43,800 --> 00:07:40,460

plenty of energy in the inner parts of

191

00:07:47,170 --> 00:07:43,810

the envelope the planet will shed

192

00:07:49,659 --> 00:07:47,180

several tons to up to 70% of all the gas

193

00:07:53,589 --> 00:07:49,669

it just has retreated during the discus

194

00:07:57,430 --> 00:07:53,599

virzal phase as the gases goes away and

195

00:07:58,839 --> 00:07:57,440

so as a result you not only lose several

196

00:08:01,570 --> 00:07:58,849

times of percent of the envelope math

197

00:08:04,779 --> 00:08:01,580

you just accreted but your planet also

198

00:08:06,820 --> 00:08:04,789

fairly rapidly can shrink in size to

199

00:08:09,689 --> 00:08:06,830

size us that are just a few times the

200

00:08:12,040 --> 00:08:09,699

core radius rather than these very large

201
00:08:13,990 --> 00:08:12,050
radio that are comparable to the Baniya

202
00:08:16,930 --> 00:08:14,000
radius and that's because right mass

203
00:08:18,969 --> 00:08:16,940
loss takes away energy and therefore the

204
00:08:24,790 --> 00:08:18,979
remaining material can cool and shrink

205
00:08:26,920 --> 00:08:24,800
more quickly but it's okay right

206
00:08:28,809 --> 00:08:26,930
we still again this is the what you're

207
00:08:30,820 --> 00:08:28,819
left with after this dispersal face

208
00:08:33,490 --> 00:08:30,830
you're still fine because you still get

209
00:08:36,850 --> 00:08:33,500
a percent or a few percent for your

210
00:08:38,800 --> 00:08:36,860
typical planet cases so just remember if

211
00:08:40,300 --> 00:08:38,810
you ever want to form these planets just

212
00:08:42,279 --> 00:08:40,310
make sure that you can create about a

213
00:08:44,860 --> 00:08:42,289

factor of two or more in your initial

214

00:08:47,230 --> 00:08:44,870

envelope mass then you need so that you

215

00:08:51,670 --> 00:08:47,240

okay with losing about half of it during

216

00:08:54,069 --> 00:08:51,680

the gas this parental phase what happens

217

00:08:56,319 --> 00:08:54,079

next was sort of interesting and that we

218

00:08:58,000 --> 00:08:56,329

didn't really expect it until we thought

219

00:09:01,780 --> 00:08:58,010

about it in detail well

220

00:09:03,340 --> 00:09:01,790

now we thought both probably be good now

221

00:09:06,250 --> 00:09:03,350

we get to keep the rest of the envelope

222

00:09:08,230 --> 00:09:06,260

and we're done and in some cases who's

223

00:09:10,660 --> 00:09:08,240

actually true so what we discovered is

224

00:09:12,400 --> 00:09:10,670

from then on they're two different

225

00:09:13,930 --> 00:09:12,410

pathways for your planets they're two

226

00:09:16,150 --> 00:09:13,940

different regimes in which your planet

227

00:09:17,830 --> 00:09:16,160

can cool and contract so tell me about

228

00:09:19,510 --> 00:09:17,840

the more obvious one and the one that

229

00:09:23,680 --> 00:09:19,520

has been studied and love more detail

230

00:09:25,750 --> 00:09:23,690

first so and the first regime when you

231

00:09:29,230 --> 00:09:25,760

look at the total energy budget of the

232

00:09:31,270 --> 00:09:29,240

planet that's available for cooling if

233

00:09:32,800 --> 00:09:31,280

that's dominated by basically the

234

00:09:36,130 --> 00:09:32,810

thermal and variational energy in your

235

00:09:38,200 --> 00:09:36,140

envelope in those cases your planet will

236

00:09:39,640 --> 00:09:38,210

indeed from then onwards just cool and

237

00:09:41,680 --> 00:09:39,650

contract

238

00:09:46,120 --> 00:09:41,690

and you get to keep the atmosphere you

239

00:09:47,410 --> 00:09:46,130

have accreted and this is many of our

240

00:09:50,050 --> 00:09:47,420

solar system planets are still at the

241

00:09:53,110 --> 00:09:50,060

face and the cooling time right can take

242

00:09:54,760 --> 00:09:53,120

Giga years and your planet just cools

243

00:09:56,380 --> 00:09:54,770

and contracts if you look at the profile

244

00:09:58,750 --> 00:09:56,390

right what happens is the radius

245

00:10:01,480 --> 00:09:58,760

collector foundry we'll just move inward

246

00:10:04,720 --> 00:10:01,490

in time and the isothermal region will

247

00:10:08,290 --> 00:10:04,730

expand and it's all good when are you in

248

00:10:10,120 --> 00:10:08,300

this room you're in this regime when the

249

00:10:11,200 --> 00:10:10,130

heat capacity for cooling is dominated

250

00:10:14,020 --> 00:10:11,210

by the envelope wouldn't that

251
00:10:16,090 --> 00:10:14,030
corresponds to typical course that our

252
00:10:18,100 --> 00:10:16,100
model on the earth and a hydrant helium

253
00:10:20,560 --> 00:10:18,110
envelope when you have about five

254
00:10:24,310 --> 00:10:20,570
percent or more of the total mass in

255
00:10:26,560 --> 00:10:24,320
these envelopes more interesting is the

256
00:10:28,360 --> 00:10:26,570
second regime where this is reversed so

257
00:10:29,620 --> 00:10:28,370
if you have only a few percent of the

258
00:10:32,620 --> 00:10:29,630
total mass in the envelope

259
00:10:35,020 --> 00:10:32,630
then you actually have more thermal

260
00:10:37,720 --> 00:10:35,030
energy stored in your core that's

261
00:10:39,610 --> 00:10:37,730
available for cooling then binding

262
00:10:41,920 --> 00:10:39,620
energy of your envelope so what this

263
00:10:44,950 --> 00:10:41,930

means is the fine the envelope will want

264

00:10:47,680 --> 00:10:44,960

to cool and contract of course but as

265

00:10:50,140 --> 00:10:47,690

its am giving away energy and once the

266

00:10:51,640 --> 00:10:50,150

current are basically the same amount of

267

00:10:54,250 --> 00:10:51,650

energy is being resupplied by the

268

00:10:55,930 --> 00:10:54,260

underlying core and instead of

269

00:10:59,590 --> 00:10:55,940

contracting your envelope basically

270

00:11:03,370 --> 00:10:59,600

stalls at this radius and it keeps

271

00:11:05,290 --> 00:11:03,380

losing mass so until you can drain

272

00:11:07,510 --> 00:11:05,300

basically enough energy from the core

273

00:11:10,000 --> 00:11:07,520

that both the envelope and core can cool

274

00:11:11,210 --> 00:11:10,010

significantly you continue this mass

275

00:11:13,610 --> 00:11:11,220

loss and so

276

00:11:16,189 --> 00:11:13,620

this case you can strip the entire

277

00:11:19,249 --> 00:11:16,199

envelope energetically you have enough

278

00:11:20,929 --> 00:11:19,259

energy and it gets easier and easier

279

00:11:24,949 --> 00:11:20,939

from an energy point of view right once

280

00:11:27,079 --> 00:11:24,959

you lose half your envelope mass it's

281

00:11:29,480 --> 00:11:27,089

even easier energetic little second half

282

00:11:32,210 --> 00:11:29,490

because you're not shrinking your rate

283

00:11:33,860 --> 00:11:32,220

of convective boundary so that was

284

00:11:35,960 --> 00:11:33,870

really intriguing so basically what plan

285

00:11:37,100 --> 00:11:35,970

four major will tell you by default you

286

00:11:39,199 --> 00:11:37,110

should expect a bimodal distribution

287

00:11:40,579 --> 00:11:39,209

planet sizes the ones that got to keep

288

00:11:47,629 --> 00:11:40,589

the hydrogen helium envelopes and the

289

00:11:50,629 --> 00:11:47,639

ones that get to lose it there's one

290

00:11:52,579 --> 00:11:50,639

other thing to keep in mind it's not

291

00:11:54,860 --> 00:11:52,589

only an energy argument there are

292

00:11:57,410 --> 00:11:54,870

planets for which they have enough

293

00:11:59,389 --> 00:11:57,420

energy to unbound the envelopes and lose

294

00:12:01,369 --> 00:11:59,399

them however that there's not enough

295

00:12:03,170 --> 00:12:01,379

plane so they could be not enough time

296

00:12:06,619 --> 00:12:03,180

because this mass loss center can take

297

00:12:08,119 --> 00:12:06,629

actually get gears but in many cases it

298

00:12:10,309 --> 00:12:08,129

actually turns out that the cooling time

299

00:12:10,759 --> 00:12:10,319

scale can catch up with a mass lost time

300

00:12:15,769 --> 00:12:10,769

scale

301
00:12:18,429 --> 00:12:15,779
so basically when your mass loss becomes

302
00:12:21,889 --> 00:12:18,439
long compared to your cooling time scale

303
00:12:23,900 --> 00:12:21,899
then your envelope can cool and contract

304
00:12:26,299 --> 00:12:23,910
and you can shut off any subsequent mass

305
00:12:28,369 --> 00:12:26,309
loss and the reason for this is again

306
00:12:31,069 --> 00:12:28,379
because of the isothermal structure on

307
00:12:33,170 --> 00:12:31,079
the outside because you have an

308
00:12:35,360 --> 00:12:33,180
exponential tail in there and so as soon

309
00:12:37,280 --> 00:12:35,370
as you increase the region over which

310
00:12:39,290 --> 00:12:37,290
this exponent is expanding just a little

311
00:12:41,689 --> 00:12:39,300
bit the mass loss rate drops

312
00:12:43,129 --> 00:12:41,699
significantly any concern of the mass

313
00:12:46,309 --> 00:12:43,139

loss and you can cool it a little bit

314

00:12:47,540 --> 00:12:46,319

more and save your atmosphere so what

315

00:12:49,100 --> 00:12:47,550

I'll show you is the criterion for

316

00:12:51,170 --> 00:12:49,110

keeping most of the envelopes is that

317

00:12:52,790 --> 00:12:51,180

basically your cooling time scale has to

318

00:12:54,259 --> 00:12:52,800

become faster than your math last time

319

00:12:56,900 --> 00:12:54,269

scale okay

320

00:12:58,309 --> 00:12:56,910

so much for a theory let's try to put

321

00:12:59,660 --> 00:12:58,319

this all together so with what I told

322

00:13:01,819 --> 00:12:59,670

you you know kind of make it our model

323

00:13:04,689 --> 00:13:01,829

making your own planet you can take the

324

00:13:08,210 --> 00:13:04,699

sort of observed mass distribution of

325

00:13:09,769 --> 00:13:08,220

planetary cores which are good proxy for

326

00:13:11,480 --> 00:13:09,779

the total mass of the planet because

327

00:13:13,910 --> 00:13:11,490

these envelopes are only a small

328

00:13:15,920 --> 00:13:13,920

fraction of the total mass then I told

329

00:13:17,900 --> 00:13:15,930

you you can calculate how much hydrogen

330

00:13:19,669 --> 00:13:17,910

helium they should accrete

331

00:13:21,919 --> 00:13:19,679

how much they should lose during the

332

00:13:24,259 --> 00:13:21,929

distance brizl phase and then we can

333

00:13:25,300 --> 00:13:24,269

just involve them under the what we call

334

00:13:29,510 --> 00:13:25,310

core apart masks

335

00:13:31,520 --> 00:13:29,520

scenario and indeed what we found is you

336

00:13:33,890 --> 00:13:31,530

do get this portal distribution to the

337

00:13:36,590 --> 00:13:33,900

thread histogram is basically the

338

00:13:38,600 --> 00:13:36,600

outcome of this very simple model in

339

00:13:42,530 --> 00:13:38,610

this gray is a comparison with the

340

00:13:44,810 --> 00:13:42,540

actual observation so what the drinking

341

00:13:46,970 --> 00:13:44,820

is just from a pure planet formation

342

00:13:49,940 --> 00:13:46,980

point of view you seem to be able to

343

00:13:54,020 --> 00:13:49,950

reproduce this by mortal distribution

344

00:13:55,760 --> 00:13:54,030

that's observed in the exoplanet size

345

00:13:57,800 --> 00:13:55,770

distribution of these super earth and

346

00:14:00,740 --> 00:13:57,810

subnet tune and we heard from James

347

00:14:05,090 --> 00:14:00,750

already so this is by no way to say that

348

00:14:08,810 --> 00:14:05,100

this is the only thing going on and we

349

00:14:11,450 --> 00:14:08,820

heard that food preparation can give you

350

00:14:14,660 --> 00:14:11,460

this bimodal distribution also and I

351
00:14:17,300 --> 00:14:14,670
think we need to actually combine those

352
00:14:20,090 --> 00:14:17,310
two to really come up with a model that

353
00:14:22,280 --> 00:14:20,100
can do it all but it's very intriguing

354
00:14:24,620 --> 00:14:22,290
to me that just for information would

355
00:14:27,470 --> 00:14:24,630
give you this and this was just a first

356
00:14:29,990 --> 00:14:27,480
cut my current grad student has done a

357
00:14:33,410 --> 00:14:30,000
more detailed comparison so we not only

358
00:14:36,350 --> 00:14:33,420
have histograms right we now also have a

359
00:14:39,020 --> 00:14:36,360
two-dimensional distribution of oval

360
00:14:42,950 --> 00:14:39,030
period and size distribution these are

361
00:14:45,740 --> 00:14:42,960
the observations you see up here he

362
00:14:49,850 --> 00:14:45,750
repeated the same model but just plotted

363
00:14:51,950 --> 00:14:49,860

this now in 2d to do a comparison and

364

00:14:55,760 --> 00:14:51,960

again I think he finds a very good

365

00:14:59,210 --> 00:14:55,770

agreement with observations specifically

366

00:15:01,910 --> 00:14:59,220

we get a similar slope in this radius

367

00:15:03,710 --> 00:15:01,920

valley as the observation is very easy

368

00:15:05,930 --> 00:15:03,720

to understand where the slope comes from

369

00:15:07,700 --> 00:15:05,940

in the coop at Mastro's mechanism I told

370

00:15:09,290 --> 00:15:07,710

you what separates the planets that keep

371

00:15:11,780 --> 00:15:09,300

the envelope where's the ones that lose

372

00:15:13,700 --> 00:15:11,790

is just whether the cooling timescale is

373

00:15:15,860 --> 00:15:13,710

faster or smaller than the mass less

374

00:15:18,560 --> 00:15:15,870

time scale so setting those two equal we

375

00:15:19,940 --> 00:15:18,570

can solve for the slope and these are

376

00:15:22,490 --> 00:15:19,950

complicated things because they depend

377

00:15:23,990 --> 00:15:22,500

on many things of your planet but the

378

00:15:26,870 --> 00:15:24,000

nice thing is because one of them has

379

00:15:28,970 --> 00:15:26,880

this exponential in it so to first order

380

00:15:30,230 --> 00:15:28,980

all that really matters is the things in

381

00:15:32,390 --> 00:15:30,240

the exponent and the things in the

382

00:15:33,800 --> 00:15:32,400

exponent is only is it just the mass of

383

00:15:35,870 --> 00:15:33,810

the planet the speed of sound and

384

00:15:38,600 --> 00:15:35,880

basically the size of your planet the

385

00:15:42,350 --> 00:15:38,610

race vector boundary so we know those

386

00:15:44,030 --> 00:15:42,360

and so you can you can rewrite them as a

387

00:15:45,650 --> 00:15:44,040

function of period and science because

388

00:15:48,980 --> 00:15:45,660

that's what the would-be observations

389

00:15:50,630 --> 00:15:48,990

are plotted in and derive what the slope

390

00:15:53,990 --> 00:15:50,640

should be it's just straight out of here

391

00:15:57,019 --> 00:15:54,000

and what you get is this minus 0.1 we're

392

00:15:58,819 --> 00:15:57,029

just in very good observations that

393

00:16:02,449 --> 00:15:58,829

actually James also showed from the fun

394

00:16:04,699 --> 00:16:02,459

alien paper similar to the foot

395

00:16:06,560 --> 00:16:04,709

evaporation results very exactly the

396

00:16:08,240 --> 00:16:06,570

slope will fall depends on the density

397

00:16:10,910 --> 00:16:08,250

you can see this again just from the

398

00:16:13,850 --> 00:16:10,920

things that are in the exponent so the

399

00:16:16,340 --> 00:16:13,860

location of the slope we to find it's

400

00:16:18,860 --> 00:16:16,350

consistent with rocky compositions and

401
00:16:21,470 --> 00:16:18,870
that we found that at most you can have

402
00:16:27,949 --> 00:16:21,480
about 20% water fraction in those

403
00:16:30,319 --> 00:16:27,959
planets then of course you can do better

404
00:16:32,480 --> 00:16:30,329
so so far we had assumed that all stars

405
00:16:34,130 --> 00:16:32,490
exactly like the Sun so the first thing

406
00:16:39,560 --> 00:16:34,140
was to actually model the true stellar

407
00:16:43,100 --> 00:16:39,570
population of the Kepler data set and by

408
00:16:44,750 --> 00:16:43,110
doing so much surprisingly but it's good

409
00:16:46,759 --> 00:16:44,760
to confirm we've got an even better

410
00:16:48,380 --> 00:16:46,769
agreement with observations you can see

411
00:16:50,000 --> 00:16:48,390
this the spreads out a little bit

412
00:16:54,439 --> 00:16:50,010
because the spread and stellar

413
00:16:56,269 --> 00:16:54,449

properties but nothing revolutionary new

414

00:17:00,560 --> 00:16:56,279

here we knew that it should be similar

415

00:17:02,060 --> 00:17:00,570

so that's good but what is nice is now

416

00:17:03,769 --> 00:17:02,070

we can ask questions and make

417

00:17:05,900 --> 00:17:03,779

predictions of how the corporate

418

00:17:07,880 --> 00:17:05,910

massless mechanism should depend on

419

00:17:09,319 --> 00:17:07,890

various stellar properties and where it

420

00:17:12,650 --> 00:17:09,329

gives different results from what you

421

00:17:15,319 --> 00:17:12,660

would expect if this radius valley is

422

00:17:18,949 --> 00:17:15,329

shaped predominately by foot evaporation

423

00:17:22,309 --> 00:17:18,959

so I want to give you two examples one

424

00:17:24,860 --> 00:17:22,319

is how it depends on the bulla metric

425

00:17:27,020 --> 00:17:24,870

luminosity of the star here it's plotted

426

00:17:30,190 --> 00:17:27,030

as stellar mass again just because this

427

00:17:32,930 --> 00:17:30,200

is what's been done by the observers so

428

00:17:35,750 --> 00:17:32,940

in the core part mattress mechanism

429

00:17:37,820 --> 00:17:35,760

why does a star matter at all um the

430

00:17:41,720 --> 00:17:37,830

star matters through the metric

431

00:17:43,340 --> 00:17:41,730

luminosity because the insulation or the

432

00:17:46,100 --> 00:17:43,350

effective temperature that your planet

433

00:17:48,560 --> 00:17:46,110

has sets the outer boundary condition

434

00:17:51,740 --> 00:17:48,570

for massless so this is where the star

435

00:17:53,120 --> 00:17:51,750

comes in so um

436

00:17:54,980 --> 00:17:53,130

what this means is if you have a higher

437

00:17:57,410 --> 00:17:54,990

luminosity star or a planet that has a

438

00:18:00,260 --> 00:17:57,420

higher insulation you have a faster of

439

00:18:02,540 --> 00:18:00,270

mass loss rate and so in the end you can

440

00:18:04,580 --> 00:18:02,550

strip a more mass of core if you have a

441

00:18:07,730 --> 00:18:04,590

higher bottom entry manasa T so this

442

00:18:09,380 --> 00:18:07,740

means if you have because of the mass

443

00:18:11,330 --> 00:18:09,390

from another relationship of stars which

444

00:18:15,170 --> 00:18:11,340

is well measured and studies more

445

00:18:18,080 --> 00:18:15,180

massive stars of higher luminosities we

446

00:18:21,290 --> 00:18:18,090

find in the core pod Matloff scenario

447

00:18:24,500 --> 00:18:21,300

that this this radius valley moves the

448

00:18:26,450 --> 00:18:24,510

larger stellar masses to larger planet

449

00:18:28,250 --> 00:18:26,460

sizes as a function of stellar mass and

450

00:18:31,070 --> 00:18:28,260

we can even measure the slope this

451

00:18:34,250 --> 00:18:31,080

actually isn't quite as agreement with

452

00:18:36,110 --> 00:18:34,260

observation you can again derive this

453

00:18:38,660 --> 00:18:36,120

analytically very simply again from

454

00:18:41,000 --> 00:18:38,670

exactly the same argument same exponent

455

00:18:43,550 --> 00:18:41,010

again you're just rewriting this because

456

00:18:46,100 --> 00:18:43,560

now you're writing this explicitly in

457

00:18:47,720 --> 00:18:46,110

terms of the insulation received and you

458

00:18:49,010 --> 00:18:47,730

can analytically even derive the slope

459

00:18:51,560 --> 00:18:49,020

but you can of course do this

460

00:18:52,940 --> 00:18:51,570

numerically also this is one thing where

461

00:18:54,980 --> 00:18:52,950

we predict something quite different

462

00:18:57,140 --> 00:18:54,990

from fort evaporation right for

463

00:19:01,130 --> 00:18:57,150

preparation as we prayed from James is

464

00:19:04,160 --> 00:19:01,140

driven by the x-ray and UV radiation

465

00:19:06,110 --> 00:19:04,170

from the star this is more strong

466

00:19:09,500 --> 00:19:06,120

relative to the below metric luminosity

467

00:19:12,230 --> 00:19:09,510

for lower mass stars so a lower mass

468

00:19:15,040 --> 00:19:12,240

stars for given bolometric luminosity

469

00:19:17,540 --> 00:19:15,050

should be more efficient as stripping

470

00:19:20,660 --> 00:19:17,550

planetary course should be able to strip

471

00:19:22,640 --> 00:19:20,670

a larger core than then higher math

472

00:19:26,780 --> 00:19:22,650

stars for the same volumetric luminosity

473

00:19:29,600 --> 00:19:26,790

and so when this data was interpreted by

474

00:19:32,780 --> 00:19:29,610

jung chanwoo using for reparation models

475

00:19:35,180 --> 00:19:32,790

she's to basically get the strength she

476

00:19:37,940 --> 00:19:35,190

suggested that the underlying planet's

477

00:19:40,820 --> 00:19:37,950

mass distribution needs to be have a

478

00:19:42,890 --> 00:19:40,830

coral positive linear correlation with a

479

00:19:46,940 --> 00:19:42,900

stellar host master to get this positive

480

00:19:48,620 --> 00:19:46,950

trend so for us we have the same

481

00:19:50,360 --> 00:19:48,630

underlying time mass distribution would

482

00:19:52,580 --> 00:19:50,370

say it's independent of stella host mass

483

00:19:54,590 --> 00:19:52,590

because we get this trend if you wish by

484

00:19:56,900 --> 00:19:54,600

default just from their bolometric

485

00:19:58,900 --> 00:19:56,910

luminosity that's one way where there's

486

00:20:03,300 --> 00:19:58,910

quite different predictions

487

00:20:05,040 --> 00:20:03,310

between these two mechanisms there is a

488

00:20:06,360 --> 00:20:05,050

there are several others but this is

489

00:20:11,730 --> 00:20:06,370

another one which I think it's quite

490

00:20:14,250 --> 00:20:11,740

clean this is dependent on Stella age so

491

00:20:15,990 --> 00:20:14,260

we heard from James that it's the

492

00:20:19,410 --> 00:20:16,000

youngsters that are really active right

493

00:20:21,270 --> 00:20:19,420

its youngsters that drive most of the

494

00:20:23,520 --> 00:20:21,280

math laws and most of the food of

495

00:20:24,840 --> 00:20:23,530

operation is happening in the core part

496

00:20:27,000 --> 00:20:24,850

math class

497

00:20:29,270 --> 00:20:27,010

this happens over Giga time skill is

498

00:20:31,710 --> 00:20:29,280

basically continuously happened from

499

00:20:33,840 --> 00:20:31,720

basically the birth of your planet until

500

00:20:37,080 --> 00:20:33,850

today so their plan is even today that

501
00:20:39,690 --> 00:20:37,090
are still being converted from super sub

502
00:20:42,480 --> 00:20:39,700
Neptune into supers and so if you plot

503
00:20:45,960 --> 00:20:42,490
basically this is now a relative

504
00:20:48,180 --> 00:20:45,970
occurrence of sub Neptune's to super

505
00:20:50,780 --> 00:20:48,190
earth as a function of age you can see

506
00:20:53,070 --> 00:20:50,790
if you go from 1 to say 10 Giga here's

507
00:20:54,900 --> 00:20:53,080
your plan is still shrink you can see

508
00:20:57,000 --> 00:20:54,910
this 2 here but you also see that you

509
00:20:58,350 --> 00:20:57,010
get more and larger super Earths because

510
00:21:00,120 --> 00:20:58,360
you know the Neptune's that are still

511
00:21:03,380 --> 00:21:00,130
stripped sub Neptune's that are so

512
00:21:06,030 --> 00:21:03,390
stripped and converted into super so

513
00:21:07,950 --> 00:21:06,040

what this means is that if you can study

514

00:21:10,890 --> 00:21:07,960

these populations as a function of age

515

00:21:12,990 --> 00:21:10,900

that we predict that the occurrence rate

516

00:21:14,430 --> 00:21:13,000

of super Earths should still increase if

517

00:21:17,040 --> 00:21:14,440

you go from half a giggle year to a

518

00:21:22,380 --> 00:21:17,050

giggle year to several giga years with

519

00:21:30,210 --> 00:21:27,530

[Music]

520

00:21:32,610 --> 00:21:30,220

and that there will be a few planets

521

00:21:35,490 --> 00:21:32,620

today that you can catch in the valley

522

00:21:37,770 --> 00:21:35,500

losing mass right now just because some

523

00:21:42,080 --> 00:21:37,780

of them have just the right time scales

524

00:21:47,400 --> 00:21:42,090

for that so let me conclude

525

00:21:49,470 --> 00:21:47,410

so planet formation itself seems to give

526
00:21:52,110 --> 00:21:49,480
you a bimodal distribution and planet

527
00:21:54,060 --> 00:21:52,120
sizes so core cooling just by itself

528
00:21:55,710 --> 00:21:54,070
wants to either let you have these

529
00:22:00,240 --> 00:21:55,720
hydrogen helium envelopes or strip you

530
00:22:03,540 --> 00:22:00,250
entirely light atmospheres that contain

531
00:22:06,600 --> 00:22:03,550
less than about 5% of the total mass of

532
00:22:09,090 --> 00:22:06,610
the planet and can be stripped entirely

533
00:22:11,400 --> 00:22:09,100
because there's enough energy and to do

534
00:22:14,460 --> 00:22:11,410
so whereas heavy atmosphere is more than

535
00:22:16,870 --> 00:22:14,470
roughly 5% of the total planet's mass

536
00:22:20,470 --> 00:22:16,880
and will just cool and contract

537
00:22:23,140 --> 00:22:20,480
Virgilia time feels the majority of the

538
00:22:24,910 --> 00:22:23,150

rocky and exoplanets are basically fully

539

00:22:27,790 --> 00:22:24,920

consistent with having formed with the

540

00:22:30,580 --> 00:22:27,800

hydrogen helium envelope and that

541

00:22:33,850 --> 00:22:30,590

basically being stripped course of what

542

00:22:35,680 --> 00:22:33,860

we see today we find that these cores on

543

00:22:38,080 --> 00:22:35,690

average have densities quite similar to

544

00:22:41,830 --> 00:22:38,090

the earth so suggest that they are not

545

00:22:43,540 --> 00:22:41,840

true Waterworld may be pointing

546

00:22:46,420 --> 00:22:43,550

deformation inside the ice line but

547

00:22:50,080 --> 00:22:46,430

we'll see as we have better models and

548

00:22:51,610 --> 00:22:50,090

better data the curve the coop at

549

00:22:54,520 --> 00:22:51,620

massless proceeds over

550

00:22:56,140 --> 00:22:54,530

Agia timescales the occurrence rate or

551
00:23:01,540 --> 00:22:56,150
super earth respect to sub Neptune's

552
00:23:03,310 --> 00:23:01,550
will increase with time the cursed core

553
00:23:06,970 --> 00:23:03,320
cooling does depend on the below metric

554
00:23:10,330 --> 00:23:06,980
luminosity of the star we predict that

555
00:23:13,960 --> 00:23:10,340
the radius valley should shift to larger

556
00:23:16,030 --> 00:23:13,970
planet sizes of masses and as you go to

557
00:23:20,850 --> 00:23:16,040
increasing stellar masses because of the

558
00:23:22,840 --> 00:23:20,860
stellar mass luminosity relationship we

559
00:23:24,400 --> 00:23:22,850
predicted there's no change in the

560
00:23:25,720 --> 00:23:24,410
underlying silent mass distributions

561
00:23:28,150 --> 00:23:25,730
with the typical planet masses are the

562
00:23:30,940 --> 00:23:28,160
same around a sun-like star and the star

563
00:23:32,620 --> 00:23:30,950

that's a 0.8 0.6 times the height of the

564

00:23:38,800 --> 00:23:32,630

Sun so again that's something that you

565

00:23:42,400 --> 00:23:38,810

can test observational II and I think

566

00:23:45,550 --> 00:23:42,410

most importantly I think in future work

567

00:23:48,370 --> 00:23:45,560

that basically we started but it's still

568

00:23:50,650 --> 00:23:48,380

ongoing is it's basically the effort to

569

00:23:53,520 --> 00:23:50,660

really combine the foot evaporation

570

00:23:57,550 --> 00:23:53,530

models and the crop out mass loss models

571

00:23:59,980 --> 00:23:57,560

to correctly and completely model this

572

00:24:01,570 --> 00:23:59,990

atmospheric loss because my suspicion is

573

00:24:03,820 --> 00:24:01,580

that probably this will be needed to

574

00:24:06,220 --> 00:24:03,830

correctly interpret the observations and

575

00:24:09,520 --> 00:24:06,230

make inferences for example about the

576

00:24:11,970 --> 00:24:09,530

planets densities in their evolution so

577

00:24:18,430 --> 00:24:11,980

thank you very much

578

00:24:21,470 --> 00:24:18,440

[Applause]

579

00:24:23,419 --> 00:24:21,480

and sorry about the 3d numbering I don't

580

00:24:26,330 --> 00:24:23,429

know what I don't know I can just say

581

00:24:29,049 --> 00:24:26,340

it's my dead leg somehow this this made

582

00:24:38,539 --> 00:24:29,059

sense some time ago

583

00:24:41,240 --> 00:24:38,549

thank you very much hookah Denis Oh

584

00:24:43,340 --> 00:24:41,250

Geoff University of Exeter it's probably

585

00:24:46,970 --> 00:24:43,350

a weird question but can there be a

586

00:24:51,169 --> 00:24:46,980

situation when an atmosphere of a planet

587

00:24:54,159 --> 00:24:51,179

being stripped away from from one planet

588

00:24:56,450 --> 00:24:54,169

and then being gained by another planet

589

00:24:57,769 --> 00:24:56,460

it's like it's a great question I

590

00:25:00,440 --> 00:24:57,779

thought about this a little but I think

591

00:25:02,899 --> 00:25:00,450

it's hard in reality so for starters we

592

00:25:06,110 --> 00:25:02,909

see this happening all the time or it's

593

00:25:08,720 --> 00:25:06,120

not so uncommon I think it's harder for

594

00:25:10,460 --> 00:25:08,730

planets and the reason is that unlike

595

00:25:12,289 --> 00:25:10,470

stars a binary star that's close and can

596

00:25:14,029 --> 00:25:12,299

have mass transfer the planets are not

597

00:25:15,740 --> 00:25:14,039

closed spacial for a long time because

598

00:25:17,720 --> 00:25:15,750

of the capillary and shear so they do

599

00:25:19,879 --> 00:25:17,730

come by and they're not that far apart

600

00:25:21,590 --> 00:25:19,889

but that's only a short time in their

601
00:25:23,330 --> 00:25:21,600
orbit right because then the complaining

602
00:25:25,970 --> 00:25:23,340
here most of the time is actually spent

603
00:25:28,460 --> 00:25:25,980
quite far apart so for that reason I

604
00:25:37,789 --> 00:25:28,470
think it's very unlikely to have to

605
00:25:41,269 --> 00:25:37,799
happen yeah Daniel from MIT in the plot

606
00:25:44,480 --> 00:25:41,279
of planet radius versus period the lower

607
00:25:47,480 --> 00:25:44,490
population the average size seems to go

608
00:25:49,310 --> 00:25:47,490
down with periods so if these are

609
00:25:52,310 --> 00:25:49,320
supposed to be like rocky cores why

610
00:25:53,810 --> 00:25:52,320
would they get smaller with increasing

611
00:25:55,580 --> 00:25:53,820
period is there a reason from planet

612
00:25:57,259 --> 00:25:55,590
formation to expect that okay no so I

613
00:26:00,320 --> 00:25:57,269

think so let me just make sure what we

614

00:26:02,779 --> 00:26:00,330

talk about the same plot the one where

615

00:26:05,720 --> 00:26:02,789

you have period on the x axis and radius

616

00:26:15,950 --> 00:26:07,760

it's not letting me go back it's

617

00:26:18,950 --> 00:26:15,960

hilarious it does it doesn't let me go

618

00:26:20,690 --> 00:26:18,960

back so they're okay only forward Oh

619

00:26:23,210 --> 00:26:20,700

thought this one is good right you mean

620

00:26:24,980 --> 00:26:23,220

this one right yes or the lower red blob

621

00:26:26,990 --> 00:26:24,990

right you're saying this goes down with

622

00:26:29,360 --> 00:26:27,000

period right or at least it looks like

623

00:26:31,310 --> 00:26:29,370

yeah so the reason is it gets harder

624

00:26:33,260 --> 00:26:31,320

because the lower because when you're

625

00:26:35,540 --> 00:26:33,270

further away from the star you receive a

626

00:26:37,640 --> 00:26:35,550

lower bolometric luminosity so it gets

627

00:26:40,460 --> 00:26:37,650

harder to strip the core so it means you

628

00:26:41,840 --> 00:26:40,470

can only strip lower mass planets and so

629

00:26:44,390 --> 00:26:41,850

that's why they look smaller so the

630

00:26:47,630 --> 00:26:44,400

equivalent planets that are that would

631

00:26:51,380 --> 00:26:47,640

be here I still stuck in this model in

632

00:26:53,090 --> 00:26:51,390

the sub Neptune population because the

633

00:26:55,730 --> 00:26:53,100

outer boundary condition that's given by

634

00:26:57,920 --> 00:26:55,740

the volumetric luminosity of the star is

635

00:27:01,970 --> 00:26:57,930

such that the mass loss rate is slower

636

00:27:04,600 --> 00:27:01,980

and so you get stuck being a sub Neptune

637

00:27:07,340 --> 00:27:04,610

rather than being converted into a super

638

00:27:09,860 --> 00:27:07,350

this is where that dependence on period

639

00:27:17,870 --> 00:27:09,870

comes from as you go to larger orbital

640

00:27:19,640 --> 00:27:17,880

periods does it make sense yeah maybe

641

00:27:22,400 --> 00:27:19,650

I'll have to think hard about it but if

642

00:27:24,110 --> 00:27:22,410

I interpret the lower red blob it's just

643

00:27:26,690 --> 00:27:24,120

a core that's like stripped of

644

00:27:28,340 --> 00:27:26,700

everything mmm I would assume that like

645

00:27:29,960 --> 00:27:28,350

everything that falls into that

646

00:27:33,230 --> 00:27:29,970

population is roughly gonna have the

647

00:27:34,850 --> 00:27:33,240

same size now so like not like you're

648

00:27:36,620 --> 00:27:34,860

right and saying like some of them might

649

00:27:39,200 --> 00:27:36,630

not make it to that population at longer

650

00:27:41,180 --> 00:27:39,210

periods but if you do make it to that

651
00:27:44,180 --> 00:27:41,190
population shouldn't you have the same

652
00:27:45,830 --> 00:27:44,190
size regardless of period no because

653
00:27:49,340 --> 00:27:45,840
there's this mass dependence right but

654
00:27:51,920 --> 00:27:49,350
because because you receive you have a

655
00:27:53,540 --> 00:27:51,930
you have a colder outer boundary

656
00:27:56,060 --> 00:27:53,550
condition your mass loss rate is lower

657
00:27:58,820 --> 00:27:56,070
if you go further away so a large a

658
00:28:01,040 --> 00:27:58,830
larger masses can still hold on to their

659
00:28:03,170 --> 00:28:01,050
envelope and that's why these guys get

660
00:28:05,210 --> 00:28:03,180
stuck up there so if you would plot this

661
00:28:07,070 --> 00:28:05,220
on planet Mars you'll see that in each

662
00:28:09,230 --> 00:28:07,080
period you have the same planet mass

663
00:28:11,480 --> 00:28:09,240

distributions but the ones that become

664

00:28:14,110 --> 00:28:11,490

super Earth are different depending on

665

00:28:17,629 --> 00:28:14,120

how far away you are from the star

666

00:28:25,849 --> 00:28:24,229

I was wondering we think that in the

667

00:28:28,999 --> 00:28:25,859

process of planet formation there are

668

00:28:31,789 --> 00:28:29,009

also a lot of giant in yes so I was

669

00:28:33,979 --> 00:28:31,799

wondering how that like having impact my

670

00:28:35,239 --> 00:28:33,989

effect these populations thank you for

671

00:28:41,799 --> 00:28:35,249

asking that question because those

672

00:28:45,909 --> 00:28:41,809

impacts are my other big passion so

673

00:28:49,249 --> 00:28:45,919

indeed so rightful giant impact actually

674

00:28:51,469 --> 00:28:49,259

one of my PhD students are just finished

675

00:28:53,509 --> 00:28:51,479

there's quite a lot of work on the

676

00:28:56,449 --> 00:28:53,519

atmospheric loss in giant impacts and

677

00:28:58,999 --> 00:28:56,459

what he showed is that for hydrogen

678

00:29:00,709 --> 00:28:59,009

helium envelopes they're amazingly good

679

00:29:04,399 --> 00:29:00,719

at stripping the atmosphere which is

680

00:29:06,109 --> 00:29:04,409

quite different actually from sort of

681

00:29:08,779 --> 00:29:06,119

secondary atmospheres but you only get

682

00:29:09,979 --> 00:29:08,789

loss of 10 or 20% and typical 10 impact

683

00:29:11,509 --> 00:29:09,989

so that's again actually because of the

684

00:29:13,190 --> 00:29:11,519

heating you have so much energy

685

00:29:15,229 --> 00:29:13,200

deposited in the core that you

686

00:29:17,299 --> 00:29:15,239

significantly heat the core and the

687

00:29:20,209 --> 00:29:17,309

envelope that you tend to lose it all

688

00:29:21,889 --> 00:29:20,219

for those sort of systems so I would

689

00:29:23,269 --> 00:29:21,899

used to say that oh they can't be too

690

00:29:25,039 --> 00:29:23,279

many giant impacts because that will

691

00:29:27,529 --> 00:29:25,049

mess up our plot too much but it's not

692

00:29:29,629 --> 00:29:27,539

quite so clear anymore because if you

693

00:29:31,909 --> 00:29:29,639

really strip everything you could hide

694

00:29:35,209 --> 00:29:31,919

many giant impacts in here and just be

695

00:29:40,180 --> 00:29:35,219

either a neptune or a super-earth and

696

00:29:42,799 --> 00:29:40,190

not that much in between I I do think

697

00:29:44,569 --> 00:29:42,809

they happen at some level maybe not

698

00:29:46,489 --> 00:29:44,579

quite as prominent as I believe they

699

00:29:48,229 --> 00:29:46,499

used to be but I think the fact that he

700

00:29:51,499 --> 00:29:48,239

found that you tend to strip everything

701

00:30:01,959 --> 00:29:51,509

and makes it more easily reconcilable

702

00:30:06,589 --> 00:30:04,909

Rowan worth Harvard's um I was wondering

703

00:30:08,209 --> 00:30:06,599

do you take rays of cooling mechanisms

704

00:30:09,409 --> 00:30:08,219

into account in your outflows do you

705

00:30:11,930 --> 00:30:09,419

think that's going to be important

706

00:30:13,369 --> 00:30:11,940

that's all that's a great question uh we

707

00:30:15,889 --> 00:30:13,379

think we thought about this a little bit

708

00:30:19,699 --> 00:30:15,899

but I think it does need and deserves

709

00:30:21,949 --> 00:30:19,709

more attention so the reason why you

710

00:30:23,810 --> 00:30:21,959

need both the star so as James said so

711

00:30:26,209 --> 00:30:23,820

nicely right in the score pot math laws

712

00:30:28,309 --> 00:30:26,219

the energy basically comes from the

713

00:30:30,199 --> 00:30:28,319

interior of the planet both the what's

714

00:30:30,770 --> 00:30:30,209

left in the envelope and the core and

715

00:30:32,300 --> 00:30:30,780

that's

716

00:30:34,250 --> 00:30:32,310

basically providing the energy to lift

717

00:30:36,350 --> 00:30:34,260

the material sort of out of the

718

00:30:38,270 --> 00:30:36,360

potential well however its cooling it

719

00:30:41,360 --> 00:30:38,280

erratically so it's not enough to just

720

00:30:45,680 --> 00:30:41,370

escape and so this is why the star comes

721

00:30:48,470 --> 00:30:45,690

in again so because you do need the the

722

00:30:50,900 --> 00:30:48,480

photons the volumetric luminosity is not

723

00:30:53,720 --> 00:30:50,910

the hard photons just the normal photons

724

00:30:56,240 --> 00:30:53,730

to keep your gas at sort of the typical

725

00:30:58,310 --> 00:30:56,250

temperature you would expect so as long

726

00:31:00,410 --> 00:30:58,320

as you can satisfy this that you will

727

00:31:02,390 --> 00:31:00,420

roughly be in the naive equilibrium you

728

00:31:04,130 --> 00:31:02,400

expect you're okay but there can be

729

00:31:06,410 --> 00:31:04,140

cases especially if you go far enough

730

00:31:08,120 --> 00:31:06,420

away from the star where this will this

731

00:31:10,430 --> 00:31:08,130

assumption will break down and that's

732

00:31:14,770 --> 00:31:10,440

definitely something that we started

733

00:31:17,720 --> 00:31:14,780

thinking about it in more detail yes