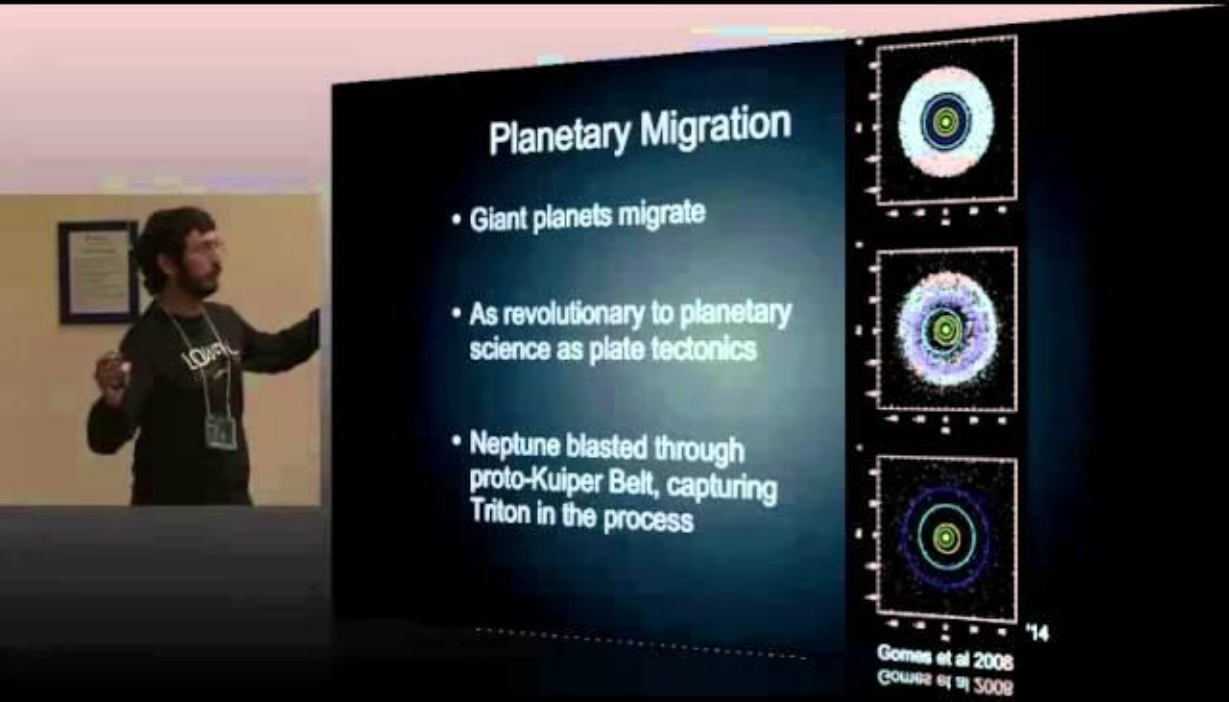
Planetary Migration
• Giant planets migrate
• As revolutionary to planetary science as plate tectonics
• Neptune blasted through proto-Kuiper Belt, capturing Triton in the process
Gomes et al 2008

1
00:00:10,450 --> 00:00:08,350
yeah so I can be talking about large

2
00:00:15,130 --> 00:00:10,460
captured satellites and that natural

3
00:00:16,990 --> 00:00:15,140
satellites exomoons and just briefly

4
00:00:20,710 --> 00:00:17,000
we've talked a lot about Kepler in this

5
00:00:25,720 --> 00:00:20,720
session and these are the all the

6
00:00:27,040 --> 00:00:25,730
results as of the last double a s so far

7
00:00:28,890 --> 00:00:27,050
and you can see there are tons of

8
00:00:31,090 --> 00:00:28,900
planets they're getting but they cannot

9
00:00:32,710 --> 00:00:31,100
you know when we get out here in the

10
00:00:33,910 --> 00:00:32,720
habitable zone they start to get fewer

11
00:00:36,160 --> 00:00:33,920
and fewer because you get fewer and

12
00:00:37,270 --> 00:00:36,170
fewer transits it's harder to detect so

13
00:00:40,120 --> 00:00:37,280

most of the planets we actually know

14
00:00:41,860 --> 00:00:40,130
about that are out in this region you

15
00:00:45,400 --> 00:00:41,870
know it's similar temperatures to earth

16
00:00:48,520 --> 00:00:45,410
are much larger than Earth they're giant

17
00:00:51,040 --> 00:00:48,530
planets and really didn't expect this

18
00:00:53,080 --> 00:00:51,050
but you know ten years ago people said

19
00:00:54,549 --> 00:00:53,090
you're crazy if you thought there are so

20
00:00:57,729 --> 00:00:54,559
many giant planets out here but there

21
00:00:59,290 --> 00:00:57,739
are tons of them there aren't there

22
00:01:01,360 --> 00:00:59,300
aren't the majority of planets in there

23
00:01:03,700 --> 00:01:01,370
but there are lots of them there and we

24
00:01:05,650 --> 00:01:03,710
know that they're there so you know

25
00:01:08,290 --> 00:01:05,660
potentially you know if you want to try

26
00:01:13,059 --> 00:01:08,300
and find habitable places this sounds

27
00:01:14,800 --> 00:01:13,069
like a good place to start especially is

28
00:01:16,359 --> 00:01:14,810
you know if they're big enough they

29
00:01:21,339 --> 00:01:16,369
might have satellites that are large

30
00:01:24,070 --> 00:01:21,349
enough to be habitable in order to be

31
00:01:27,160 --> 00:01:24,080
handle on the surface you need to be at

32
00:01:31,029 --> 00:01:27,170
least somewhat new as a large desert you

33
00:01:32,260 --> 00:01:31,039
know Mars astronomer somewhat is large

34
00:01:34,210 --> 00:01:32,270
so you know with an order of magnitude

35
00:01:36,999 --> 00:01:34,220
to the size of Earth is what we're

36
00:01:39,219 --> 00:01:37,009
talking about here but that's still

37
00:01:41,350 --> 00:01:39,229
pretty hard for the satellites in our

38
00:01:46,419 --> 00:01:41,360

solar system so you need something quite

39
00:01:48,609 --> 00:01:46,429
large to do that but if you look at the

40
00:01:51,580 --> 00:01:48,619
natural satellites in our solar system

41
00:01:54,490 --> 00:01:51,590
the largest one is Ganymede it's just a

42
00:01:56,290 --> 00:01:54,500
little bit larger than mercury and which

43
00:01:57,880 --> 00:01:56,300
means is quite smaller than Earth the

44
00:01:59,650 --> 00:01:57,890
only one of them actually even has an

45
00:02:02,919 --> 00:01:59,660
atmosphere is Titan and that's because

46
00:02:04,839 --> 00:02:02,929
it's so cold at time wouldn't keep its

47
00:02:07,900 --> 00:02:04,849
atmosphere if you were as close to the

48
00:02:10,900 --> 00:02:07,910
Sun as Earth is simply because they just

49
00:02:15,220 --> 00:02:10,910
get too hot and the it would escape away

50
00:02:19,600 --> 00:02:15,230
pretty fast so it's really hard to have

51
00:02:23,260 --> 00:02:19,610
a large satellite close into

52
00:02:26,740 --> 00:02:23,270
a star it's just it gets they the the

53
00:02:29,170 --> 00:02:26,750
dynamics of how it creats around the the

54
00:02:31,420 --> 00:02:29,180
planet just make it so that you know

55
00:02:34,210 --> 00:02:31,430
you're not going to get you know

56
00:02:36,880 --> 00:02:34,220
naturally forming satellites around the

57
00:02:41,470 --> 00:02:36,890
planet that are much larger than

58
00:02:45,370 --> 00:02:41,480
Ganymede even if you have a much larger

59
00:02:48,430 --> 00:02:45,380
joint plan to start out with so it sort

60
00:02:52,840 --> 00:02:48,440
of tricky to get you know much better

61
00:02:56,340 --> 00:02:52,850
than this unless you start to look at

62
00:02:58,600 --> 00:02:56,350
other means of having satellites and

63
00:03:00,729 --> 00:02:58,610

bright yellow you say regular satellites

64
00:03:03,400 --> 00:03:00,739
these are satellites are formed from the

65
00:03:04,960 --> 00:03:03,410
from a sir compliant airy disk you know

66
00:03:06,760 --> 00:03:04,970
like like the disk around the stars

67
00:03:08,530 --> 00:03:06,770
begin with but it's around the planet

68
00:03:11,710 --> 00:03:08,540
and they form a little miniature solar

69
00:03:14,800 --> 00:03:11,720
system irregular satellites are objects

70
00:03:17,949 --> 00:03:14,810
that form somewhere else somewhere else

71
00:03:20,979 --> 00:03:17,959
is usually for the giant planets meaning

72
00:03:25,000 --> 00:03:20,989
on the Kuiper belt region but it also

73
00:03:27,840 --> 00:03:25,010
mean asteroids as well which come in and

74
00:03:31,030 --> 00:03:27,850
then afterwards get captured and

75
00:03:34,330 --> 00:03:31,040
afterwards is still a long time ago you

76
00:03:36,160 --> 00:03:34,340
know solar system wise but it was still

77
00:03:37,690 --> 00:03:36,170
much after all the planets and

78
00:03:40,330 --> 00:03:37,700
everything had formed and then as things

79
00:03:42,490 --> 00:03:40,340
were so dynamically evening evening out

80
00:03:43,930 --> 00:03:42,500
these captures happen we've only been to

81
00:03:46,449 --> 00:03:43,940
one of these irregular satellites and

82
00:03:50,500 --> 00:03:46,459
that's Phoebe because they tend to be in

83
00:03:53,320 --> 00:03:50,510
very wide orbits very you know serve it

84
00:03:54,759 --> 00:03:53,330
you know eccentric at the edges sort of

85
00:03:56,710 --> 00:03:54,769
thing and that's how we can tell that

86
00:03:58,810 --> 00:03:56,720
they're they've obviously been captured

87
00:04:00,490 --> 00:03:58,820
because you have to have been captured

88
00:04:02,080 --> 00:04:00,500

to be there there are probably much

89
00:04:04,000 --> 00:04:02,090
closer in satellites but they were also

90
00:04:06,070 --> 00:04:04,010
captured we just can't tell who they're

91
00:04:11,830 --> 00:04:06,080
captured because they've sort of evened

92
00:04:13,810 --> 00:04:11,840
out and one of the ones that's evened

93
00:04:17,440 --> 00:04:13,820
out quite a bit but it's still obviously

94
00:04:19,240 --> 00:04:17,450
a capture is neb is frightening now most

95
00:04:21,819 --> 00:04:19,250
capture satellites are very small this

96
00:04:23,200 --> 00:04:21,829
is the largest of the Saturnian capture

97
00:04:27,490 --> 00:04:23,210
satellites and this is only a couple

98
00:04:29,589 --> 00:04:27,500
hundred kilometers across where is this

99
00:04:32,540 --> 00:04:29,599
guy here is about the size of our moon

100
00:04:36,719 --> 00:04:32,550
so it's about 3,000 kilometers or

101
00:04:39,570 --> 00:04:36,729
and it's the only large satellite of

102
00:04:41,189 --> 00:04:39,580
Neptune all the other Giants sell

103
00:04:45,570 --> 00:04:41,199
although other giant planets have

104
00:04:47,850 --> 00:04:45,580
certain nice little systems of this is

105
00:04:51,420 --> 00:04:47,860
Jupiter Saturn yours all of these nice

106
00:04:53,339 --> 00:04:51,430
systems of regular satellites don't have

107
00:04:57,570 --> 00:04:53,349
that on Neptune Neptune you just have

108
00:04:59,610 --> 00:04:57,580
Triton and a few very very small guys so

109
00:05:03,570 --> 00:04:59,620
and Trident is in this retrograde

110
00:05:05,040 --> 00:05:03,580
backwards orbit so the only story that

111
00:05:07,680 --> 00:05:05,050
makes sense here is that you used to

112
00:05:11,670 --> 00:05:07,690
have a regular satellite system and then

113
00:05:14,189 --> 00:05:11,680

something happens such that Triton came

114
00:05:17,760 --> 00:05:14,199
through bulldozer threw away all of

115
00:05:20,490 --> 00:05:17,770
those regular satellites and that were

116
00:05:25,740 --> 00:05:20,500
much smaller than it and you had and you

117
00:05:27,629 --> 00:05:25,750
know did just left itself and you know

118
00:05:29,070 --> 00:05:27,639
in that way you end up sort of trading

119
00:05:31,860 --> 00:05:29,080
up because you start out with a much

120
00:05:35,730 --> 00:05:31,870
much smaller satellites and end up with

121
00:05:38,189 --> 00:05:35,740
something that's quite a bit larger you

122
00:05:39,240 --> 00:05:38,199
know we thankfully we have actually been

123
00:05:42,240 --> 00:05:39,250
to train this is a bit of a synthetic

124
00:05:43,680 --> 00:05:42,250
image but you can actually see these all

125
00:05:45,959 --> 00:05:43,690
streaks on there those are actually

126
00:05:48,209 --> 00:05:45,969
little plumes of nitrogen they're

127
00:05:50,939 --> 00:05:48,219
trailing up dust onto the surface this

128
00:06:03,680 --> 00:05:50,949
is an active dynamic surface out of the

129
00:06:11,340 --> 00:06:09,450
all right kidney hear me okay so what we

130
00:06:14,160 --> 00:06:11,350
think probably happened to cause this

131
00:06:17,010 --> 00:06:14,170
this capture event was that giant

132
00:06:18,690 --> 00:06:17,020
planets migrate and if you've not been

133
00:06:20,340 --> 00:06:18,700
following planetary science this is the

134
00:06:22,500 --> 00:06:20,350
most revolutionary thing that has

135
00:06:24,630 --> 00:06:22,510
happened in solar system science in the

136
00:06:27,960 --> 00:06:24,640
past ten years is this realization that

137
00:06:30,270 --> 00:06:27,970
the giant planets are in many cases

138
00:06:31,860 --> 00:06:30,280

nowhere near where they were when they

139
00:06:33,990 --> 00:06:31,870
actually originally formed and we used

140
00:06:35,820 --> 00:06:34,000
to we used to map out with the the

141
00:06:37,410 --> 00:06:35,830
protoplanetary disk was like we just

142
00:06:39,180 --> 00:06:37,420
kind of assumed all the planets where

143
00:06:40,680 --> 00:06:39,190
they were and then we just saw spread

144
00:06:43,830 --> 00:06:40,690
out that material and said okay it's a

145
00:06:46,080 --> 00:06:43,840
disk reality they're much more compact

146
00:06:49,800 --> 00:06:46,090
we had a much more massive disk so

147
00:06:51,800 --> 00:06:49,810
they're all very close in and in Neptune

148
00:06:57,120 --> 00:06:51,810
actually probably was inside of Uranus

149
00:06:58,830 --> 00:06:57,130
and then Jupiter and Saturn gun to me

150
00:07:00,420 --> 00:06:58,840
motion residents with each other they

151
00:07:02,790 --> 00:07:00,430
kind of moved it around a little bit you

152
00:07:04,950 --> 00:07:02,800
can see there but they really moved

153
00:07:09,930 --> 00:07:04,960
around the smaller of the two giants and

154
00:07:12,570 --> 00:07:09,940
so Neptune's swiftness and went out into

155
00:07:14,490 --> 00:07:12,580
this big disk of material which is the

156
00:07:18,630 --> 00:07:14,500
you know the prototype er belt and

157
00:07:20,670 --> 00:07:18,640
dissipated most of it and in the process

158
00:07:23,010 --> 00:07:20,680
of dissipating it encounter a lot of

159
00:07:25,710 --> 00:07:23,020
things and one of those that encountered

160
00:07:27,300 --> 00:07:25,720
was frightened it's probably the largest

161
00:07:29,550 --> 00:07:27,310
thing it actually had a close encounter

162
00:07:32,820 --> 00:07:29,560
with and trying got captured and

163
00:07:36,810 --> 00:07:32,830

bulldozer delay all of the original

164
00:07:41,700 --> 00:07:36,820
satellites of Uranus and just left

165
00:07:45,060 --> 00:07:41,710
itself so how supposed to be a picture

166
00:07:47,640 --> 00:07:45,070
their butts condo never mind so you know

167
00:07:49,770 --> 00:07:47,650
planets migrate and this migration

168
00:07:53,340 --> 00:07:49,780
happens both ways in our solar system it

169
00:07:54,570 --> 00:07:53,350
happened in outward motion with you know

170
00:07:56,550 --> 00:07:54,580
missions like Kepler we're starting to

171
00:07:59,250 --> 00:07:56,560
get all the all the migrations that have

172
00:08:02,220 --> 00:07:59,260
not in word so this can go in both

173
00:08:05,130 --> 00:08:02,230
directions and the drawing plans come in

174
00:08:06,300 --> 00:08:05,140
that can go out and and one there when

175
00:08:07,500 --> 00:08:06,310
they're migrating they aren't counting

176
00:08:10,560 --> 00:08:07,510
lots of objects that were there

177
00:08:14,460 --> 00:08:10,570
previously and you can have these

178
00:08:17,250 --> 00:08:14,470
captures occur but to have a capture

179
00:08:19,680 --> 00:08:17,260
you need to it's a angular momentum

180
00:08:23,100 --> 00:08:19,690
switch right is if you're coming in and

181
00:08:25,020 --> 00:08:23,110
it you know at a hyperbolic orbit when

182
00:08:27,570 --> 00:08:25,030
you're approaching a planet you're going

183
00:08:30,360 --> 00:08:27,580
at least parabolic if not hyperbolic you

184
00:08:33,000 --> 00:08:30,370
have as much energy going out as you

185
00:08:34,680 --> 00:08:33,010
came in with if nothing happens so what

186
00:08:36,779 --> 00:08:34,690
you need is some sort of an event when

187
00:08:38,490 --> 00:08:36,789
you're close to the planet which causes

188
00:08:41,190 --> 00:08:38,500

you to lose a little bit of energy and

189
00:08:46,050 --> 00:08:41,200
trade angular momentum with the system

190
00:08:48,390 --> 00:08:46,060
and the two two ways you can do this one

191
00:08:51,720 --> 00:08:48,400
is that you already have a satellite and

192
00:08:53,730 --> 00:08:51,730
you get rid of it along the way so this

193
00:08:57,480 --> 00:08:53,740
is what the method that is our most

194
00:09:01,410 --> 00:08:57,490
commonly you know given for the capture

195
00:09:03,090 --> 00:09:01,420
of Triton is he you have Trident and

196
00:09:05,640 --> 00:09:03,100
then you have maybe a satellite and it

197
00:09:07,920 --> 00:09:05,650
comes in close comes in close and you

198
00:09:11,100 --> 00:09:07,930
know the motion of the two objects

199
00:09:12,480 --> 00:09:11,110
themselves together is hyperbolic but

200
00:09:14,040 --> 00:09:12,490
then when they get close here one's

201
00:09:15,600 --> 00:09:14,050
going a little bit faster than I

202
00:09:18,079 --> 00:09:15,610
prologue and one's going a little bit

203
00:09:22,079 --> 00:09:18,089
slower so then right at closest approach

204
00:09:24,060 --> 00:09:22,089
you kick off one of them and it goes off

205
00:09:25,590 --> 00:09:24,070
really fast and the other guy is going

206
00:09:29,940 --> 00:09:25,600
but much slower and it gets captured

207
00:09:31,920 --> 00:09:29,950
into the elliptical orbit around here so

208
00:09:34,500 --> 00:09:31,930
that's a really clean it's a very neat

209
00:09:37,290 --> 00:09:34,510
way of doing it unfortunately you also

210
00:09:39,720 --> 00:09:37,300
you have to presuppose that you have a

211
00:09:42,450 --> 00:09:39,730
satellite on there which makes it a lot

212
00:09:47,400 --> 00:09:42,460
more complicated then cuz it's a

213
00:09:49,920 --> 00:09:47,410

two-stage process the other way to do

214
00:09:53,540 --> 00:09:49,930
that is to say that you already have a

215
00:09:55,530 --> 00:09:53,550
satellite around the giant planet which

216
00:09:58,260 --> 00:09:55,540
you know makes sense because all the

217
00:10:01,110 --> 00:09:58,270
giant planets have many satellites and

218
00:10:03,350 --> 00:10:01,120
then and you actually swap places with

219
00:10:05,940 --> 00:10:03,360
it with that now it's a much smaller

220
00:10:08,370 --> 00:10:05,950
cross-section to do this you need to be

221
00:10:12,780 --> 00:10:08,380
just or just just right to get in there

222
00:10:16,740 --> 00:10:12,790
but you know do you have much more

223
00:10:20,910 --> 00:10:16,750
satellites to work with so potentially

224
00:10:24,300 --> 00:10:20,920
is a much more effective method so oh so

225
00:10:26,640 --> 00:10:24,310
that so this is a case here where you're

226
00:10:27,639 --> 00:10:26,650
coming in and so the squigglies there

227
00:10:29,290 --> 00:10:27,649
are

228
00:10:31,269 --> 00:10:29,300
the small satellite around one of the

229
00:10:33,730 --> 00:10:31,279
the large objects the red object and

230
00:10:36,609 --> 00:10:33,740
then you got the blue here which is the

231
00:10:39,340 --> 00:10:36,619
other large object and they get close

232
00:10:41,559 --> 00:10:39,350
here and then this small guy absorbs

233
00:10:43,210 --> 00:10:41,569
most of the momentum of the system gets

234
00:10:45,040 --> 00:10:43,220
and just gets tossed out of there at

235
00:10:47,439 --> 00:10:45,050
like 10 kilometers a second it's just

236
00:10:49,150 --> 00:10:47,449
zooming out and so it's taking away all

237
00:10:50,949 --> 00:10:49,160
this momentum and they get trapped in

238
00:10:52,900 --> 00:10:50,959

into a nice elliptical orbit around each

239
00:10:56,259 --> 00:10:52,910
other and you let that go long enough

240
00:11:00,400 --> 00:10:56,269
and they'll actually circularize just

241
00:11:03,220 --> 00:11:00,410
something that's nice and stable so I

242
00:11:06,819 --> 00:11:03,230
meant to do a bunch of simulations that

243
00:11:09,009 --> 00:11:06,829
for various reasons it didn't happen but

244
00:11:11,109 --> 00:11:09,019
simulations that I've done so far mainly

245
00:11:15,040 --> 00:11:11,119
with this first method and those what

246
00:11:17,290 --> 00:11:15,050
they re student some for last where we

247
00:11:19,179 --> 00:11:17,300
were just sort of taking making

248
00:11:23,109 --> 00:11:19,189
synthetic systems where you had a earth

249
00:11:28,449 --> 00:11:23,119
and a moon or earth with a moon that's

250
00:11:30,040 --> 00:11:28,459
the size of Mars or Mars with the moon

251
00:11:31,809 --> 00:11:30,050
that's the size of our moon and just

252
00:11:34,419 --> 00:11:31,819
kind of toss that at a giant planet and

253
00:11:35,860 --> 00:11:34,429
see if the captures or not and you know

254
00:11:38,049 --> 00:11:35,870
in general we were getting so captures

255
00:11:39,879 --> 00:11:38,059
maybe sir ten five percent of the time

256
00:11:41,679 --> 00:11:39,889
and some you know depending on the

257
00:11:44,470 --> 00:11:41,689
circus is up to twenty percent of the

258
00:11:45,489 --> 00:11:44,480
time so you know it's it's not that it

259
00:11:49,059 --> 00:11:45,499
happens every time there's a close

260
00:11:52,239 --> 00:11:49,069
encounter but it's not incredibly rare

261
00:11:54,249 --> 00:11:52,249
either now of course you can see here

262
00:11:55,749 --> 00:11:54,259
the most common outcome for most of

263
00:11:58,840 --> 00:11:55,759

these was that there was an impact so

264
00:12:00,429 --> 00:11:58,850
that your most common case the large one

265
00:12:02,230 --> 00:12:00,439
impacts or maybe the smaller win impacts

266
00:12:04,480 --> 00:12:02,240
but the red line there is the actual

267
00:12:06,220 --> 00:12:04,490
capture event and it it does happen is

268
00:12:11,319 --> 00:12:06,230
more likely in these cases that the

269
00:12:13,150 --> 00:12:11,329
larger of the two captures it's good and

270
00:12:15,160 --> 00:12:13,160
then we've all you know that when they

271
00:12:16,989 --> 00:12:15,170
capture they always capture in two very

272
00:12:18,970 --> 00:12:16,999
eccentric orbits but they don't stay

273
00:12:21,069 --> 00:12:18,980
that way because eccentric orbits are

274
00:12:22,749 --> 00:12:21,079
not stable when you're near something so

275
00:12:24,759 --> 00:12:22,759
their body tied circular isaam pretty

276
00:12:27,160 --> 00:12:24,769
fast and they circle eyes and they're

277
00:12:28,749 --> 00:12:27,170
tidally locked they are we talking about

278
00:12:31,809 --> 00:12:28,759
tightly lock a lot today but they're

279
00:12:33,460 --> 00:12:31,819
tightly locked to the planet and they

280
00:12:37,660 --> 00:12:33,470
tend to be in orbits that are a couple

281
00:12:40,030 --> 00:12:37,670
days so you know as far as lumination is

282
00:12:41,240 --> 00:12:40,040
concerned you know the they're seeing

283
00:12:43,040 --> 00:12:41,250
the Sun just

284
00:12:46,070 --> 00:12:43,050
often as they would if they were you

285
00:12:49,640 --> 00:12:46,080
know in a 24-day rotation period at 1a

286
00:12:52,010 --> 00:12:49,650
you and in fact if you were on the far

287
00:12:53,450 --> 00:12:52,020
side of one of these exomoons you'd

288
00:12:58,540 --> 00:12:53,460

never know that you're in orbit around a

289
00:13:05,530 --> 00:13:01,460
so they get you know about fifty percent

290
00:13:09,860 --> 00:13:05,540
of them then it have captured our serve

291
00:13:11,540 --> 00:13:09,870
you know circular as well and they get

292
00:13:14,000 --> 00:13:11,550
and the circularization happens fast

293
00:13:15,860 --> 00:13:14,010
this happens in about a million years so

294
00:13:20,120 --> 00:13:15,870
they get a lot of heat they're like I oh

295
00:13:22,130 --> 00:13:20,130
very briefly they get a lot of heat you

296
00:13:24,560 --> 00:13:22,140
know in this pulse but they're also

297
00:13:26,090 --> 00:13:24,570
bulldozing away all the other moons IO

298
00:13:27,590 --> 00:13:26,100
has heating there because it's

299
00:13:32,510 --> 00:13:27,600
interacting with the other satellites in

300
00:13:35,390 --> 00:13:32,520
the solar system peter system if Triton

301
00:13:36,770 --> 00:13:35,400
doesn't have that and we're really

302
00:13:38,450 --> 00:13:36,780
looking at cases more like Triton words

303
00:13:40,490 --> 00:13:38,460
bulldozing away everything else and

304
00:13:42,590 --> 00:13:40,500
you're just left without with that one

305
00:13:44,510 --> 00:13:42,600
so you're not gonna have long term tidal

306
00:13:48,560 --> 00:13:44,520
heating in these there any heating

307
00:13:51,260 --> 00:13:48,570
interior is going to be radiogenic long

308
00:13:54,740 --> 00:13:51,270
live stuff and finally are they

309
00:13:57,410 --> 00:13:54,750
detectable probably but you need a lot

310
00:13:58,490 --> 00:13:57,420
of transits to tell the first few

311
00:13:59,930 --> 00:13:58,500
transits they're just gonna be off a

312
00:14:02,120 --> 00:13:59,940
little bit and it's going to look like

313
00:14:04,010 --> 00:14:02,130

noise in the data you lots and lots of

314
00:14:06,829 --> 00:14:04,020
transits to tell and it's only the

315
00:14:08,780 --> 00:14:06,839
furthest most of the exoplanets that we

316
00:14:10,280 --> 00:14:08,790
can actually do this for so 7 plus

317
00:14:11,660 --> 00:14:10,290
transits for something as a 1a you

318
00:14:14,780 --> 00:14:11,670
around a solar type star that takes

319
00:14:16,400 --> 00:14:14,790
seven years it's going to take a little

320
00:14:17,720 --> 00:14:16,410
while before we start to get these XM

321
00:14:21,520 --> 00:14:17,730
ones because we just need lots and lots

322
00:14:24,500 --> 00:14:21,530
of transits and so just wrapping it up

323
00:14:26,060 --> 00:14:24,510
exit wounds are potentially large enough

324
00:14:27,920 --> 00:14:26,070
to be habitable the ones that are

325
00:14:30,170 --> 00:14:27,930
potentially habitable are the easiest to

326
00:14:32,120 --> 00:14:30,180
detect so if we hear about any exit

327
00:14:33,770 --> 00:14:32,130
wounds within the next 10 years they're

328
00:14:37,400 --> 00:14:33,780
going to be ones we want to look at for

329
00:14:38,630 --> 00:14:37,410
habitability you know to capture these

330
00:14:43,070 --> 00:14:38,640
there are a couple of different ways to

331
00:14:45,470 --> 00:14:43,080
do it but Sir training up satellites is

332
00:14:47,810 --> 00:14:45,480
potentially most effective way to do it

333
00:14:49,430 --> 00:14:47,820
and then once you're captured the about

334
00:15:00,920 --> 00:14:49,440
a fifty percent chance that the tides

335
00:15:06,120 --> 00:15:04,019
um so what does that sudden peak in

336
00:15:07,440 --> 00:15:06,130
tidal heating mean for habitability so

337
00:15:09,420 --> 00:15:07,450
if there was life before would be

338
00:15:12,600 --> 00:15:09,430

completely sterilized from the capturing

339
00:15:14,250 --> 00:15:12,610
process probably but it's also i mean

340
00:15:15,990 --> 00:15:14,260
we're talking about like a couple of

341
00:15:18,269 --> 00:15:16,000
million years after the disc dissipation

342
00:15:20,220 --> 00:15:18,279
so that was that would be before life

343
00:15:21,600 --> 00:15:20,230
the earliest evidence they have real

344
00:15:24,030 --> 00:15:21,610
life on Earth this is sort of the same

345
00:15:26,910 --> 00:15:24,040
time scale is the moon-forming impact on

346
00:15:28,829 --> 00:15:26,920
earth which was a sterilization event so

347
00:15:32,430 --> 00:15:28,839
yeah you can think about the same sort

348
00:15:34,170 --> 00:15:32,440
of it's actually less dramatic than the

349
00:15:35,699 --> 00:15:34,180
moon firing because the movie forming

350
00:15:38,519 --> 00:15:35,709
impacts tripped into our surface this

351
00:15:43,980 --> 00:15:38,529
would just heat up the surface but only

352
00:15:47,819 --> 00:15:43,990
for about a million years did you

353
00:15:49,980 --> 00:15:47,829
mention that you had any candidates so

354
00:15:53,040 --> 00:15:49,990
that they've been looking so this is

355
00:15:54,629 --> 00:15:53,050
this is Kepler data for one that they

356
00:15:58,290 --> 00:15:54,639
thought was and it turns out this was

357
00:16:00,000 --> 00:15:58,300
actually a an unseen non transiting

358
00:16:03,060 --> 00:16:00,010
planet that was causing these timing

359
00:16:06,150 --> 00:16:03,070
variations but this the search miss

360
00:16:09,090 --> 00:16:06,160
horny and kipping were doing was just

361
00:16:11,569 --> 00:16:09,100
too I was looking for them and it's

362
00:16:13,650 --> 00:16:11,579
eventually going to look like that but

363
00:16:15,509 --> 00:16:13,660

you know they were going to be a lot

364
00:16:17,040 --> 00:16:15,519
more and this one you can tell this is

365
00:16:19,920 --> 00:16:17,050
days on the bottom there so this is all

366
00:16:21,449 --> 00:16:19,930
very large variation the variations were

367
00:16:25,800 --> 00:16:21,459
going to probably looking for for the

368
00:16:29,009 --> 00:16:25,810
dialects and moons are serve five to one

369
00:16:31,319 --> 00:16:29,019
minute type variations so you need

370
00:16:34,699 --> 00:16:31,329
really good data any lots of it to be

371
00:16:37,199 --> 00:16:34,709
very confident they're going to see it

372
00:16:40,530 --> 00:16:37,209
but potentially it could be there in the

373
00:16:42,389 --> 00:16:40,540
Kepler data if we mine it enough it's

374
00:16:47,970 --> 00:16:42,399
really computationally intensive to do

375
00:16:51,300 --> 00:16:47,980
though so is there some sort of minimum

376
00:16:53,189 --> 00:16:51,310
ratio for satellite exchange like do you

377
00:16:55,559 --> 00:16:53,199
have to have a mars-sized satellite

378
00:16:57,090 --> 00:16:55,569
initially for an earth-sized satellite

379
00:16:59,400 --> 00:16:57,100
to take its place there's not a minimum

380
00:17:02,790 --> 00:16:59,410
ratio but the you know the closer the

381
00:17:06,060 --> 00:17:02,800
ratio the the higher the cross section

382
00:17:11,520 --> 00:17:06,070
for it but yeah you know I further

383
00:17:13,260 --> 00:17:11,530
for for that case the small guy there is

384
00:17:17,700 --> 00:17:13,270
a hundredth of the mass of the other two

385
00:17:20,940 --> 00:17:17,710
guys so he's Oommen off there at you