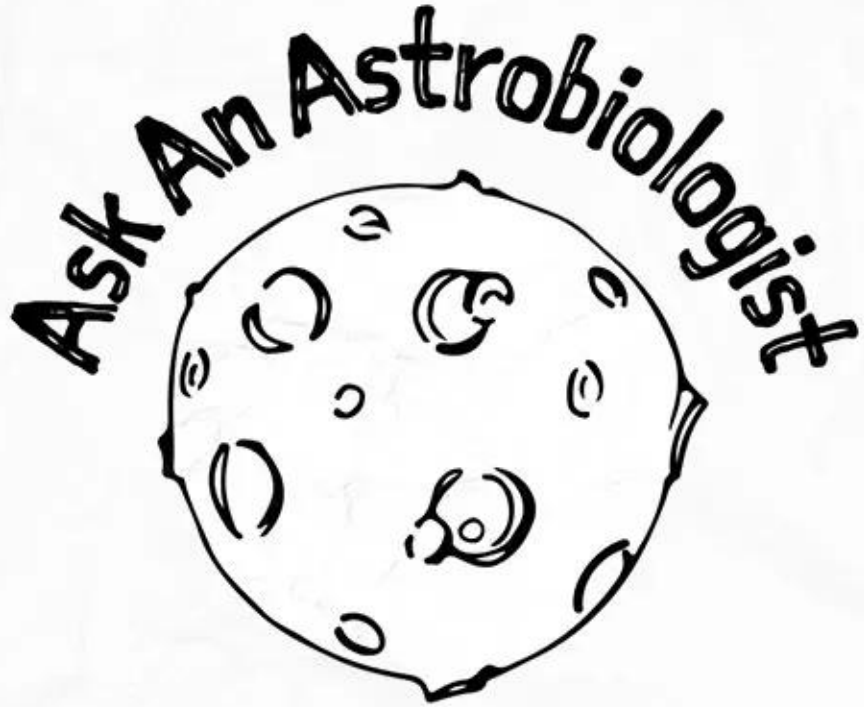

Episode 10: January 25th, 2018

Dr. Sean Raymond

NASA Astrobiology Program

1
00:00:29,830 --> 00:00:07,200
[Music]

2
00:00:34,340 --> 00:00:31,880
greetings friends of astrobiology

3
00:00:36,350 --> 00:00:34,350
welcome to a brand new episode of ask an

4
00:00:38,900 --> 00:00:36,360
astrobiologist a show where we celebrate

5
00:00:40,729 --> 00:00:38,910
science and celebrate scientists money

6
00:00:42,380 --> 00:00:40,739
may enjoy some and this program is made

7
00:00:45,470 --> 00:00:42,390
possible by contributions from the NASA

8
00:00:47,660 --> 00:00:45,480
Astrobiology program Elsi the earth Life

9
00:00:49,940 --> 00:00:47,670
Science Institute at Tokyo Tech and the

10
00:00:52,220 --> 00:00:49,950
nonprofit blue Bravo space we're very

11
00:00:54,470 --> 00:00:52,230
excited this months to have a researcher

12
00:00:57,229 --> 00:00:54,480
from France dr. Sean Raymond who is a

13
00:00:59,630 --> 00:00:57,239

astronomer at the ostrov Astrophysical

14
00:01:02,090 --> 00:00:59,640
laboratory in the city of Bordeaux in

15
00:01:03,830 --> 00:01:02,100
France ABS yo attitudes I took the a to

16
00:01:05,780 --> 00:01:03,840
ski to connect the Philip a francophone

17
00:01:08,270 --> 00:01:05,790
EF new a tus you know some a Mojave

18
00:01:10,070 --> 00:01:08,280
deserve our dr. Raymond it's a pleasure

19
00:01:11,780 --> 00:01:10,080
to have you here I know from your

20
00:01:13,760 --> 00:01:11,790
publication record you're so busy

21
00:01:16,300 --> 00:01:13,770
studying all these really cool stuff and

22
00:01:18,350 --> 00:01:16,310
so thanks for being with us today

23
00:01:21,109 --> 00:01:18,360
well thanks a lot it's a pleasure to be

24
00:01:22,789 --> 00:01:21,119
here like we enjoy doing in this show is

25
00:01:25,370 --> 00:01:22,799
before we start talking about the

26
00:01:27,410 --> 00:01:25,380
science is go back in time a little bit

27
00:01:31,280 --> 00:01:27,420
but before we actually talk about that

28
00:01:33,440 --> 00:01:31,290
we had our monthly background quiz that

29
00:01:35,569 --> 00:01:33,450
we need to get started with first so

30
00:01:37,640 --> 00:01:35,579
this month it's a magnificent place on

31
00:01:38,990 --> 00:01:37,650
our solar system that we have the

32
00:01:41,030 --> 00:01:39,000
pleasure of having as a background and

33
00:01:43,639 --> 00:01:41,040
last month it was a different moon in

34
00:01:45,260 --> 00:01:43,649
the solar system that was our background

35
00:01:48,350 --> 00:01:45,270
and the question this month was well

36
00:01:50,330 --> 00:01:48,360
what was that moon and a few of you got

37
00:01:52,310 --> 00:01:50,340
it right um I think only one actually

38
00:01:55,190 --> 00:01:52,320

and that's Adam Robinson shout out to

39
00:01:57,080 --> 00:01:55,200
you good job it was indeed Europa and a

40
00:02:00,649 --> 00:01:57,090
beautiful lynnae's that are on the moon

41
00:02:02,120 --> 00:02:00,659
so next time on the show what is the

42
00:02:06,920 --> 00:02:02,130
planet behind me and I'll give you a

43
00:02:10,430 --> 00:02:06,930
shout outs so was that said Sean if we

44
00:02:13,190 --> 00:02:10,440
go back in time many many years ago in a

45
00:02:13,790 --> 00:02:13,200
galaxy not too far away what caused you

46
00:02:17,180 --> 00:02:13,800
to become a

47
00:02:19,130 --> 00:02:17,190
scientists in the first place I mean I

48
00:02:22,190 --> 00:02:19,140
don't think my story is pretty common

49
00:02:23,720 --> 00:02:22,200
among scientists it was I kind of day

50
00:02:26,300 --> 00:02:23,730
dreamed a lot when I was a kid I read

51
00:02:28,130 --> 00:02:26,310
lots of science fiction books and I was

52
00:02:29,600 --> 00:02:28,140
good at math and so when you put those

53
00:02:31,670 --> 00:02:29,610
things together you naturally gonna

54
00:02:34,940 --> 00:02:31,680
gravitate to what science I got really

55
00:02:37,100 --> 00:02:34,950
into into space stuff in high school

56
00:02:38,690 --> 00:02:37,110
when I started reading all these classic

57
00:02:41,320 --> 00:02:38,700
science fiction stories by people like

58
00:02:44,360 --> 00:02:41,330
Isaac Asimov and arthur c clarke and

59
00:02:46,970 --> 00:02:44,370
from there I mean that was kind of the

60
00:02:48,560 --> 00:02:46,980
seed of my interest in so how did you

61
00:02:50,030 --> 00:02:48,570
develop that interest growing up in high

62
00:02:51,920 --> 00:02:50,040
school and then I know you traveled

63
00:02:54,470 --> 00:02:51,930

quite a bit until your position today

64
00:02:57,830 --> 00:02:54,480
like take us through that path and what

65
00:02:59,540 --> 00:02:57,840
triggered I'd interested in astronomy so

66
00:03:02,120 --> 00:02:59,550
so when I got to college I was

67
00:03:04,460 --> 00:03:02,130
interested in math and science in

68
00:03:06,740 --> 00:03:04,470
general and so I took a bunch of math

69
00:03:08,780 --> 00:03:06,750
classes I took physics and I took

70
00:03:10,100 --> 00:03:08,790
astronomy there was one astronomy class

71
00:03:13,220 --> 00:03:10,110
in the college I went to the small

72
00:03:14,930 --> 00:03:13,230
College in Maine called Bowdoin and so

73
00:03:17,210 --> 00:03:14,940
there's only one astronomy class and I

74
00:03:18,920 --> 00:03:17,220
loved it it was really exciting to me

75
00:03:21,440 --> 00:03:18,930
but there was nowhere to go from there

76
00:03:23,570 --> 00:03:21,450
so so I wasn't sure what to do next and

77
00:03:26,930 --> 00:03:23,580
so what I did is is junior year of

78
00:03:28,400 --> 00:03:26,940
college a lot of my friends didn't there

79
00:03:31,610 --> 00:03:28,410
a semester abroad where they went

80
00:03:34,820 --> 00:03:31,620
and basically partied somewhere you know

81
00:03:36,979 --> 00:03:34,830
they went to they often went to to Spain

82
00:03:39,560 --> 00:03:36,989
or places like that and I did the

83
00:03:40,850 --> 00:03:39,570
opposite I ended up applying to to go to

84
00:03:42,050 --> 00:03:40,860
Caltech for a year to learn about

85
00:03:43,970 --> 00:03:42,060
astronomy because I knew they had good

86
00:03:45,920 --> 00:03:43,980
astronomy there so I went there I

87
00:03:48,170 --> 00:03:45,930
learned a bunch of astronomy it got me

88
00:03:50,420 --> 00:03:48,180

even more excited about it then I

89
00:03:52,190 --> 00:03:50,430
applied to grad so I went to Seattle to

90
00:03:55,310 --> 00:03:52,200
do astronomy and then it kind of just

91
00:03:57,620 --> 00:03:55,320
went from there and then you moved out

92
00:03:59,870 --> 00:03:57,630
of the United States to start a research

93
00:04:01,820 --> 00:03:59,880
career in France how is that transition

94
00:04:03,680 --> 00:04:01,830
is it easy to do and I know as a postdoc

95
00:04:06,080 --> 00:04:03,690
you had a kid - so you changing

96
00:04:08,660 --> 00:04:06,090
countries having kid how did you get

97
00:04:11,290 --> 00:04:08,670
that keep going that's awesome so so

98
00:04:15,259 --> 00:04:11,300
grad school I was in Seattle then I

99
00:04:18,890 --> 00:04:15,269
actually had a an unusual experience for

100
00:04:21,170 --> 00:04:18,900
for being a postdoc - so I when I by the

101
00:04:22,850 --> 00:04:21,180
time I finished my thesis my wife had

102
00:04:25,400 --> 00:04:22,860
already started a program in genic

103
00:04:27,270 --> 00:04:25,410
counseling in Denver and so I only

104
00:04:29,670 --> 00:04:27,280
applied for jobs there

105
00:04:31,860 --> 00:04:29,680
and I didn't get any and so I was stuck

106
00:04:33,360 --> 00:04:31,870
I had no job for several months I got

107
00:04:35,340 --> 00:04:33,370
really bummed out I was getting close to

108
00:04:39,030 --> 00:04:35,350
applying to you know REI or places like

109
00:04:41,270 --> 00:04:39,040
this I didn't quite come to that I ended

110
00:04:44,220 --> 00:04:41,280
up getting rescued by Vicky Meadows of

111
00:04:46,290 --> 00:04:44,230
virtual planetary laboratory Fame who

112
00:04:48,600 --> 00:04:46,300
hired me to work for her for a year

113
00:04:50,670 --> 00:04:48,610

until I got this other fellowship - to

114
00:04:52,830 --> 00:04:50,680
keep things going and so yeah while I

115
00:04:55,770 --> 00:04:52,840
was in Colorado as a postdoc I had a kid

116
00:04:58,890 --> 00:04:55,780
we had a our son Owen who just turned 10

117
00:05:01,920 --> 00:04:58,900
now and while we were in Colorado I also

118
00:05:04,260 --> 00:05:01,930
was invited out to France to basically

119
00:05:06,210 --> 00:05:04,270
as a sabbatical sort of when I was still

120
00:05:07,980 --> 00:05:06,220
a postdoc which is really cool so I came

121
00:05:10,140 --> 00:05:07,990
to Bordeaux then and stayed for about

122
00:05:12,900 --> 00:05:10,150
three months met a lot of people and

123
00:05:15,420 --> 00:05:12,910
they they kind of persuaded me to apply

124
00:05:16,770 --> 00:05:15,430
for a permanent job here and I was kind

125
00:05:19,110 --> 00:05:16,780
of nervous about it and they persuaded

126
00:05:20,280 --> 00:05:19,120
me to apply by saying hi you know that

127
00:05:22,560 --> 00:05:20,290
you probably won't get it usually had to

128
00:05:24,930 --> 00:05:22,570
apply many years in a row so if you

129
00:05:26,280 --> 00:05:24,940
apply now then maybe in 2 3 4 years

130
00:05:28,320 --> 00:05:26,290
you'll be in a good position to get the

131
00:05:30,210 --> 00:05:28,330
job but then somehow I was in the right

132
00:05:32,790 --> 00:05:30,220
place at the right time and I got the

133
00:05:35,400 --> 00:05:32,800
job the first time and and we came here

134
00:05:38,219 --> 00:05:35,410
and the rest is history like they say

135
00:05:40,050 --> 00:05:38,229
you mentioned Vicky Meadows she's been a

136
00:05:42,870 --> 00:05:40,060
mentor for many of us early careers in

137
00:05:45,480 --> 00:05:42,880
astrobiology over the years is he and is

138
00:05:47,820 --> 00:05:45,490

there any other people that you looked

139
00:05:51,450 --> 00:05:47,830
up to growing up as a scientist that

140
00:05:54,090 --> 00:05:51,460
helped you along the way so so yeah if I

141
00:05:55,290 --> 00:05:54,100
was gonna I can think of two people that

142
00:05:57,659 --> 00:05:55,300
I would consider kind of mentors

143
00:05:59,640 --> 00:05:57,669
starting saying grad school - no and one

144
00:06:02,280 --> 00:05:59,650
of them is Vicky meadows she helped me

145
00:06:05,219 --> 00:06:02,290
out a lot in many different ways and the

146
00:06:07,409 --> 00:06:05,229
other one is Susanne Holly professor at

147
00:06:09,420 --> 00:06:07,419
University of Washington she was kind of

148
00:06:11,250 --> 00:06:09,430
a mentor to half the grad students I

149
00:06:12,870 --> 00:06:11,260
think she organized some she played

150
00:06:15,000 --> 00:06:12,880
sports with us play basketball and

151
00:06:17,640 --> 00:06:15,010
softball with us she had us over to her

152
00:06:19,620 --> 00:06:17,650
house to Beatson and drink beer and gave

153
00:06:21,600 --> 00:06:19,630
us like kind of specific advice on how

154
00:06:23,969 --> 00:06:21,610
to approach different problems that came

155
00:06:25,590 --> 00:06:23,979
up it was really helpful so so those are

156
00:06:27,990 --> 00:06:25,600
kind of the two key people they helped

157
00:06:29,370 --> 00:06:28,000
me out I think that's a common story for

158
00:06:31,110 --> 00:06:29,380
all of us or scientists or really

159
00:06:33,090 --> 00:06:31,120
benefit from mentoring to develop this

160
00:06:34,920 --> 00:06:33,100
career so all of you who are watching

161
00:06:36,450 --> 00:06:34,930
who want to become scientists make sure

162
00:06:38,159 --> 00:06:36,460
you connect with good mentors you know

163
00:06:40,980 --> 00:06:38,169

that's important and we all done it and

164
00:06:42,210 --> 00:06:40,990
that's it's makes life a lot easier

165
00:06:43,140 --> 00:06:42,220
so since you've been in Bordeaux you've

166
00:06:45,120 --> 00:06:43,150
been studying some really incredible

167
00:06:47,700 --> 00:06:45,130
stuff I was mentioning the history of

168
00:06:50,219 --> 00:06:47,710
water on earth you were actually on the

169
00:06:52,050 --> 00:06:50,229
paper that announced the discovery of

170
00:06:53,520 --> 00:06:52,060
those the seven planet system the

171
00:06:55,740 --> 00:06:53,530
Trappist system a couple of months ago

172
00:06:57,540 --> 00:06:55,750
which is fantastic and you also you

173
00:07:00,110 --> 00:06:57,550
simulates different types of solar

174
00:07:02,040 --> 00:07:00,120
system so we can talk forever so perhaps

175
00:07:04,200 --> 00:07:02,050
let's or was the beginning I know you

176
00:07:05,730 --> 00:07:04,210
research to begin with for your very

177
00:07:07,230 --> 00:07:05,740
doctorate was around the history of

178
00:07:11,430 --> 00:07:07,240
water on Earth

179
00:07:14,189 --> 00:07:11,440
well what did our oceans come from so

180
00:07:15,719 --> 00:07:14,199
that's a big question so it's really

181
00:07:17,610 --> 00:07:15,729
interesting though because based on

182
00:07:20,580 --> 00:07:17,620
everything that we think we know about

183
00:07:22,980 --> 00:07:20,590
how planets form all the building blocks

184
00:07:25,800 --> 00:07:22,990
of the earth at least around where earth

185
00:07:27,990 --> 00:07:25,810
is now around orbits close to us should

186
00:07:30,089 --> 00:07:28,000
have been dry so we know that the

187
00:07:31,920 --> 00:07:30,099
mystery is weird and earth gets water

188
00:07:34,320 --> 00:07:31,930

from them and so we think it had to be

189
00:07:35,820 --> 00:07:34,330
delivered from somewhere colder from

190
00:07:37,860 --> 00:07:35,830
somewhere further away from the Sun

191
00:07:40,529 --> 00:07:37,870
where the conditions were such that yet

192
00:07:44,670 --> 00:07:40,539
ice and they you know that could

193
00:07:47,670 --> 00:07:44,680
condense somehow the icy icy bodies

194
00:07:50,249 --> 00:07:47,680
maybe icy asteroids or comets bashed

195
00:07:51,839 --> 00:07:50,259
into the earth as it was grown and so it

196
00:07:53,640 --> 00:07:51,849
used to be thought that the earth formed

197
00:07:56,399 --> 00:07:53,650
dry then there was this big kind of

198
00:07:59,610 --> 00:07:56,409
deluge of comets that delivered the

199
00:08:02,879 --> 00:07:59,620
water and that was the state of the art

200
00:08:05,550 --> 00:08:02,889
around year 2000 or so and that's when

201
00:08:06,959 --> 00:08:05,560
things started to change and then it it

202
00:08:09,540 --> 00:08:06,969
switched from thinking that it was

203
00:08:11,490 --> 00:08:09,550
mostly comets to mostly asteroids and

204
00:08:13,499 --> 00:08:11,500
the reason for that is that the chemical

205
00:08:15,899 --> 00:08:13,509
signature of water and comets is

206
00:08:17,279 --> 00:08:15,909
different than in asteroids and the one

207
00:08:19,620 --> 00:08:17,289
asteroids basically it's kind of

208
00:08:21,689 --> 00:08:19,630
asteroids called sea types that are

209
00:08:23,580 --> 00:08:21,699
linked with carbonaceous chondrite

210
00:08:25,890 --> 00:08:23,590
meteorites so we have pieces of them and

211
00:08:27,330 --> 00:08:25,900
we can measure the water in these sea

212
00:08:30,089 --> 00:08:27,340
types these carbonaceous meteorites

213
00:08:32,399 --> 00:08:30,099

looks like water on earth and so then we

214
00:08:34,079 --> 00:08:32,409
thought that it was just kind of a you

215
00:08:36,510 --> 00:08:34,089
know that the earth formed mostly from

216
00:08:38,699 --> 00:08:36,520
stuff nearby but as it was forming some

217
00:08:40,560 --> 00:08:38,709
little fraction of that originated

218
00:08:43,350 --> 00:08:40,570
further out out and what's now the

219
00:08:45,210 --> 00:08:43,360
asteroid belt of course then the story

220
00:08:47,310 --> 00:08:45,220
kept getting more and more complicated

221
00:08:49,439 --> 00:08:47,320
because those models that did great like

222
00:08:51,569 --> 00:08:49,449
getting water on earth didn't match

223
00:08:52,710 --> 00:08:51,579
other parts of the solar system so we've

224
00:08:54,130 --> 00:08:52,720
been spending a lot of time trying to

225
00:08:55,360 --> 00:08:54,140
you know have a model

226
00:08:57,640 --> 00:08:55,370
that can reproduce the whole solar

227
00:08:59,500 --> 00:08:57,650
system and it doesn't you know it's

228
00:09:01,690 --> 00:08:59,510
great to understand where water on earth

229
00:09:03,610 --> 00:09:01,700
came from that's only one piece of this

230
00:09:05,050 --> 00:09:03,620
big puzzle and you gotta get all the

231
00:09:07,510 --> 00:09:05,060
pieces to fit otherwise it doesn't work

232
00:09:08,860 --> 00:09:07,520
and so so since then the story's evolved

233
00:09:11,470 --> 00:09:08,870
there's new models for how the solar

234
00:09:12,820 --> 00:09:11,480
system may have formed and going along

235
00:09:15,250 --> 00:09:12,830
with each model there's different

236
00:09:17,710 --> 00:09:15,260
mechanisms for how because water it's

237
00:09:19,600 --> 00:09:17,720
tough somehow got close to the soul you

238
00:09:21,340 --> 00:09:19,610

know closer to the Sun and bashed into

239
00:09:23,170 --> 00:09:21,350
the earth as a group and right now the

240
00:09:25,960 --> 00:09:23,180
latest thinking is that Jupiter played a

241
00:09:28,240 --> 00:09:25,970
key role just by growing does Jupiter

242
00:09:30,160 --> 00:09:28,250
growing toss is a bunch of nearby stuff

243
00:09:31,270 --> 00:09:30,170
all over the place that stuff should

244
00:09:33,030 --> 00:09:31,280
probably have had a decent amount of

245
00:09:35,080 --> 00:09:33,040
water and some of the bashing of years

246
00:09:36,610 --> 00:09:35,090
sorry that was probably longer answer

247
00:09:39,190 --> 00:09:36,620
than you were expected but no it's

248
00:09:41,770 --> 00:09:39,200
really interesting this is really

249
00:09:43,480 --> 00:09:41,780
interesting because it does perhaps play

250
00:09:45,280 --> 00:09:43,490
into a role in thinking about life on

251
00:09:47,920 --> 00:09:45,290
other worlds if life does indeed depend

252
00:09:49,900 --> 00:09:47,930
on water and earth is in the right

253
00:09:51,940 --> 00:09:49,910
habitable zone of the star not too far

254
00:09:54,490 --> 00:09:51,950
not too close and yet you also need a

255
00:09:56,260 --> 00:09:54,500
giant planet far away to kind of send

256
00:09:58,810 --> 00:09:56,270
all the material into the inner solar

257
00:10:01,120 --> 00:09:58,820
system to see the planet with water for

258
00:10:03,550 --> 00:10:01,130
example that does does that mean that

259
00:10:05,860 --> 00:10:03,560
you know for our life to evolve on a

260
00:10:10,300 --> 00:10:05,870
planet doesn't need a large jupiter-like

261
00:10:13,360 --> 00:10:10,310
planet outside of it so that's a good

262
00:10:15,790 --> 00:10:13,370
question so the question that you asked

263
00:10:17,950 --> 00:10:15,800

me and the most people asked is you know

264
00:10:20,740 --> 00:10:17,960
it's basically and also the way I framed

265
00:10:24,910 --> 00:10:20,750
the answer is why is Earth so what right

266
00:10:26,620 --> 00:10:24,920
why do we have water at all but another

267
00:10:28,720 --> 00:10:26,630
question and these days we're kind of

268
00:10:31,450 --> 00:10:28,730
flipping other things around is why is

269
00:10:33,700 --> 00:10:31,460
Earth so dry but he's done how we think

270
00:10:37,780 --> 00:10:33,710
these things form it's really hard to

271
00:10:40,270 --> 00:10:37,790
prevent things from getting from water

272
00:10:44,110 --> 00:10:40,280
rich bodies coming into the inner solar

273
00:10:46,570 --> 00:10:44,120
system and so it's possible that we

274
00:10:48,400 --> 00:10:46,580
think a Jupiter played a key role you

275
00:10:50,140 --> 00:10:48,410
know it did as it grew we think it's

276
00:10:51,820 --> 00:10:50,150
sprinkled some water it's stuff onto the

277
00:10:54,070 --> 00:10:51,830
earth and got the water that we have

278
00:10:55,360 --> 00:10:54,080
onto there but it's possible that it

279
00:10:57,700 --> 00:10:55,370
played another role in terms of

280
00:11:00,550 --> 00:10:57,710
protecting the inner solar system from

281
00:11:02,590 --> 00:11:00,560
what was beyond Jupiter and so we think

282
00:11:04,600 --> 00:11:02,600
that as planets grow you know they grow

283
00:11:07,670 --> 00:11:04,610
in these big discs of gas and dust

284
00:11:10,430 --> 00:11:07,680
around young stars and as they grow

285
00:11:13,250 --> 00:11:10,440
tend to launch density waves in the gas

286
00:11:15,410 --> 00:11:13,260
once say once a once an object is about

287
00:11:17,180 --> 00:11:15,420
the size of the earth or so and so we're

288
00:11:19,639 --> 00:11:17,190

talking more you know things that are

289
00:11:21,740 --> 00:11:19,649
like the cores of the giant planets or

290
00:11:24,500 --> 00:11:21,750
Uranus Neptune saturn those things not

291
00:11:26,030 --> 00:11:24,510
the growing earth so further out those

292
00:11:28,160 --> 00:11:26,040
things launch density ways and that

293
00:11:31,930 --> 00:11:28,170
tends to change their orbits it tends to

294
00:11:34,550 --> 00:11:31,940
make a move inward and what we think is

295
00:11:36,980 --> 00:11:34,560
Jupiter's role may not have been so much

296
00:11:38,780 --> 00:11:36,990
to but just the right amount of water on

297
00:11:41,210 --> 00:11:38,790
earth but it may have been even more

298
00:11:44,000 --> 00:11:41,220
important that it blocked the inward

299
00:11:47,329 --> 00:11:44,010
migration of these bodies and so we see

300
00:11:49,310 --> 00:11:47,339
planets that you know that are very

301
00:11:51,560 --> 00:11:49,320
close to their stars so-called

302
00:11:53,750 --> 00:11:51,570
super-earth planets they exist around

303
00:11:55,030 --> 00:11:53,760
half of all stars all right they're

304
00:11:57,560 --> 00:11:55,040
super common they're all over the place

305
00:11:59,990 --> 00:11:57,570
one model for how they got there is that

306
00:12:02,000 --> 00:12:00,000
they've started off you know farther out

307
00:12:04,100 --> 00:12:02,010
like like you're innocent Neptune or

308
00:12:06,370 --> 00:12:04,110
Saturn and then they migrated inward and

309
00:12:08,750 --> 00:12:06,380
end up really close to their stars and

310
00:12:10,310 --> 00:12:08,760
so Jupiter's role may have been to

311
00:12:13,340 --> 00:12:10,320
basically block that migration and

312
00:12:15,740 --> 00:12:13,350
protect the growing rocky planets from

313
00:12:17,600 --> 00:12:15,750

those invaders so so again it's another

314
00:12:19,970 --> 00:12:17,610
idea that's out there but it's

315
00:12:22,070 --> 00:12:19,980
fascinating so that means that the

316
00:12:25,280 --> 00:12:22,080
location where the planets are in our

317
00:12:28,699 --> 00:12:25,290
current solar system has changed over

318
00:12:30,560 --> 00:12:28,709
time is it still changing so they

319
00:12:33,500 --> 00:12:30,570
definitely changed over time it's not

320
00:12:35,720 --> 00:12:33,510
changing much now not the planets orbits

321
00:12:37,760 --> 00:12:35,730
are their orbital distances are more or

322
00:12:40,190 --> 00:12:37,770
less fixed and so they evolve and they

323
00:12:41,449 --> 00:12:40,200
exchange angular momentum by kicking

324
00:12:44,449 --> 00:12:41,459
each other a little bit here and there

325
00:12:47,110 --> 00:12:44,459
but there's not much chance of a big

326
00:12:49,579 --> 00:12:47,120
change in the future between now and

327
00:12:51,410 --> 00:12:49,589
when the Sun becomes a red giant in a

328
00:12:53,960 --> 00:12:51,420
you know five billion years there's

329
00:12:55,250 --> 00:12:53,970
something like a 1% chance that the

330
00:12:57,710 --> 00:12:55,260
terrestrial planet system will go

331
00:12:59,690 --> 00:12:57,720
unstable and you know there'll be a

332
00:13:01,100 --> 00:12:59,700
collision between planets this is

333
00:13:03,350 --> 00:13:01,110
actually this punch guy is less gosh

334
00:13:05,449 --> 00:13:03,360
there were this really nice thing so

335
00:13:07,670 --> 00:13:05,459
that that's possible but unlikely

336
00:13:09,380 --> 00:13:07,680
so much more likely is just that our

337
00:13:11,449 --> 00:13:09,390
orbits will be stable they're still

338
00:13:13,190 --> 00:13:11,459

chaotic you can't predict what they'll

339
00:13:15,410 --> 00:13:13,200
you know what they'll do and you know

340
00:13:18,470 --> 00:13:15,420
indefinitely into the future but they're

341
00:13:20,360 --> 00:13:18,480
unlikely to go unstable for those of you

342
00:13:21,600 --> 00:13:20,370
who are sci-fi writer as you're welcome

343
00:13:23,910 --> 00:13:21,610
for the amazing material

344
00:13:25,380 --> 00:13:23,920
just talked about so let's talk about

345
00:13:27,300 --> 00:13:25,390
the solar systems a bit more that's

346
00:13:29,519 --> 00:13:27,310
something you simulates in a computer is

347
00:13:31,530 --> 00:13:29,529
try to predict what kind of planetary

348
00:13:34,139 --> 00:13:31,540
configurations could be stable around

349
00:13:36,060 --> 00:13:34,149
different kind of stars how special how

350
00:13:37,949 --> 00:13:36,070
unique is our solar system do with you

351
00:13:40,500 --> 00:13:37,959
would we expect it elsewhere what other

352
00:13:44,639 --> 00:13:40,510
stable planetary configurations have you

353
00:13:46,560 --> 00:13:44,649
found that's a big question so so

354
00:13:47,850 --> 00:13:46,570
there's there's two kinds of ways to

355
00:13:50,250 --> 00:13:47,860
answer I can either answer from the

356
00:13:53,100 --> 00:13:50,260
point of view of observations of what we

357
00:13:54,509 --> 00:13:53,110
know empirically or from what comes out

358
00:13:57,690 --> 00:13:54,519
of the computer so let me do the

359
00:13:59,490 --> 00:13:57,700
observations part first so so take the

360
00:14:01,620 --> 00:13:59,500
solar system and put it around another

361
00:14:04,680 --> 00:14:01,630
star and then let's observe it with our

362
00:14:07,230 --> 00:14:04,690
current Earth technology what could we

363
00:14:09,389 --> 00:14:07,240

see we have eight planets the only one

364
00:14:11,130 --> 00:14:09,399
that we can find is Jupiter so if we're

365
00:14:12,300 --> 00:14:11,140
trying to figure out how common solar

366
00:14:15,660 --> 00:14:12,310
systems are what we're really looking

367
00:14:17,910 --> 00:14:15,670
for our Sun Jupiter systems and so based

368
00:14:19,170 --> 00:14:17,920
on just the orbit of Jupiter you know

369
00:14:20,639 --> 00:14:19,180
well it was stupid we know Jupiter's

370
00:14:22,319 --> 00:14:20,649
mass well we can measure stupider is

371
00:14:24,930 --> 00:14:22,329
mass and kind of its orbital distance

372
00:14:26,189 --> 00:14:24,940
and its orbital shape and if you put

373
00:14:28,079 --> 00:14:26,199
those three things together what

374
00:14:31,949 --> 00:14:28,089
fraction of stars like the Sun have that

375
00:14:33,990 --> 00:14:31,959
it's about one percent it's about 10% of

376
00:14:35,939 --> 00:14:34,000
stars have a planet of Jupiter's mass

377
00:14:37,680 --> 00:14:35,949
and about ten percent of those have

378
00:14:40,259 --> 00:14:37,690
orbits you know broadly similar to

379
00:14:43,110 --> 00:14:40,269
Jupiter's so we don't know how common

380
00:14:45,509 --> 00:14:43,120
solar systems are overall but they can't

381
00:14:47,310 --> 00:14:45,519
be more common than one percent because

382
00:14:49,829 --> 00:14:47,320
we know that all we can see is is that

383
00:14:51,930 --> 00:14:49,839
so it's possible that Earth's are more

384
00:14:54,780 --> 00:14:51,940
common than that but solar systems can't

385
00:14:57,990 --> 00:14:54,790
be more common if they're interesting

386
00:15:00,030 --> 00:14:58,000
interesting yeah that's great if any of

387
00:15:02,970 --> 00:15:00,040
you who are watching have questions for

388
00:15:05,699 --> 00:15:02,980

dr. Raymond please use hashtag ask ask

389
00:15:07,050 --> 00:15:05,709
for bio on Twitter or if you are on say

390
00:15:08,220 --> 00:15:07,060
Gannett type into the chat room for

391
00:15:11,400 --> 00:15:08,230
those of you who are connecting on

392
00:15:13,079 --> 00:15:11,410
Facebook live yeah I think ask questions

393
00:15:16,050 --> 00:15:13,089
there too we'll be monitoring monitoring

394
00:15:18,000 --> 00:15:16,060
of those so Shawn you've been working on

395
00:15:20,790 --> 00:15:18,010
these exoplanets and habitability of

396
00:15:22,650 --> 00:15:20,800
these of these of these other worlds and

397
00:15:24,269 --> 00:15:22,660
you've been on the paper of the Trappist

398
00:15:25,829 --> 00:15:24,279
system could you remind us what Trappist

399
00:15:27,990 --> 00:15:25,839
is how do you got involved and what does

400
00:15:32,370 --> 00:15:28,000
that possibly mean as a observational

401
00:15:34,319 --> 00:15:32,380
target so that I mean so Trappist one is

402
00:15:34,960 --> 00:15:34,329
it's one of the coolest planetary

403
00:15:37,540 --> 00:15:34,970
systems that's

404
00:15:39,369 --> 00:15:37,550
found today so the star itself is this

405
00:15:42,429 --> 00:15:39,379
puny little starts barely a star tool

406
00:15:44,920 --> 00:15:42,439
just barely above the brown dwarf star

407
00:15:46,660 --> 00:15:44,930
boundary so it's it's only about eight

408
00:15:49,420 --> 00:15:46,670
percent the mass of the Sun it's really

409
00:15:52,210 --> 00:15:49,430
faint but it has a system of seven known

410
00:15:54,389 --> 00:15:52,220
planets that are all on very compact

411
00:15:56,740 --> 00:15:54,399
orbits and since this thing is so faint

412
00:15:58,990 --> 00:15:56,750
these orbits that are so close to the

413
00:16:00,429 --> 00:15:59,000

star are in you know several them are in

414
00:16:04,569 --> 00:16:00,439
the habitable zone which is pretty cool

415
00:16:07,689 --> 00:16:04,579
and so they're all all seven are broadly

416
00:16:08,889 --> 00:16:07,699
earth sized and within a factor of you

417
00:16:12,069 --> 00:16:08,899
know thirty percent of something like

418
00:16:13,800 --> 00:16:12,079
that of the size of the earth and to me

419
00:16:16,269 --> 00:16:13,810
with the coolest part of all is that

420
00:16:16,929 --> 00:16:16,279
their orbital configuration is very

421
00:16:20,499 --> 00:16:16,939
special

422
00:16:22,869 --> 00:16:20,509
their each pair of planets is in what we

423
00:16:24,579 --> 00:16:22,879
call an orbital resonance so they go

424
00:16:28,090 --> 00:16:24,589
around and kind of integer multiple

425
00:16:29,590 --> 00:16:28,100
times each other so for example a couple

426
00:16:30,910 --> 00:16:29,600
of them are in three to two residents

427
00:16:33,879 --> 00:16:30,920
that means that the inner planet goes

428
00:16:36,670 --> 00:16:33,889
around three times for every two orbits

429
00:16:39,910 --> 00:16:36,680
of the outer world and the whole seven

430
00:16:42,460 --> 00:16:39,920
planet system is in a giant resonant

431
00:16:48,610 --> 00:16:42,470
chain which is really cool it's a really

432
00:16:50,889 --> 00:16:48,620
nice setup and it's perfectly stable if

433
00:16:52,269 --> 00:16:50,899
you take into account that the planets

434
00:16:54,299 --> 00:16:52,279
didn't just kind of form there by chance

435
00:16:59,410 --> 00:16:54,309
by bashing into each other they probably

436
00:17:01,119 --> 00:16:59,420
migrated inward Jupiter protecting the

437
00:17:03,340 --> 00:17:01,129
inner solar system from things migrating

438
00:17:05,679 --> 00:17:03,350

inward this is an example it's pretty

439
00:17:06,970 --> 00:17:05,689
clear these planets did migrate at least

440
00:17:09,850 --> 00:17:06,980
to some degree to end up in that

441
00:17:12,059 --> 00:17:09,860
configuration so so that's the system

442
00:17:13,929 --> 00:17:12,069
and I played a very small role in

443
00:17:16,179 --> 00:17:13,939
discovering but it was really fun and

444
00:17:18,549 --> 00:17:16,189
exciting I was really happy to be part I

445
00:17:21,039 --> 00:17:18,559
was contacted me and and another guy

446
00:17:24,399 --> 00:17:21,049
says he's in Bordeaux we were contacted

447
00:17:26,140 --> 00:17:24,409
I guess a couple years ago now after

448
00:17:29,799 --> 00:17:26,150
they had found three planets around

449
00:17:33,159 --> 00:17:29,809
Travis one and the third of those

450
00:17:35,230 --> 00:17:33,169
planets looked weird so they only had a

451
00:17:37,930 --> 00:17:35,240
few different transits they had seen and

452
00:17:39,520 --> 00:17:37,940
at least in two cases the transits were

453
00:17:41,049 --> 00:17:39,530
double it looked like there were two

454
00:17:44,649 --> 00:17:41,059
planets crossing in front of the star at

455
00:17:46,480 --> 00:17:44,659
the same time and this means something's

456
00:17:48,740 --> 00:17:46,490
you know something's going on because

457
00:17:50,180 --> 00:17:48,750
the odds of seeing two planets at once

458
00:17:53,360 --> 00:17:50,190
right as they're passing in front of a

459
00:17:55,580 --> 00:17:53,370
star very small so what they thought the

460
00:17:57,740 --> 00:17:55,590
you know because you know the main guy

461
00:17:59,720 --> 00:17:57,750
and I'm oh hey Tia what they thought at

462
00:18:02,149 --> 00:17:59,730
the time was it was it possible that

463
00:18:04,519 --> 00:18:02,159

this was actually a binary planet so a

464
00:18:07,580 --> 00:18:04,529
planet you know instead of an Earth Moon

465
00:18:10,519 --> 00:18:07,590
system like an earth Earth system in

466
00:18:12,139 --> 00:18:10,529
orbit around the star and they asked me

467
00:18:13,759 --> 00:18:12,149
and Punk and then another guy said I

468
00:18:15,649 --> 00:18:13,769
mean a cone to kind of think about this

469
00:18:18,470 --> 00:18:15,659
you know would this be possible could

470
00:18:19,940 --> 00:18:18,480
this ever form would it be stable you

471
00:18:22,009 --> 00:18:19,950
know what would it look like if we were

472
00:18:23,840 --> 00:18:22,019
measuring it and so we started thinking

473
00:18:25,789 --> 00:18:23,850
about that in the meantime they got more

474
00:18:28,730 --> 00:18:25,799
observations and they found that there

475
00:18:31,789 --> 00:18:28,740
was this long resonant chain and so then

476
00:18:33,350 --> 00:18:31,799
the explanation for why they saw double

477
00:18:35,899 --> 00:18:33,360
transits was because of the resonance is

478
00:18:37,940 --> 00:18:35,909
not and not because it was a binary but

479
00:18:40,940 --> 00:18:37,950
it was still exciting it was fun to be

480
00:18:44,180 --> 00:18:40,950
Barba's yeah fascinating fascinating

481
00:18:46,159 --> 00:18:44,190
so the James Webb Space Telescope should

482
00:18:48,499 --> 00:18:46,169
be launching towards the end of this

483
00:18:51,369 --> 00:18:48,509
year and the Trappist system is not

484
00:18:53,539 --> 00:18:51,379
particularly far astronomically speaking

485
00:18:55,789 --> 00:18:53,549
what do you think we will learn new

486
00:19:01,070 --> 00:18:55,799
about this system if we have a point to

487
00:19:03,049 --> 00:19:01,080
it was there was a James Webb I this is

488
00:19:05,690 --> 00:19:03,059

a that's a good question I don't know

489
00:19:07,460 --> 00:19:05,700
the answer to that I asked people about

490
00:19:11,060 --> 00:19:07,470
this kind of thing a lot exactly what

491
00:19:13,519 --> 00:19:11,070
can be nailed down from observations and

492
00:19:15,769 --> 00:19:13,529
it's very I mean planets are complicated

493
00:19:18,320 --> 00:19:15,779
and so exactly what is gonna come out I

494
00:19:20,600 --> 00:19:18,330
can't predict I don't know I think it's

495
00:19:22,730 --> 00:19:20,610
always worth going and looking because

496
00:19:25,009 --> 00:19:22,740
you can never it's great to come up with

497
00:19:27,350 --> 00:19:25,019
as many crazy ideas as you possibly can

498
00:19:29,299 --> 00:19:27,360
there's any gotta test them so I don't

499
00:19:30,919 --> 00:19:29,309
think it's worth you know thinking that

500
00:19:32,180 --> 00:19:30,929
we know it's coming in advance it's

501
00:19:34,970 --> 00:19:32,190
worth going and looking and seeing and

502
00:19:37,430 --> 00:19:34,980
we don't have wisdom about what you may

503
00:19:39,200 --> 00:19:37,440
found do we know if these planets have

504
00:19:42,980 --> 00:19:39,210
atmospheres because that was fears tend

505
00:19:45,560 --> 00:19:42,990
to hold the signatures of life it would

506
00:19:47,840 --> 00:19:45,570
be awesome if they do I mean I think

507
00:19:49,430 --> 00:19:47,850
given that there that they migrated

508
00:19:52,759 --> 00:19:49,440
clearly they migrated at least to some

509
00:19:54,289 --> 00:19:52,769
degree that means that they must have

510
00:19:55,850 --> 00:19:54,299
started off a little bit further out

511
00:19:58,730 --> 00:19:55,860
than they are now right now the

512
00:20:00,499 --> 00:19:58,740
outermost ones are the outermost couple

513
00:20:01,810 --> 00:20:00,509

couple planets are near even a little

514
00:20:04,090 --> 00:20:01,820
bit past

515
00:20:07,870 --> 00:20:04,100
would call the snow line the snow line

516
00:20:11,200 --> 00:20:07,880
is is the distance from the star beyond

517
00:20:12,670 --> 00:20:11,210
which ice can condense so inside the

518
00:20:14,380 --> 00:20:12,680
snow line you can build plants out of

519
00:20:16,630 --> 00:20:14,390
rocks past the snow line you can build

520
00:20:18,010 --> 00:20:16,640
plants out of rocks and water so you

521
00:20:20,260 --> 00:20:18,020
expect things to be much more water rich

522
00:20:22,360 --> 00:20:20,270
past there so at least the outermost one

523
00:20:23,740 --> 00:20:22,370
or two planets this probably has a

524
00:20:26,110 --> 00:20:23,750
decent amount of water just from where

525
00:20:27,730 --> 00:20:26,120
it is now and if the other ones migrate

526
00:20:29,980 --> 00:20:27,740
inward it's possible that they all have

527
00:20:31,510 --> 00:20:29,990
a decent amount of water and if they

528
00:20:32,830 --> 00:20:31,520
have water then they probably have all

529
00:20:35,650 --> 00:20:32,840
the other volatiles that can contribute

530
00:20:37,390 --> 00:20:35,660
to an atmosphere so so this is kind of

531
00:20:38,890 --> 00:20:37,400
you know a line of thinking that would

532
00:20:41,680 --> 00:20:38,900
argue they probably have atmospheres but

533
00:20:43,060 --> 00:20:41,690
like I said you gotta go Jeff we have to

534
00:20:44,620 --> 00:20:43,070
check indeed um

535
00:20:47,950 --> 00:20:44,630
fingers crossed that it's an exciting

536
00:20:48,580 --> 00:20:47,960
system so Trappist is another solar

537
00:20:51,220 --> 00:20:48,590
system

538
00:20:53,050 --> 00:20:51,230

we're in ours and only recently have we

539
00:20:55,090 --> 00:20:53,060
found out the possibility that you can

540
00:20:57,700 --> 00:20:55,100
have material transit between solar

541
00:21:00,340 --> 00:20:57,710
systems we were visited was in a couple

542
00:21:03,640 --> 00:21:00,350
months ago by this cigar-shaped object

543
00:21:05,860 --> 00:21:03,650
called muah-muah that came from faraway

544
00:21:07,750 --> 00:21:05,870
zoom by our star and is on its way out

545
00:21:09,010 --> 00:21:07,760
and I know you've been thinking and

546
00:21:11,130 --> 00:21:09,020
studying it a little bit can you tell us

547
00:21:14,200 --> 00:21:11,140
more about this this strange body oh

548
00:21:16,780 --> 00:21:14,210
yeah this is a super exciting discovery

549
00:21:17,950 --> 00:21:16,790
it had been anticipated for decades

550
00:21:20,200 --> 00:21:17,960
people have been thinking about this

551
00:21:22,330 --> 00:21:20,210
because we know that planets you know

552
00:21:24,490 --> 00:21:22,340
planet formation is not 100% efficient

553
00:21:26,620 --> 00:21:24,500
and models have shown for a long time

554
00:21:28,420 --> 00:21:26,630
that you know a lot of the building

555
00:21:29,740 --> 00:21:28,430
blocks of planets whatever doesn't end

556
00:21:31,780 --> 00:21:29,750
up in a planet a lot of it gets chucked

557
00:21:32,710 --> 00:21:31,790
out and some of that something gets

558
00:21:35,170 --> 00:21:32,720
chucked out of other solar systems

559
00:21:37,480 --> 00:21:35,180
should wander long and come through ours

560
00:21:40,780 --> 00:21:37,490
and that's what happened so in October

561
00:21:43,360 --> 00:21:40,790
this year the pan-starrs survey out of

562
00:21:46,300 --> 00:21:43,370
Hawaii found this really fast moving

563
00:21:48,220 --> 00:21:46,310

pretty small object named Oh mwah mwah

564
00:21:52,660 --> 00:21:48,230
you know a visitor from from far away

565
00:21:55,930 --> 00:21:52,670
and so this thing is very strange it's

566
00:21:57,670 --> 00:21:55,940
it seems to be very stretched out that's

567
00:21:59,170 --> 00:21:57,680
interpreted that's inferred basically

568
00:22:02,020 --> 00:21:59,180
from its brightness variations in

569
00:22:03,670 --> 00:22:02,030
brightness changes by about two and half

570
00:22:06,790 --> 00:22:03,680
magnitudes that's about it a factor of

571
00:22:09,010 --> 00:22:06,800
ten an actual brightness every seven

572
00:22:10,300 --> 00:22:09,020
hours or so and it's thought that that's

573
00:22:12,700 --> 00:22:10,310
because of its shape they think it's

574
00:22:14,470 --> 00:22:12,710
this kind of weird cigar shaped thing

575
00:22:15,010 --> 00:22:14,480
that's sort of humbling it's not even

576
00:22:17,380 --> 00:22:15,020
rotating

577
00:22:19,420 --> 00:22:17,390
nice way it's tumbling not along any of

578
00:22:21,520 --> 00:22:19,430
its principal accidents and every so

579
00:22:23,080 --> 00:22:21,530
often it's kind of pointed at us and so

580
00:22:26,050 --> 00:22:23,090
the surface area is so small that the

581
00:22:27,790 --> 00:22:26,060
brightness dips a lot and so so that's

582
00:22:30,340 --> 00:22:27,800
one weird thing it's also weird that

583
00:22:32,920 --> 00:22:30,350
it's it passed very close to the Sun

584
00:22:36,580 --> 00:22:32,930
inside Mercury's orbit but it didn't

585
00:22:38,380 --> 00:22:36,590
give off any water or anything yet its

586
00:22:40,360 --> 00:22:38,390
colors if you measure you know its

587
00:22:43,030 --> 00:22:40,370
brightness in different wavelengths its

588
00:22:45,060 --> 00:22:43,040

colors look like objects in the solar

589
00:22:48,070 --> 00:22:45,070
system that have a lot of water like

590
00:22:50,830 --> 00:22:48,080
like C type asteroids or d-type

591
00:22:52,690 --> 00:22:50,840
asteroids or those kind of things and so

592
00:22:55,150 --> 00:22:52,700
it's this weird conundrum no one knows

593
00:22:57,310 --> 00:22:55,160
quite what to make of it

594
00:23:02,800 --> 00:22:57,320
there's this tumbling makes for a pretty

595
00:23:04,270 --> 00:23:02,810
terrible alien spaceship it's very

596
00:23:06,250 --> 00:23:04,280
similar to Arthur seek our book

597
00:23:08,500 --> 00:23:06,260
rendezvous with Rama you can just you

598
00:23:09,820 --> 00:23:08,510
know this perfect cylinder comes in the

599
00:23:12,640 --> 00:23:09,830
source I actually reread that book

600
00:23:14,800 --> 00:23:12,650
recently just after they discovered omoi

601
00:23:16,810 --> 00:23:14,810
wa because it reminded me of it

602
00:23:19,570 --> 00:23:16,820
except except the key difference like

603
00:23:21,100 --> 00:23:19,580
it's the same story humanity discovers

604
00:23:22,870 --> 00:23:21,110
this thing entering the solar system

605
00:23:25,150 --> 00:23:22,880
there's a couple little subtle

606
00:23:28,360 --> 00:23:25,160
differences like omoi was brightness

607
00:23:30,190 --> 00:23:28,370
variations are huge and in Rama they're

608
00:23:32,140 --> 00:23:30,200
tiny and the reason they're tiny and

609
00:23:33,730 --> 00:23:32,150
Rama scuzz is a smooth metal surface

610
00:23:35,100 --> 00:23:33,740
that always reflects the same amount of

611
00:23:37,540 --> 00:23:35,110
light

612
00:23:39,160 --> 00:23:37,550
so the ecliptic plane of all the planets

613
00:23:40,840 --> 00:23:39,170

is like this one more I came like

614
00:23:43,740 --> 00:23:40,850
essentially vertical and straight

615
00:23:46,330 --> 00:23:43,750
through all right can we can we back out

616
00:23:49,390 --> 00:23:46,340
the trajectory and kind of know where it

617
00:23:51,580 --> 00:23:49,400
came from people have been trying to do

618
00:23:55,060 --> 00:23:51,590
this and there's no conclusive

619
00:23:56,770 --> 00:23:55,070
determination of you know a given star

620
00:24:00,160 --> 00:23:56,780
or star forming region that it came from

621
00:24:02,800 --> 00:24:00,170
so it has its its velocity and space is

622
00:24:05,200 --> 00:24:02,810
similar to that of the nearby stars so

623
00:24:07,660 --> 00:24:05,210
that means you can't no disentangle it -

624
00:24:10,000 --> 00:24:07,670
well from just other storm so it came

625
00:24:12,460 --> 00:24:10,010
from out there somewhere so so there's

626
00:24:14,530 --> 00:24:12,470
different models for how it got there

627
00:24:17,170 --> 00:24:14,540
I have my own model so I'll explain mine

628
00:24:18,970 --> 00:24:17,180
mine is my thinking is that it's just a

629
00:24:22,480 --> 00:24:18,980
leftover from the planet you know from

630
00:24:25,300 --> 00:24:22,490
planet formation but it's probably just

631
00:24:26,740 --> 00:24:25,310
to account for for some details it I

632
00:24:28,570 --> 00:24:26,750
would think that it's not a leftover

633
00:24:32,409 --> 00:24:28,580
what's called a planet test

634
00:24:34,960 --> 00:24:32,419
but that's a leftover chunk of one so I

635
00:24:37,210 --> 00:24:34,970
think that in the process a symbol again

636
00:24:38,799 --> 00:24:37,220
I should explain this you're right

637
00:24:41,770 --> 00:24:38,809
so planetesimals basically a building

638
00:24:44,409 --> 00:24:41,780

blocks of plants things that are say ten

639
00:24:46,480 --> 00:24:44,419
hundred kilometers in size so the big

640
00:24:50,169 --> 00:24:46,490
big potato shaped things from Star Wars

641
00:24:52,029 --> 00:24:50,179
that's like a planetesimals and so so

642
00:24:53,950 --> 00:24:52,039
that's what we think plants are born

643
00:24:55,659 --> 00:24:53,960
from you know what a bunch of those form

644
00:24:57,610 --> 00:24:55,669
within these discs of gas and then they

645
00:24:59,500 --> 00:24:57,620
bash them to each other to form larger

646
00:25:03,010 --> 00:24:59,510
things they're kind of the seeds of

647
00:25:04,899 --> 00:25:03,020
plants and so when plants get big they

648
00:25:07,480 --> 00:25:04,909
have so much gravity that near planet s

649
00:25:10,450 --> 00:25:07,490
can get kicked around and if a planet as

650
00:25:12,070 --> 00:25:10,460
big as Jupiter forms its gravity is so

651
00:25:15,279 --> 00:25:12,080
strong that a lot of the stuff nearby

652
00:25:16,960 --> 00:25:15,289
gets flung into space you know it can

653
00:25:20,350 --> 00:25:16,970
give such strong gravitational kicks

654
00:25:23,169 --> 00:25:20,360
they can kick planetesimals you know out

655
00:25:25,419 --> 00:25:23,179
so fast that they never come back but

656
00:25:27,580 --> 00:25:25,429
once in a while they get really close to

657
00:25:30,310 --> 00:25:27,590
Jupiter on the way too similar to

658
00:25:31,690 --> 00:25:30,320
comment shoemaker-levy 9 and in the

659
00:25:34,630 --> 00:25:31,700
early 90s they came very close to

660
00:25:37,930 --> 00:25:34,640
Jupiter and was torn to pieces that can

661
00:25:41,529 --> 00:25:37,940
happen sometimes and so so our model is

662
00:25:44,649 --> 00:25:41,539
that that om was one of those pieces not

663
00:25:45,610 --> 00:25:44,659

a pristine planetesimals and a piece it

664
00:25:47,919 --> 00:25:45,620
was something that got torn to pieces

665
00:25:50,320 --> 00:25:47,929
torn to shreds on its way to getting

666
00:25:52,299 --> 00:25:50,330
launched into space and that can maybe

667
00:25:56,039 --> 00:25:52,309
account for why it's tumbling and it's

668
00:25:57,909 --> 00:25:56,049
weird shaped and stuff so that's awesome

669
00:25:59,680 --> 00:25:57,919
so does that mean that presumably

670
00:26:00,850 --> 00:25:59,690
there's some early pieces of our own

671
00:26:02,950 --> 00:26:00,860
solar systems that are going through

672
00:26:04,750 --> 00:26:02,960
other galaxies right now I'm not a

673
00:26:07,149 --> 00:26:04,760
legality sorry other solar systems I

674
00:26:10,180 --> 00:26:07,159
mean definitely it's it's unavoidable

675
00:26:11,529 --> 00:26:10,190
so there's pieces from there's multiple

676
00:26:14,649 --> 00:26:11,539
generations of stuff that's gotten

677
00:26:16,930 --> 00:26:14,659
kicked out basically stuff anything past

678
00:26:19,060 --> 00:26:16,940
Earth's orbit even interiors orbit there

679
00:26:20,950 --> 00:26:19,070
are pieces you know at least according

680
00:26:23,649 --> 00:26:20,960
to our computer simulations of how the

681
00:26:26,049 --> 00:26:23,659
planets form you know the process of

682
00:26:27,820 --> 00:26:26,059
planet formation is maybe half efficient

683
00:26:29,169 --> 00:26:27,830
so probably about half the building

684
00:26:31,539 --> 00:26:29,179
blocks within the solar system stuck

685
00:26:32,890 --> 00:26:31,549
around the other half got kicked out so

686
00:26:35,350 --> 00:26:32,900
most of it is probably in the form of

687
00:26:39,570 --> 00:26:35,360
small things but we may even have lost

688
00:26:41,620 --> 00:26:39,580

an ice giant that's that's an idea for

689
00:26:44,170 --> 00:26:41,630
one idea that the David

690
00:26:46,240 --> 00:26:44,180
Varney had it in swearing the idea being

691
00:26:48,060 --> 00:26:46,250
that we think the giant planets and the

692
00:26:52,600 --> 00:26:48,070
sources in Jupiter Saturn Uranus Neptune

693
00:26:54,700 --> 00:26:52,610
had a late instability and that might

694
00:26:56,860 --> 00:26:54,710
explain things like the late heavy

695
00:26:58,690 --> 00:26:56,870
bombardment and to make their models

696
00:27:01,360 --> 00:26:58,700
work much better like an order of

697
00:27:03,340 --> 00:27:01,370
magnitude better they invoke the

698
00:27:05,800 --> 00:27:03,350
existence of an extra planet at the

699
00:27:08,980 --> 00:27:05,810
start so that basically carries away

700
00:27:11,200 --> 00:27:08,990
excess energy and is ejected and so it's

701
00:27:13,300 --> 00:27:11,210
possible that that we had another planet

702
00:27:15,910 --> 00:27:13,310
or even two other planets that were

703
00:27:18,460 --> 00:27:15,920
injected shortly after they form and

704
00:27:21,430 --> 00:27:18,470
they're wandering and wandering within

705
00:27:22,750 --> 00:27:21,440
the galaxy you know I don't think we'd

706
00:27:25,330 --> 00:27:22,760
recognize them anymore but they're

707
00:27:27,790 --> 00:27:25,340
they're out there so a gas giant that's

708
00:27:29,740 --> 00:27:27,800
flying away from a star would have

709
00:27:35,140 --> 00:27:29,750
probably his its atmosphere just

710
00:27:38,740 --> 00:27:35,150
collapse down into a solid right I mean

711
00:27:41,830 --> 00:27:38,750
so so a giant planet yeah you mentioned

712
00:27:43,180 --> 00:27:41,840
an ice giant was flung out yeah I mean

713
00:27:44,290 --> 00:27:43,190

people have modeled this because it's

714
00:27:47,470 --> 00:27:44,300
not too different from the idea of

715
00:27:48,940 --> 00:27:47,480
Planet nine you know the this possible

716
00:27:50,890 --> 00:27:48,950
extra plant in the solar system that's

717
00:27:53,200 --> 00:27:50,900
out you know it's several hundred a year

718
00:27:55,540 --> 00:27:53,210
people haven't been modeling that to see

719
00:27:56,980 --> 00:27:55,550
what would it look like and so people in

720
00:27:58,930 --> 00:27:56,990
modeling you know different possible

721
00:28:00,700 --> 00:27:58,940
atmospheres what they would do it

722
00:28:04,090 --> 00:28:00,710
evolved over billions of years in very

723
00:28:06,070 --> 00:28:04,100
cold temperatures and I am afraid I

724
00:28:08,290 --> 00:28:06,080
don't know the answer but people have

725
00:28:08,890 --> 00:28:08,300
been thinking about this that's

726
00:28:13,000 --> 00:28:08,900
fascinating

727
00:28:14,590 --> 00:28:13,010
talk on this stuff for a long time and

728
00:28:16,540 --> 00:28:14,600
definitely want to switch the question

729
00:28:18,580 --> 00:28:16,550
through the Q&A time to our audience

730
00:28:20,620 --> 00:28:18,590
again if you have any questions for dr.

731
00:28:24,010 --> 00:28:20,630
Raymond please use hashtag ask Esther

732
00:28:25,870 --> 00:28:24,020
bio and we'll get them answered I'm the

733
00:28:28,780 --> 00:28:25,880
first question I see is from Jacob hello

734
00:28:30,460 --> 00:28:28,790
Jacob and he asks what are some of the

735
00:28:32,890 --> 00:28:30,470
most salient differences you have

736
00:28:34,660 --> 00:28:32,900
noticed between basic science funding in

737
00:28:38,650 --> 00:28:34,670
France and the EU compared with the

738
00:28:40,960 --> 00:28:38,660

United States ok science fun there so

739
00:28:42,520 --> 00:28:40,970
the general structure of how things are

740
00:28:47,350 --> 00:28:42,530
funded here is quite different

741
00:28:50,320 --> 00:28:47,360
so the standard track is is somewhat

742
00:28:51,670 --> 00:28:50,330
different the like are I mean I'll just

743
00:28:53,170 --> 00:28:51,680
art describing the difference in like my

744
00:28:55,120 --> 00:28:53,180
department versus departments in the

745
00:28:57,790 --> 00:28:55,130
u.s. in the US

746
00:29:00,010 --> 00:28:57,800
a professor has many grad students and

747
00:29:02,290 --> 00:29:00,020
postdocs and there's kind of this sort

748
00:29:04,540 --> 00:29:02,300
of like pyramid shape where there's one

749
00:29:07,210 --> 00:29:04,550
or maybe a few people with permanent

750
00:29:09,340 --> 00:29:07,220
jobs and a lot of people with temporary

751
00:29:12,460 --> 00:29:09,350
jobs those dogs grad students who are

752
00:29:14,770 --> 00:29:12,470
learning and and and that's kind of this

753
00:29:16,090 --> 00:29:14,780
general structure you're in France it's

754
00:29:17,350 --> 00:29:16,100
quite different and it but it changes

755
00:29:20,410 --> 00:29:17,360
from country to country because in

756
00:29:22,840 --> 00:29:20,420
Germany it's more like that pyramid type

757
00:29:24,040 --> 00:29:22,850
structure here in France is more kind of

758
00:29:28,780 --> 00:29:24,050
a higher proportion of people with

759
00:29:30,580 --> 00:29:28,790
permanent jobs and that and a few would

760
00:29:33,400 --> 00:29:30,590
rad students it's hardly harder to get

761
00:29:34,660 --> 00:29:33,410
funding for for many grad students you

762
00:29:38,320 --> 00:29:34,670
know we have some but just not quite as

763
00:29:41,050 --> 00:29:38,330

many and that just kind of changes the

764
00:29:43,210 --> 00:29:41,060
dynamic of things in terms of I guess in

765
00:29:44,830 --> 00:29:43,220
terms of overall funding for things it's

766
00:29:47,320 --> 00:29:44,840
not that different there's there's

767
00:29:48,940 --> 00:29:47,330
decent amount of astrobiology type

768
00:29:49,420 --> 00:29:48,950
research and interested in different

769
00:29:51,550 --> 00:29:49,430
things

770
00:29:54,610 --> 00:29:51,560
overall the general the means are not

771
00:29:57,160 --> 00:29:54,620
quite as big as in the US and so it's

772
00:29:59,890 --> 00:29:57,170
often oftentimes in terms of making

773
00:30:01,210 --> 00:29:59,900
decisions they kind of see where other

774
00:30:03,280 --> 00:30:01,220
places are going and trying to find a

775
00:30:06,160 --> 00:30:03,290
niche where you can have the most impact

776
00:30:08,520 --> 00:30:06,170
for your contribution rather than trying

777
00:30:10,900 --> 00:30:08,530
to repeat what someone else is doing I

778
00:30:13,660 --> 00:30:10,910
don't know that's that's what comes to

779
00:30:16,690 --> 00:30:13,670
mind yeah well thank you the next

780
00:30:18,340 --> 00:30:16,700
question is from penny who asks do you

781
00:30:20,470 --> 00:30:18,350
have a sense of how much interstellar

782
00:30:22,330 --> 00:30:20,480
organic carbon might survive the process

783
00:30:24,850 --> 00:30:22,340
of solar system formation and canotary

784
00:30:26,620 --> 00:30:24,860
accretion do you think new solar system

785
00:30:28,360 --> 00:30:26,630
has to start all over again to make

786
00:30:31,140 --> 00:30:28,370
organic carbon its plants or does it

787
00:30:36,310 --> 00:30:31,150
inherit a legacy it's good question

788
00:30:38,050 --> 00:30:36,320

that's a good one so hey I mean so I'm

789
00:30:39,850 --> 00:30:38,060
not a chemist who studies this because I

790
00:30:42,940 --> 00:30:39,860
know people do that but I think that

791
00:30:46,090 --> 00:30:42,950
that a lot of that pristine material is

792
00:30:48,240 --> 00:30:46,100
is preserved Canobie there's a debate

793
00:30:51,160 --> 00:30:48,250
you know when you're forming planets

794
00:30:54,130 --> 00:30:51,170
whether within a disc everything gets

795
00:30:57,040 --> 00:30:54,140
really hot and then rican densest or

796
00:30:58,510 --> 00:30:57,050
whether the stuff only only the stuff

797
00:31:01,000 --> 00:30:58,520
very close to the star actually gets

798
00:31:02,770 --> 00:31:01,010
that ha and the difference is if

799
00:31:04,660 --> 00:31:02,780
everything gets hot and you would lose

800
00:31:06,880 --> 00:31:04,670
volatile things maybe like organic

801
00:31:08,889 --> 00:31:06,890
carbon and then rican dancing them can

802
00:31:10,599 --> 00:31:08,899
be an issue but

803
00:31:13,539 --> 00:31:10,609
if only the area kind of close to the

804
00:31:15,849 --> 00:31:13,549
star that gets directly heated is really

805
00:31:17,469 --> 00:31:15,859
strongly heated then anything past a

806
00:31:18,609 --> 00:31:17,479
certain distance can preserve its

807
00:31:21,009 --> 00:31:18,619
garment

808
00:31:23,799 --> 00:31:21,019
my impression not being a specialist in

809
00:31:25,690 --> 00:31:23,809
this area is that people are leaning

810
00:31:27,129 --> 00:31:25,700
towards the idea that you can preserve a

811
00:31:29,739 --> 00:31:27,139
decent amount of molecules from the

812
00:31:31,029 --> 00:31:29,749
interstellar medium or at least from you

813
00:31:33,549 --> 00:31:31,039

know further out in the solar system

814
00:31:37,139 --> 00:31:33,559
and we see that you know for example in

815
00:31:38,379 --> 00:31:37,149
comets that have a lot of organic matter

816
00:31:40,359 --> 00:31:38,389
cool

817
00:31:44,769 --> 00:31:40,369
I'll keep you questions coming otherwise

818
00:31:46,570 --> 00:31:44,779
I have a bunch for harsh on myself so

819
00:31:48,099 --> 00:31:46,580
what are you working on these days do

820
00:31:50,049 --> 00:31:48,109
you have all these incredible projects

821
00:31:52,719 --> 00:31:50,059
so a bunch of different topics what how

822
00:31:54,279 --> 00:31:52,729
do you keep your attention focused well

823
00:31:58,209 --> 00:31:54,289
that's the thing I don't I don't keep it

824
00:32:00,719 --> 00:31:58,219
that focused so this is a big thing like

825
00:32:04,629 --> 00:32:00,729
how do you decide what to do next and

826
00:32:06,849 --> 00:32:04,639
you you know in grad school I had a boss

827
00:32:08,649 --> 00:32:06,859
he said you know my advisories you kind

828
00:32:11,289 --> 00:32:08,659
of pointed me in a certain direction as

829
00:32:13,060 --> 00:32:11,299
a postdoc I had applied to officially do

830
00:32:14,979 --> 00:32:13,070
a certain project

831
00:32:17,169 --> 00:32:14,989
I eventually changed directions a little

832
00:32:19,089 --> 00:32:17,179
bit and then lately over the past

833
00:32:21,279 --> 00:32:19,099
several years I had this internal debate

834
00:32:23,589 --> 00:32:21,289
like should I do things that are kind of

835
00:32:24,759 --> 00:32:23,599
doing what's already been done in what

836
00:32:25,959 --> 00:32:24,769
I've already done just kind of keep

837
00:32:28,659 --> 00:32:25,969
doing a little better and better to get

838
00:32:31,209 --> 00:32:28,669

at the details or should I look for kind

839
00:32:32,799 --> 00:32:31,219
of crazy ideas here and there and I made

840
00:32:35,019 --> 00:32:32,809
the conscious decision to try to go for

841
00:32:36,999 --> 00:32:35,029
the crazy ideas because I think they're

842
00:32:38,589 --> 00:32:37,009
kind of underrepresented and they can

843
00:32:40,329 --> 00:32:38,599
sometimes they can often be valuable

844
00:32:43,239 --> 00:32:40,339
just to get a different point of view

845
00:32:45,399 --> 00:32:43,249
and sure they're wrong a lot of the time

846
00:32:46,989 --> 00:32:45,409
too but you know as long as you stay

847
00:32:48,820 --> 00:32:46,999
bounded within reason that's it's quite

848
00:32:50,619 --> 00:32:48,830
fun and so for the past few years I've

849
00:32:53,259 --> 00:32:50,629
been I've thrown out crazy ideas about

850
00:32:55,859 --> 00:32:53,269
Jupiter for example forming right next

851
00:32:57,820 --> 00:32:55,869
to the Sun and then moving outward and

852
00:33:00,489 --> 00:32:57,830
and different things related to the

853
00:33:02,789 --> 00:33:00,499
solar system and last year I had a

854
00:33:04,869 --> 00:33:02,799
couple papers about the asteroid belt

855
00:33:07,299 --> 00:33:04,879
coming up now I'm starting to work again

856
00:33:09,279 --> 00:33:07,309
on on super-earths and their

857
00:33:11,529 --> 00:33:09,289
compositions super star super

858
00:33:14,219 --> 00:33:11,539
interesting in terms of no pun intended

859
00:33:16,599 --> 00:33:14,229
there they're interesting in terms of

860
00:33:17,589 --> 00:33:16,609
their their the plants that we're first

861
00:33:20,289 --> 00:33:17,599
going to be able to constrain the

862
00:33:22,450 --> 00:33:20,299
composition and so for some super Earths

863
00:33:24,100 --> 00:33:22,460

you can constrain their compositions you

864
00:33:26,050 --> 00:33:24,110
the time you can really do it is if

865
00:33:28,210 --> 00:33:26,060
they're very dense and then you know

866
00:33:29,620 --> 00:33:28,220
they're rocky but if they're not that

867
00:33:33,540 --> 00:33:29,630
dense then you can't tell if they're

868
00:33:36,760 --> 00:33:33,550
rock plus gas or just water and so

869
00:33:39,880 --> 00:33:36,770
telling those apart is you know is a

870
00:33:42,850 --> 00:33:39,890
tricky exercise but we can try to see

871
00:33:44,620 --> 00:33:42,860
what can you learn about plants from

872
00:33:45,940 --> 00:33:44,630
their compositions whether you can rule

873
00:33:47,470 --> 00:33:45,950
out you can never really confirm

874
00:33:50,500 --> 00:33:47,480
anything we can rule out certain

875
00:33:52,120 --> 00:33:50,510
formation histories if this kind of

876
00:33:54,700 --> 00:33:52,130
distribution with compositions is

877
00:33:55,570 --> 00:33:54,710
observed for example so to wrap up I'm

878
00:33:57,010 --> 00:33:55,580
going kind of in many different

879
00:33:59,650 --> 00:33:57,020
directions at once

880
00:33:59,920 --> 00:33:59,660
but that's sort of on purpose good for

881
00:34:04,000 --> 00:33:59,930
you

882
00:34:06,880 --> 00:34:04,010
keeps the mind busy another question we

883
00:34:08,710 --> 00:34:06,890
have from Adam Smith hi Adam he asks why

884
00:34:13,050 --> 00:34:08,720
in particular is one more very like

885
00:34:17,950 --> 00:34:13,060
cigar shaped do we have a sense of salt

886
00:34:21,820 --> 00:34:17,960
so no one knows the exact why I would

887
00:34:24,370 --> 00:34:21,830
suggest that it's indicative that I

888
00:34:27,790 --> 00:34:24,380

think it fits this general story that it

889
00:34:30,100 --> 00:34:27,800
is not a pristine object but rather one

890
00:34:32,470 --> 00:34:30,110
that was torn to pieces and so in that

891
00:34:33,820 --> 00:34:32,480
story I was telling you before about it

892
00:34:37,120 --> 00:34:33,830
kind of not being a pristine

893
00:34:40,930 --> 00:34:37,130
planetesimals Locke of planning that

894
00:34:43,780 --> 00:34:40,940
might make sense if as it was getting

895
00:34:46,030 --> 00:34:43,790
kicked out of its parent star system it

896
00:34:49,270 --> 00:34:46,040
got really close to say a Jupiter and

897
00:34:51,580 --> 00:34:49,280
was torn to pieces by tides meaning that

898
00:34:54,610 --> 00:34:51,590
you know as this object was approaching

899
00:34:57,310 --> 00:34:54,620
it's this other jupiter-like planet

900
00:34:59,680 --> 00:34:57,320
the gravity across the object was so

901
00:35:01,180 --> 00:34:59,690
strong basically the part that was

902
00:35:02,290 --> 00:35:01,190
really close to the planet was so much

903
00:35:05,200 --> 00:35:02,300
stronger than the part further away

904
00:35:06,340 --> 00:35:05,210
they've got stretched out and that

905
00:35:07,660 --> 00:35:06,350
probably wouldn't produce a woolen

906
00:35:10,720 --> 00:35:07,670
stretch that thing APRI so a whole bunch

907
00:35:12,250 --> 00:35:10,730
of a cloud of fragments but it might be

908
00:35:14,410 --> 00:35:12,260
a way to form a really stretched out

909
00:35:16,060 --> 00:35:14,420
thing apart from that I haven't heard

910
00:35:17,440 --> 00:35:16,070
about other models that could do it

911
00:35:19,480 --> 00:35:17,450
maybe it's doable by another mechanism

912
00:35:22,760 --> 00:35:19,490
too but that's that's the one that comes

913
00:35:28,190 --> 00:35:22,770

to mind well

914
00:35:30,620 --> 00:35:28,200
poke census asks Shawn if you had if you

915
00:35:32,210 --> 00:35:30,630
had to spend a couple billion euros a

916
00:35:34,359 --> 00:35:32,220
couple billion dollars

917
00:35:36,800 --> 00:35:34,369
what kind of mission would you build

918
00:35:39,050 --> 00:35:36,810
this is a good question and ask people

919
00:35:41,599 --> 00:35:39,060
this all the time so when I had this

920
00:35:43,630 --> 00:35:41,609
thought I hadn't I've had a few dinners

921
00:35:45,800 --> 00:35:43,640
with people where I asked them this and

922
00:35:49,460 --> 00:35:45,810
I've gotten different answers

923
00:35:52,340 --> 00:35:49,470
lately I still am leaning towards the

924
00:35:56,120 --> 00:35:52,350
idea of really hammering out at one

925
00:35:58,099 --> 00:35:56,130
angle really well so so a few years ago

926
00:36:01,490 --> 00:35:58,109
I would have said that I would take that

927
00:36:03,859 --> 00:36:01,500
money and I would build maybe ten big

928
00:36:06,470 --> 00:36:03,869
telescopes on the ground to do really

929
00:36:07,630 --> 00:36:06,480
precise radial velocity measurements but

930
00:36:11,000 --> 00:36:07,640
on a massive scale

931
00:36:15,170 --> 00:36:11,010
because a lot we've learned a ton from

932
00:36:16,880 --> 00:36:15,180
doing them from so so radial velocity

933
00:36:18,670 --> 00:36:16,890
measurements what that is is basically

934
00:36:21,320 --> 00:36:18,680
using a spectrograph to measure the

935
00:36:23,060 --> 00:36:21,330
velocities of stars how fast stars are

936
00:36:25,960 --> 00:36:23,070
wobbling and you can measure the

937
00:36:29,060 --> 00:36:25,970
velocity only towards are away from us

938
00:36:32,060 --> 00:36:29,070

but that's how the first several hundred

939
00:36:33,640 --> 00:36:32,070
exoplanets were found and a lot of other

940
00:36:36,380 --> 00:36:33,650
interesting things that come from that

941
00:36:39,290 --> 00:36:36,390
and spectrographs are getting more and

942
00:36:41,540 --> 00:36:39,300
more precise and you know these days the

943
00:36:43,340 --> 00:36:41,550
best ones can measure about 10

944
00:36:45,410 --> 00:36:43,350
centimeters per second of precision in

945
00:36:47,450 --> 00:36:45,420
this velocity so one option for this

946
00:36:49,730 --> 00:36:47,460
billion dollars is to build 10 of those

947
00:36:51,560 --> 00:36:49,740
and to really hammer out do a giant

948
00:36:53,599 --> 00:36:51,570
survey and have really good statistics

949
00:36:57,560 --> 00:36:53,609
to look for planets with it the other

950
00:36:59,150 --> 00:36:57,570
possibility might be to just build I

951
00:37:01,730 --> 00:36:59,160
don't know I don't remember exactly how

952
00:37:03,620 --> 00:37:01,740
much Kepler cost I think it was half a

953
00:37:05,060 --> 00:37:03,630
billion dollars something like that so I

954
00:37:09,109 --> 00:37:05,070
would just launched for Kepler's and

955
00:37:11,210 --> 00:37:09,119
just go nuts boom because I think that

956
00:37:15,050 --> 00:37:11,220
man I think the size of the stuff that

957
00:37:17,660 --> 00:37:15,060
you would get from those is is hard too

958
00:37:20,210 --> 00:37:17,670
I think we learn a lot just from doing

959
00:37:22,220 --> 00:37:20,220
the same experiments but a little better

960
00:37:24,800 --> 00:37:22,230
and longer and on a much bigger scale I

961
00:37:25,970 --> 00:37:24,810
know the idea it's always tempting and

962
00:37:28,099 --> 00:37:25,980
most of the funding goes towards

963
00:37:30,230 --> 00:37:28,109

fundamentally different projects a lot

964
00:37:32,810 --> 00:37:30,240
of it does anyway I think that that

965
00:37:35,990 --> 00:37:32,820
redoing the same one a little better can

966
00:37:38,690 --> 00:37:36,000
make big leagues

967
00:37:40,130 --> 00:37:38,700
yeah given how successful Kepler was it

968
00:37:42,010 --> 00:37:40,140
would be neat to think about what you

969
00:37:45,410 --> 00:37:42,020
could do if you had such a larger scale

970
00:37:48,980 --> 00:37:45,420
mission cool next question is from

971
00:37:52,120 --> 00:37:48,990
Melissa who asks would super-earth have

972
00:37:55,640 --> 00:37:52,130
plate tectonics like modern earth does

973
00:37:57,020 --> 00:37:55,650
so I have no idea this is a very good

974
00:37:59,570 --> 00:37:57,030
question and people are very interested

975
00:38:01,970 --> 00:37:59,580
in this because on earth you think that

976
00:38:03,920 --> 00:38:01,980
this carbonate silicate cycle that's

977
00:38:06,080 --> 00:38:03,930
driven by plate tectonics it's like the

978
00:38:07,599 --> 00:38:06,090
Earth's thermostat and so it prevents

979
00:38:11,120 --> 00:38:07,609
Earth from getting too hot or too cold

980
00:38:13,670 --> 00:38:11,130
now a lot of thing about habitability of

981
00:38:16,550 --> 00:38:13,680
other planets it's tempting to say well

982
00:38:18,950 --> 00:38:16,560
let's link it with plate tectonics now

983
00:38:21,410 --> 00:38:18,960
like I know I'm no specialist in this

984
00:38:23,030 --> 00:38:21,420
but I've seen talks by people who claim

985
00:38:26,359 --> 00:38:23,040
that there's no it's not clear that

986
00:38:27,230 --> 00:38:26,369
plate tectonics was active for a good

987
00:38:29,410 --> 00:38:27,240
chunk of Earth's history

988
00:38:31,609 --> 00:38:29,420

so it's not clear that that's really

989
00:38:34,760 --> 00:38:31,619
necessarily as important as we think on

990
00:38:36,650 --> 00:38:34,770
earth um like I said I can't really

991
00:38:40,070 --> 00:38:36,660
judge that but I've seen other studies

992
00:38:42,200 --> 00:38:40,080
get this for it for supers and it seems

993
00:38:45,560 --> 00:38:42,210
that all of the key kind of stresses

994
00:38:47,810 --> 00:38:45,570
that are that play a role in causing

995
00:38:50,660 --> 00:38:47,820
plate tectonics on earth should be a

996
00:38:53,180 --> 00:38:50,670
little bit stronger that's right my

997
00:38:55,460 --> 00:38:53,190
understanding from seeing papers is that

998
00:38:57,500 --> 00:38:55,470
it's it's likely that plate tectonics or

999
00:39:01,030 --> 00:38:57,510
it's more likely than not that plate

1000
00:39:03,560 --> 00:39:01,040
tectonics can't operate on unser groans

1001
00:39:05,660 --> 00:39:03,570
yeah these perhaps plate tectonics not

1002
00:39:07,670 --> 00:39:05,670
necessarily for life to start but could

1003
00:39:10,040 --> 00:39:07,680
be necessary to sustain life on a planet

1004
00:39:13,420 --> 00:39:10,050
for several billion years interesting

1005
00:39:15,770 --> 00:39:13,430
question I'm not gonna hurt anyway yeah

1006
00:39:19,900 --> 00:39:15,780
all right the next question is from Ned

1007
00:39:22,520 --> 00:39:19,910
Senate hello and he or she asks about

1008
00:39:24,650 --> 00:39:22,530
gold and platinum formation at what

1009
00:39:26,630 --> 00:39:24,660
stage do we get to these to these

1010
00:39:31,790 --> 00:39:26,640
elements and in country formation

1011
00:39:33,980 --> 00:39:31,800
history so gold and platinum stuff I

1012
00:39:37,339 --> 00:39:33,990
believe they're part of the rare earth

1013
00:39:40,329 --> 00:39:37,349

elements if I'm not mistaken and those

1014
00:39:42,470 --> 00:39:40,339
are not very abundant on our surface

1015
00:39:44,540 --> 00:39:42,480
they're thought to have been brought in

1016
00:39:47,329 --> 00:39:44,550
basically they're really interesting on

1017
00:39:49,490 --> 00:39:47,339
earth because they're thought to follow

1018
00:39:49,730 --> 00:39:49,500
iron and so why do we care about this

1019
00:39:51,920 --> 00:39:49,740
how

1020
00:39:54,530 --> 00:39:51,930
earth form uniform through a succession

1021
00:39:56,660 --> 00:39:54,540
of big impacts and whenever there was

1022
00:39:58,640 --> 00:39:56,670
enough a strong enough impact we think

1023
00:40:01,010 --> 00:39:58,650
that there was a core forming event

1024
00:40:03,710 --> 00:40:01,020
basically the earth got you know molten

1025
00:40:05,240 --> 00:40:03,720
enough that iron sunk in the core and it

1026
00:40:07,880 --> 00:40:05,250
dragged all these other things with it

1027
00:40:09,890 --> 00:40:07,890
like gold and platinum and iridium is

1028
00:40:11,000 --> 00:40:09,900
one that's often used to traces too but

1029
00:40:13,160 --> 00:40:11,010
these kind of elements got sucked into

1030
00:40:14,840 --> 00:40:13,170
the core and so you can imagine if earth

1031
00:40:17,120 --> 00:40:14,850
formed by these big collisions and it's

1032
00:40:18,260 --> 00:40:17,130
final you know the final thing in

1033
00:40:20,870 --> 00:40:18,270
Earth's formation was a big collision

1034
00:40:22,609 --> 00:40:20,880
all that iron all that gold platinum

1035
00:40:24,920 --> 00:40:22,619
would be sucked in the core and we would

1036
00:40:26,420 --> 00:40:24,930
have none we wouldn't have I got a gold

1037
00:40:28,400 --> 00:40:26,430
ring man you we wouldn't have these

1038
00:40:30,560 --> 00:40:28,410

kinds of things there wouldn't be any on

1039
00:40:33,290 --> 00:40:30,570
the surface but there is so we think

1040
00:40:35,630 --> 00:40:33,300
that it came from the small amount of

1041
00:40:37,490 --> 00:40:35,640
material that hit the earth after the

1042
00:40:40,280 --> 00:40:37,500
last giant impact we think the last

1043
00:40:42,710 --> 00:40:40,290
giant impact was the one that was not

1044
00:40:45,620 --> 00:40:42,720
perfect impact it spun out a disc of

1045
00:40:49,430 --> 00:40:45,630
stuff and from that disc the moon formed

1046
00:40:53,180 --> 00:40:49,440
and after that happened we think about

1047
00:40:55,970 --> 00:40:53,190
half a percent of Earth's mass hit the

1048
00:40:58,670 --> 00:40:55,980
earth after that and so earth still was

1049
00:41:00,800 --> 00:40:58,680
able to accumulate some material

1050
00:41:05,000 --> 00:41:00,810
afterward it's bringing along all the

1051
00:41:08,090 --> 00:41:05,010
gold that we have cool thank you it's

1052
00:41:11,359 --> 00:41:08,100
the story our next question is from Maya

1053
00:41:13,490 --> 00:41:11,369
who asks if we are able if we detect one

1054
00:41:15,470 --> 00:41:13,500
of those wandering bodies planet-sized

1055
00:41:16,940 --> 00:41:15,480
bodies how would we be able to tell

1056
00:41:20,270 --> 00:41:16,950
whether it comes from our own solar

1057
00:41:24,859 --> 00:41:20,280
system I don't see how you would ever

1058
00:41:28,760 --> 00:41:24,869
tell it'll be awesome if we could so no

1059
00:41:31,040 --> 00:41:28,770
so I don't see how he would it'd be

1060
00:41:32,840 --> 00:41:31,050
really neat you know if we think like I

1061
00:41:35,420 --> 00:41:32,850
was saying the earth I mean the SOI

1062
00:41:37,220 --> 00:41:35,430
system lost probably lost an ice giant

1063
00:41:39,170 --> 00:41:37,230

you know according to these models and

1064
00:41:41,990 --> 00:41:39,180
as the terrestrial planets were forming

1065
00:41:45,530 --> 00:41:42,000
probably lost several Mars size objects

1066
00:41:47,630 --> 00:41:45,540
now we can detect these hopefully we'll

1067
00:41:49,490 --> 00:41:47,640
be able to detect these by microlensing

1068
00:41:52,640 --> 00:41:49,500
like with the W first mission in the

1069
00:41:54,470 --> 00:41:52,650
next you know decade or so but otherwise

1070
00:41:56,450 --> 00:41:54,480
you know they're not abundant enough

1071
00:41:58,160 --> 00:41:56,460
that we expect them to fly by and if we

1072
00:42:00,500 --> 00:41:58,170
happen to get super lucky and one did

1073
00:42:02,450 --> 00:42:00,510
fly by well it wouldn't be great for the

1074
00:42:05,150 --> 00:42:02,460
stability the solar system

1075
00:42:07,370 --> 00:42:05,160
but we also this all happened so long

1076
00:42:09,560 --> 00:42:07,380
ago that we wouldn't be able to trade

1077
00:42:10,609 --> 00:42:09,570
the back I mean it takes if I remember

1078
00:42:12,349 --> 00:42:10,619
it takes the Sun a couple hundred

1079
00:42:15,380 --> 00:42:12,359
million years to do a loop around the

1080
00:42:17,120 --> 00:42:15,390
center of the galaxy and the solar

1081
00:42:18,079 --> 00:42:17,130
system is what four and four and a half

1082
00:42:20,000 --> 00:42:18,089
billion years old

1083
00:42:22,430 --> 00:42:20,010
so that's more than twenty of these and

1084
00:42:24,530 --> 00:42:22,440
so anything that was launched from the

1085
00:42:27,800 --> 00:42:24,540
solar system is gone we're not gonna be

1086
00:42:30,440 --> 00:42:27,810
able to trace it back interesting good

1087
00:42:33,710 --> 00:42:30,450
question Maya so humans are currently

1088
00:42:35,030 --> 00:42:33,720

kind of stuck on earth right but it goes

1089
00:42:37,520 --> 00:42:35,040
without saying that we're trying really

1090
00:42:39,829 --> 00:42:37,530
hard to get out of it and perhaps some

1091
00:42:41,780 --> 00:42:39,839
of our soon new destinations will be

1092
00:42:45,560 --> 00:42:41,790
Mars and they'll be nice to think about

1093
00:42:49,910 --> 00:42:45,570
making Mars habitable artificially for

1094
00:42:50,780 --> 00:42:49,920
humans um come Rosamond Tony I apologize

1095
00:42:52,820 --> 00:42:50,790
if I didn't pronounce your name

1096
00:42:55,010 --> 00:42:52,830
correctly is thinking about microalgae

1097
00:42:58,040 --> 00:42:55,020
in a large scale to produce oxygen and

1098
00:42:59,210 --> 00:42:58,050
food for humans on another planet what

1099
00:43:00,650 --> 00:42:59,220
are your thoughts about you know

1100
00:43:03,920 --> 00:43:00,660
terraforming in other planets using

1101
00:43:06,200 --> 00:43:03,930
technology or otherwise I mean I think

1102
00:43:10,760 --> 00:43:06,210
it's the way to go on the for Humanity

1103
00:43:12,079 --> 00:43:10,770
on the long-term I think if we stay I've

1104
00:43:13,190 --> 00:43:12,089
heard this described by people and I

1105
00:43:17,030 --> 00:43:13,200
think it's a really good argument that

1106
00:43:19,700 --> 00:43:17,040
if we stay on earth then we're at risk

1107
00:43:25,040 --> 00:43:19,710
at risk of some kind of Cataclysm wiping

1108
00:43:26,630 --> 00:43:25,050
us out now if humanity wants to you know

1109
00:43:28,220 --> 00:43:26,640
make sure to preserve itself for the

1110
00:43:30,589 --> 00:43:28,230
long term which we don't have to want to

1111
00:43:32,450 --> 00:43:30,599
but but assuming we do then the way to

1112
00:43:35,120 --> 00:43:32,460
predict you know one way to protect it

1113
00:43:37,010 --> 00:43:35,130

I've kind of first key step you know

1114
00:43:39,050 --> 00:43:37,020
astronomically speaking is to make it so

1115
00:43:40,880 --> 00:43:39,060
that we're not reliant on one object so

1116
00:43:44,570 --> 00:43:40,890
that one bad event can can't wipe us out

1117
00:43:46,609 --> 00:43:44,580
and so you got to go to wherever you

1118
00:43:49,160 --> 00:43:46,619
know wherever the next best place that's

1119
00:43:50,930 --> 00:43:49,170
you know within the same system for for

1120
00:43:53,690 --> 00:43:50,940
life and Mars is a pretty good candidate

1121
00:43:58,010 --> 00:43:53,700
since it's nearby it's you know it's not

1122
00:44:01,000 --> 00:43:58,020
it's not habitable obviously now but you

1123
00:44:04,970 --> 00:44:01,010
know it seems like it has resources for

1124
00:44:06,980 --> 00:44:04,980
starting things over so I totally agree

1125
00:44:08,660 --> 00:44:06,990
with that sentiment and I think in the

1126
00:44:10,630 --> 00:44:08,670
coming you know centuries that'll be

1127
00:44:12,750 --> 00:44:10,640
something that's a really big though

1128
00:44:15,240 --> 00:44:12,760
indeed indeed

1129
00:44:18,630 --> 00:44:15,250
and next question is from Nitin who is

1130
00:44:22,680 --> 00:44:18,640
also has a question about umemura do we

1131
00:44:26,100 --> 00:44:22,690
have a sense of how old it is no we

1132
00:44:28,890 --> 00:44:26,110
can't tell so so one thing that's I

1133
00:44:30,960 --> 00:44:28,900
mentioned this briefly but so all the

1134
00:44:34,260 --> 00:44:30,970
stars kind of in the neighborhood in the

1135
00:44:35,760 --> 00:44:34,270
galaxy they have a characteristic kind

1136
00:44:38,220 --> 00:44:35,770
of speeds as they zoom in around and

1137
00:44:39,930 --> 00:44:38,230
stars that are born tend to be born with

1138
00:44:43,830 --> 00:44:39,940

lower speeds and in time they kind of

1139
00:44:46,140 --> 00:44:43,840
get excited and so you know if if Oh

1140
00:44:48,360 --> 00:44:46,150
mwah mwah speed was very low

1141
00:44:49,440 --> 00:44:48,370
you know relative to the galactic point

1142
00:44:51,360 --> 00:44:49,450
of you know and the galactic point of

1143
00:44:54,060 --> 00:44:51,370
view and we could kind of argue that it

1144
00:44:57,080 --> 00:44:54,070
was probably on the young son but it has

1145
00:45:01,320 --> 00:44:57,090
the similar speeds to nearby stars and

1146
00:45:02,730 --> 00:45:01,330
so you can't say anything it's really it

1147
00:45:05,910 --> 00:45:02,740
would be awesome to have better

1148
00:45:10,230 --> 00:45:05,920
constraints but right now it's really we

1149
00:45:12,450 --> 00:45:10,240
don't know that's a fine answer you are

1150
00:45:14,400 --> 00:45:12,460
very active in public outreach of

1151
00:45:16,230 --> 00:45:14,410
science and you have a fantastic block

1152
00:45:17,460 --> 00:45:16,240
or planet planet but net that I

1153
00:45:19,830 --> 00:45:17,470
encourage all of you who are listening

1154
00:45:21,450 --> 00:45:19,840
and watching to go check out could you

1155
00:45:22,920 --> 00:45:21,460
tell us how that block started and how

1156
00:45:26,280 --> 00:45:22,930
you integrate ArtReach was your

1157
00:45:28,880 --> 00:45:26,290
professional scientific career sure so

1158
00:45:32,190 --> 00:45:28,890
the blog started I mentioned it briefly

1159
00:45:33,780 --> 00:45:32,200
that when I was a kid I wanted to be

1160
00:45:36,600 --> 00:45:33,790
well I want to be a baseball player but

1161
00:45:38,370 --> 00:45:36,610
that didn't happen then I had a phase

1162
00:45:40,320 --> 00:45:38,380
where I want to be a writer and then

1163
00:45:42,540 --> 00:45:40,330

after a while you know I became less

1164
00:45:43,860 --> 00:45:42,550
interested in being a writer and veered

1165
00:45:45,990 --> 00:45:43,870
towards other things eventually I know

1166
00:45:47,760 --> 00:45:46,000
up in science but I've always kind of

1167
00:45:49,590 --> 00:45:47,770
had this interest in writing a book it

1168
00:45:53,370 --> 00:45:49,600
was kind of always on my bucket list and

1169
00:45:56,400 --> 00:45:53,380
so a few years ago I acted some people

1170
00:45:58,260 --> 00:45:56,410
actually won got Caleb shark at Columbia

1171
00:45:59,940 --> 00:45:58,270
I talked with him a bit because he

1172
00:46:02,040 --> 00:45:59,950
writes science books that are really

1173
00:46:05,550 --> 00:46:02,050
good and so I asked him how he got into

1174
00:46:06,840 --> 00:46:05,560
this and he he suggested he he liked I

1175
00:46:09,360 --> 00:46:06,850
had an idea for a book he liked the idea

1176
00:46:11,430 --> 00:46:09,370
he suggested starting a blog just to

1177
00:46:13,530 --> 00:46:11,440
practice that kind of writing writing

1178
00:46:15,270 --> 00:46:13,540
for not writing for scientists and

1179
00:46:16,560 --> 00:46:15,280
technical way but trying to write in a

1180
00:46:18,420 --> 00:46:16,570
way that hopefully other people can

1181
00:46:20,310 --> 00:46:18,430
understand even if they don't have the

1182
00:46:22,200 --> 00:46:20,320
background you know all the scientific

1183
00:46:25,710 --> 00:46:22,210
training and so I started the blog just

1184
00:46:28,110 --> 00:46:25,720
to practice and once I did it for

1185
00:46:30,180 --> 00:46:28,120
I start really annoying and it just kind

1186
00:46:31,920 --> 00:46:30,190
of kept going from there and I'm

1187
00:46:34,170 --> 00:46:31,930
thinking about writing a book still but

1188
00:46:35,730 --> 00:46:34,180

I I still have the blog and so one thing

1189
00:46:37,620 --> 00:46:35,740
one fun thing I do in the blog is you

1190
00:46:40,220 --> 00:46:37,630
know I do some stuff that's kind of to

1191
00:46:42,780 --> 00:46:40,230
be expected I summarized recent results

1192
00:46:45,690 --> 00:46:42,790
but I also do things that are kind of

1193
00:46:47,790 --> 00:46:45,700
imaginative science like one experiment

1194
00:46:49,650 --> 00:46:47,800
that I did on my blog that for the first

1195
00:46:53,160 --> 00:46:49,660
year my blog got all the traffic pretty

1196
00:46:55,290 --> 00:46:53,170
much was to say imagine right in our

1197
00:46:57,750 --> 00:46:55,300
solar system we have eight planets a

1198
00:47:00,330 --> 00:46:57,760
whole bunch of moons but we have one

1199
00:47:03,180 --> 00:47:00,340
habitable planet and that's it is there

1200
00:47:05,490 --> 00:47:03,190
a way to preserve all the orbits and all

1201
00:47:07,620 --> 00:47:05,500
the objects in the solar system but

1202
00:47:10,110 --> 00:47:07,630
rearrange them and end up with a system

1203
00:47:11,250 --> 00:47:10,120
that has more than one habitable one you

1204
00:47:13,560 --> 00:47:11,260
know that you can argue quite

1205
00:47:16,020 --> 00:47:13,570
convincingly it should more than one of

1206
00:47:18,240 --> 00:47:16,030
those should be habitable and and what I

1207
00:47:20,010 --> 00:47:18,250
did in this blog post as I kept earth

1208
00:47:22,980 --> 00:47:20,020
there I moved out the moon and I

1209
00:47:25,230 --> 00:47:22,990
substituted think Europa or maybe Titan

1210
00:47:27,480 --> 00:47:25,240
you know a large moon of Jupiter Saturn

1211
00:47:30,360 --> 00:47:27,490
I got rid of Mars since we know

1212
00:47:32,010 --> 00:47:30,370
empirically and even though it's in you

1213
00:47:33,510 --> 00:47:32,020

know it's it's wooden many estimates of

1214
00:47:35,370 --> 00:47:33,520
the habitable zone you know it's not

1215
00:47:37,800 --> 00:47:35,380
doing it it's not habitable so I checked

1216
00:47:39,510 --> 00:47:37,810
out Mars and I moved Jupiter there and I

1217
00:47:40,680 --> 00:47:39,520
gave it a bunch of big moons all the

1218
00:47:44,550 --> 00:47:40,690
biggest moves I think I might have put

1219
00:47:46,650 --> 00:47:44,560
Mars as a moon of Jupiter and in the end

1220
00:47:48,390 --> 00:47:46,660
you know I could kind of argue that I

1221
00:47:50,760 --> 00:47:48,400
ended up with something like you know

1222
00:47:53,970 --> 00:47:50,770
six or seven habitable worlds and so

1223
00:47:55,560 --> 00:47:53,980
that kind of experiment on the blog got

1224
00:47:56,790 --> 00:47:55,570
a lot of attention people were really

1225
00:47:59,130 --> 00:47:56,800
interested in it and so then I kept

1226
00:48:02,040 --> 00:47:59,140
going and and integrating kind of

1227
00:48:03,990 --> 00:48:02,050
science with imaginative snakes and when

1228
00:48:07,170 --> 00:48:04,000
I do that it's when I get the best

1229
00:48:10,080 --> 00:48:07,180
response from people so so yeah the blog

1230
00:48:13,200 --> 00:48:10,090
is really fun I really enjoy it and it

1231
00:48:15,240 --> 00:48:13,210
kind of beers between you know very more

1232
00:48:19,560 --> 00:48:15,250
serious science stuff and more almost

1233
00:48:21,630 --> 00:48:19,570
science fictiony stuff but I like it

1234
00:48:23,640 --> 00:48:21,640
when people get interested in so you

1235
00:48:26,310 --> 00:48:23,650
mentioned that you had sci-fi writers

1236
00:48:29,250 --> 00:48:26,320
contact you about using the solar

1237
00:48:31,800 --> 00:48:29,260
systems that you've simulated and using

1238
00:48:33,150 --> 00:48:31,810

physics no to be stable and if they

1239
00:48:36,960 --> 00:48:33,160
could use that for their own stories

1240
00:48:38,520 --> 00:48:36,970
that's awesome yeah yeah that was fun so

1241
00:48:39,010 --> 00:48:38,530
following that same theme that I was

1242
00:48:40,480 --> 00:48:39,020
talking about

1243
00:48:42,730 --> 00:48:40,490
about making the solar system better I

1244
00:48:44,920 --> 00:48:42,740
decided to throw everything I know about

1245
00:48:46,270 --> 00:48:44,930
orbital dynamics in there to build the

1246
00:48:46,900 --> 00:48:46,280
ultimate solar system that's what I

1247
00:48:49,090 --> 00:48:46,910
called it

1248
00:48:50,890 --> 00:48:49,100
so the question being how many planets

1249
00:48:52,960 --> 00:48:50,900
can you in theory pack into the

1250
00:48:57,790 --> 00:48:52,970
habitable zone and the last one I did

1251
00:48:58,990 --> 00:48:57,800
maybe six months ago I got 400 it which

1252
00:49:01,630 --> 00:48:59,000
doesn't seem possible but you can

1253
00:49:05,080 --> 00:49:01,640
actually have a ring of planets orbiting

1254
00:49:08,560 --> 00:49:05,090
all in the same orbit remain stable and

1255
00:49:11,680 --> 00:49:08,570
you could have missing 400 yeah you so

1256
00:49:14,380 --> 00:49:11,690
so I even I I was basing this on recent

1257
00:49:16,600 --> 00:49:14,390
papers in in in celestial mechanics and

1258
00:49:18,400 --> 00:49:16,610
I was I was skeptical about it so I ran

1259
00:49:21,070 --> 00:49:18,410
my own and body simulations to test it

1260
00:49:24,520 --> 00:49:21,080
and you can have four hundred and

1261
00:49:27,790 --> 00:49:24,530
sixteen I think you know about earth

1262
00:49:29,200 --> 00:49:27,800
sized planets in the habitable zone no I

1263
00:49:31,780 --> 00:49:29,210

don't think they would ever end up that

1264
00:49:33,550 --> 00:49:31,790
way and so so in the blog post you know

1265
00:49:35,890 --> 00:49:33,560
argue the only way you could get that is

1266
00:49:38,650 --> 00:49:35,900
if some advanced civilization designed

1267
00:49:39,400 --> 00:49:38,660
it that way you know and if they

1268
00:49:41,260 --> 00:49:39,410
designed it that way

1269
00:49:47,020 --> 00:49:41,270
couldn't they just take any planet make

1270
00:49:49,210 --> 00:49:47,030
it habitable anyway and then uh but in a

1271
00:49:51,070 --> 00:49:49,220
case it's really interesting to kind of

1272
00:49:53,350 --> 00:49:51,080
combine science with the science fiction

1273
00:49:55,030 --> 00:49:53,360
in this way awesome and to remind

1274
00:49:57,490 --> 00:49:55,040
everybody your blog is that planet

1275
00:49:59,440 --> 00:49:57,500
planet nets I encourage you to go check

1276
00:50:01,030 --> 00:49:59,450
it out and we have one question again

1277
00:50:05,860 --> 00:50:01,040
from Newton he wants to follow up with

1278
00:50:08,130 --> 00:50:05,870
from his mower question is does Earth is

1279
00:50:11,080 --> 00:50:08,140
there risk to Earth from one of these

1280
00:50:13,270 --> 00:50:11,090
extrasolar bodies that come suing by and

1281
00:50:17,410 --> 00:50:13,280
can potentially cause damage to our own

1282
00:50:21,880 --> 00:50:17,420
planet no I mean the impact probability

1283
00:50:24,280 --> 00:50:21,890
with them is tiny compared birth you

1284
00:50:26,410 --> 00:50:24,290
know gets hit by very small space junk

1285
00:50:28,000 --> 00:50:26,420
all the time and very large

1286
00:50:30,910 --> 00:50:28,010
excuse me space junk you know very

1287
00:50:32,770 --> 00:50:30,920
rarely and the biggest risk we have now

1288
00:50:35,410 --> 00:50:32,780

from class of asteroids that cross

1289
00:50:37,570 --> 00:50:35,420
Earth's orbit and even those that that

1290
00:50:39,460 --> 00:50:37,580
are crossing Earth's orbit you know

1291
00:50:41,130 --> 00:50:39,470
statistically hit us once every hundred

1292
00:50:43,270 --> 00:50:41,140
million years or something like that

1293
00:50:45,820 --> 00:50:43,280
these objects that are coming in at

1294
00:50:47,770 --> 00:50:45,830
crazy crazy angles have a much smaller

1295
00:50:50,290 --> 00:50:47,780
target effectively that they're aiming

1296
00:50:52,510 --> 00:50:50,300
for so the the risk from them is very

1297
00:50:55,030 --> 00:50:52,520
very small it's not like it's not zero

1298
00:50:59,920 --> 00:50:55,040
point zero but it's very small right

1299
00:51:01,390 --> 00:50:59,930
right so we can sleep safe tonight so

1300
00:51:02,650 --> 00:51:01,400
Shawn if you have if we have listeners

1301
00:51:04,390 --> 00:51:02,660
our students and want to become

1302
00:51:06,730 --> 00:51:04,400
professional astronomers and n-body

1303
00:51:08,890 --> 00:51:06,740
simulators that feels in scientific

1304
00:51:13,360 --> 00:51:08,900
areas similar to yours what advice would

1305
00:51:15,730 --> 00:51:13,370
you give them so a few years ago I would

1306
00:51:18,460 --> 00:51:15,740
always encourage people to to learn

1307
00:51:20,680 --> 00:51:18,470
computing because in grad school one

1308
00:51:21,910 --> 00:51:20,690
thing I had actually taken the a decent

1309
00:51:24,100 --> 00:51:21,920
amount of computer science stuff in

1310
00:51:26,680 --> 00:51:24,110
college and so I felt really happy that

1311
00:51:29,320 --> 00:51:26,690
I had because I knew how to do basic

1312
00:51:31,060 --> 00:51:29,330
stuff enough enough that I could kind of

1313
00:51:34,690 --> 00:51:31,070

basically I had the tools to learn more

1314
00:51:37,360 --> 00:51:34,700
and I used to always encourage do that I

1315
00:51:38,920 --> 00:51:37,370
don't know I'm not like since my kids

1316
00:51:42,010 --> 00:51:38,930
are the wrong age to notice ant like I

1317
00:51:44,050 --> 00:51:42,020
don't know how well people who were

1318
00:51:45,760 --> 00:51:44,060
entering grad school now like how much

1319
00:51:47,770 --> 00:51:45,770
computer training they have where that

1320
00:51:51,070 --> 00:51:47,780
it's common to already know how to use

1321
00:51:52,930 --> 00:51:51,080
you know linux-based systems and this

1322
00:51:57,880 --> 00:51:52,940
kind of stuff or not so I'm not sure how

1323
00:52:01,330 --> 00:51:57,890
relevant that is anymore but that's a

1324
00:52:04,180 --> 00:52:01,340
key thing anyway apart from that I I

1325
00:52:07,120 --> 00:52:04,190
would encourage people not to not to be

1326
00:52:11,980 --> 00:52:07,130
you know single-minded about stuff and

1327
00:52:14,950 --> 00:52:11,990
to you know to read other subjects and

1328
00:52:18,190 --> 00:52:14,960
to you know read science fiction this

1329
00:52:19,960 --> 00:52:18,200
kind of stuff just in the interests not

1330
00:52:21,010 --> 00:52:19,970
you know not that you're gonna go become

1331
00:52:22,890 --> 00:52:21,020
necessarily a science fiction writer

1332
00:52:25,780 --> 00:52:22,900
although you know why not if you want to

1333
00:52:27,630 --> 00:52:25,790
but just to kind of keep your mind used

1334
00:52:32,230 --> 00:52:27,640
to jumping around to different ideas

1335
00:52:34,270 --> 00:52:32,240
because a common danger in science is to

1336
00:52:36,310 --> 00:52:34,280
you know to be very your peer smart

1337
00:52:38,440 --> 00:52:36,320
enough you get into grad school you do a

1338
00:52:40,420 --> 00:52:38,450

project with your adviser you keep

1339
00:52:42,550 --> 00:52:40,430
pushing through and you do that project

1340
00:52:44,080 --> 00:52:42,560
and maybe you're very good at it you get

1341
00:52:46,750 --> 00:52:44,090
your PhD and then it's like what do you

1342
00:52:48,640 --> 00:52:46,760
do next and oftentimes the answer is

1343
00:52:51,250 --> 00:52:48,650
well I know how to do this so I'm gonna

1344
00:52:52,630 --> 00:52:51,260
keep doing that and that's not

1345
00:52:54,640 --> 00:52:52,640
necessarily the best use of your

1346
00:52:56,110 --> 00:52:54,650
resources if you happen to be the world

1347
00:52:57,610 --> 00:52:56,120
expert and you're gonna do the best at

1348
00:52:59,950 --> 00:52:57,620
that then sure why not

1349
00:53:01,210 --> 00:52:59,960
I'm not against Duke even doing that but

1350
00:53:04,750 --> 00:53:01,220
I think there's kind of missed

1351
00:53:05,770 --> 00:53:04,760
opportunities often by people having

1352
00:53:07,630 --> 00:53:05,780
kind of tunnel vision

1353
00:53:09,970 --> 00:53:07,640
and so just trying to break out of that

1354
00:53:12,160 --> 00:53:09,980
kind of tunnel vision in different ways

1355
00:53:15,310 --> 00:53:12,170
I think is very useful and not really

1356
00:53:16,840 --> 00:53:15,320
talked about very much that's a

1357
00:53:18,790 --> 00:53:16,850
fantastic note to end with very

1358
00:53:20,560 --> 00:53:18,800
astrobiological irrelevance when you get

1359
00:53:23,080 --> 00:53:20,570
insights from your discipline from

1360
00:53:25,330 --> 00:53:23,090
outside so on that note I wanna thank

1361
00:53:26,830 --> 00:53:25,340
you in particular and our audience for

1362
00:53:29,170 --> 00:53:26,840
sticking out and listening to our

1363
00:53:30,940 --> 00:53:29,180

presentation today it was wonderful to

1364
00:53:32,350 --> 00:53:30,950
have you Sean I know it's late in Europe

1365
00:53:35,050 --> 00:53:32,360
right now so thanks for taking the time

1366
00:53:38,020 --> 00:53:35,060
please join us next time for another ask

1367
00:53:38,570 --> 00:53:38,030
and astrobiologist and until then stay

1368
00:54:17,510 --> 00:53:38,580
curious