EARTH-LIFE
SCIENCE
INSTITUTE

# Charley Lineweaver

*Connecting the "Emergence of our biosphere"*
*to the "Emergence of biospheres"*

1
00:00:00,160 --> 00:00:14,079
[Music]

2
00:00:19,670 --> 00:00:17,210
okay thank you very much yes this is the

3
00:00:20,660 --> 00:00:19,680
topic and I should say that I'm at the

4
00:00:22,040 --> 00:00:20,670
research school of astronomy and

5
00:00:24,439 --> 00:00:22,050
astrophysics and the research school of

6
00:00:26,599 --> 00:00:24,449
Earth Sciences so what I spend my time

7
00:00:28,339 --> 00:00:26,609
doing is trying to convince astronomers

8
00:00:30,849 --> 00:00:28,349
who are focused on looking at the sky

9
00:00:32,840 --> 00:00:30,859
that the earth in fact is a planet and

10
00:00:34,549 --> 00:00:32,850
talking to the earth scientists who

11
00:00:36,290 --> 00:00:34,559
focus on the earth all the time and

12
00:00:38,479 --> 00:00:36,300
trying to convince them that the earth

13
00:00:42,319 --> 00:00:38,489

in fact is a planet it's an interesting

14
00:00:45,290 --> 00:00:42,329
debate because people are up there or

15
00:00:48,020 --> 00:00:45,300
down here and really the earth is a

16
00:00:50,270 --> 00:00:48,030
planet all right so this is a wonderful

17
00:00:52,340 --> 00:00:50,280
book and I surprises Eric Smith he

18
00:00:54,380 --> 00:00:52,350
didn't mention his book his new book

19
00:00:56,840 --> 00:00:54,390
just came out i the wonderful thing it's

20
00:00:59,770 --> 00:00:56,850
about the topic of this conference so

21
00:01:03,560 --> 00:00:59,780
don't walk run to go buy a copy and

22
00:01:06,859 --> 00:01:03,570
there it is and here's Eric and here's

23
00:01:09,590 --> 00:01:06,869
Harold and this is their book and the

24
00:01:11,810 --> 00:01:09,600
topic that of my talk is to change the

25
00:01:13,760 --> 00:01:11,820
topic of this book change the title of

26
00:01:18,050 --> 00:01:13,770
this book from the origin of nature of

27
00:01:20,710 --> 00:01:18,060
life on Earth and the emergence of 4th

28
00:01:23,570 --> 00:01:20,720
geo spheres so that's essentially a

29
00:01:25,420 --> 00:01:23,580
4-letter change or something to the book

30
00:01:29,390 --> 00:01:25,430
title so I'm just trying to generalize

31
00:01:33,499 --> 00:01:29,400
the study of the origin of life to the

32
00:01:36,260 --> 00:01:33,509
origin of life elsewhere so now this is

33
00:01:38,050 --> 00:01:36,270
a false wha because it's easier to know

34
00:01:40,550 --> 00:01:38,060
men in general than a man in particular

35
00:01:42,080 --> 00:01:40,560
so that's kind of a theme I'll be

36
00:01:45,109 --> 00:01:42,090
talking about I should talk into this

37
00:01:47,350 --> 00:01:45,119
microphone hook it's easier to no man in

38
00:01:50,359 --> 00:01:47,360

general than a man in particular so

39
00:01:51,980 --> 00:01:50,369
yesterday Eric Smith's talked about this

40
00:01:54,050 --> 00:01:51,990
particular paper I hadn't read it so I

41
00:01:55,429 --> 00:01:54,060
looked it up and attempts to define life

42
00:01:56,840 --> 00:01:55,439
do not help to understand the origin of

43
00:02:00,530 --> 00:01:56,850
life I thought that was very interesting

44
00:02:02,450 --> 00:02:00,540
and info in this paper you can see this

45
00:02:04,490 --> 00:02:02,460
what is important in the origin of life

46
00:02:06,950 --> 00:02:04,500
field is understanding the transitions

47
00:02:09,050 --> 00:02:06,960
that led from chemistry to biology

48
00:02:10,669 --> 00:02:09,060
subject well that's a nice thing I agree

49
00:02:12,559 --> 00:02:10,679
very much with that but then I said oh I

50
00:02:13,520 --> 00:02:12,569
can improve on that by changing the

51
00:02:17,000 --> 00:02:13,530
sentence from

52
00:02:19,190 --> 00:02:17,010
that to this change lead to lead and

53
00:02:20,780 --> 00:02:19,200
it's a very simple change and it just

54
00:02:23,720 --> 00:02:20,790
makes it a more generic thing and

55
00:02:27,199 --> 00:02:23,730
another way to do that is to change what

56
00:02:30,100 --> 00:02:27,209
happened on earth to what happens it's

57
00:02:32,270 --> 00:02:30,110
just a very subtle semantic shift that

58
00:02:34,790 --> 00:02:32,280
is essentially what I'll be talking

59
00:02:36,979 --> 00:02:34,800
about today so this guy's you're Donna

60
00:02:39,559 --> 00:02:36,989
Bruner he said this space we declared to

61
00:02:42,740 --> 00:02:39,569
be infinite in it or an infinity of

62
00:02:44,780 --> 00:02:42,750
worlds of the same kind as our own I'm

63
00:02:46,460 --> 00:02:44,790

not sure what daddy used to conclude

64
00:02:49,820 --> 00:02:46,470
that but he get burned at the stake for

65
00:02:51,410 --> 00:02:49,830
saying something similar now today we

66
00:02:53,930 --> 00:02:51,420
have this this is a Hubble Deep Field

67
00:02:56,420 --> 00:02:53,940
and it's a tiny tiny fraction of the sky

68
00:02:57,979 --> 00:02:56,430
if you hold your pinky up to the sky and

69
00:03:00,259 --> 00:02:57,989
look through that fingernail that's

70
00:03:02,120 --> 00:03:00,269
about the size of the sky you're looking

71
00:03:05,479 --> 00:03:02,130
at and these are thousands of galaxies

72
00:03:07,160 --> 00:03:05,489
and just for some numbers there are

73
00:03:09,920 --> 00:03:07,170
about 10 to the 11 stars in our galaxy

74
00:03:12,830 --> 00:03:09,930
and 10 to the 11 galaxies in the

75
00:03:15,020 --> 00:03:12,840
observable universe so that means there

76
00:03:17,750 --> 00:03:15,030
are about ten to twenty two stars in the

77
00:03:19,880 --> 00:03:17,760
observable universe and there are about

78
00:03:21,890 --> 00:03:19,890
twenty ten to twenty one earth in the

79
00:03:23,630 --> 00:03:21,900
observable universe when I say Earth's I

80
00:03:25,250 --> 00:03:23,640
mean wet rocky planets in the habitable

81
00:03:28,520 --> 00:03:25,260
zone but that's something that we should

82
00:03:29,930 --> 00:03:28,530
we'll talk about and you should know

83
00:03:31,160 --> 00:03:29,940
that cosmological observations are

84
00:03:33,440 --> 00:03:31,170
consistent with the universe beings

85
00:03:35,810 --> 00:03:33,450
geometrically flat and therefore

86
00:03:37,670 --> 00:03:35,820
spatially infinite so an infinite number

87
00:03:40,009 --> 00:03:37,680
of Earth so you got a lot of Earth's out

88
00:03:43,280 --> 00:03:40,019

here in the universe lots and lots of as

89
00:03:45,920 --> 00:03:43,290
many as you want now I'm a car I was a

90
00:03:47,360 --> 00:03:45,930
I'm a cosmologists so here we have what

91
00:03:49,880 --> 00:03:47,370
the universe is made of vacuum energy

92
00:03:51,949 --> 00:03:49,890
cold dark matter and about 4.5 percent

93
00:03:54,410 --> 00:03:51,959
normal matter and here's what the Sun is

94
00:03:56,300 --> 00:03:54,420
made of hydrogen helium and about 1.5

95
00:03:59,750 --> 00:03:56,310
present other elements and here's what

96
00:04:01,699 --> 00:03:59,760
life is made up now that's an

97
00:04:03,830 --> 00:04:01,709
interesting understand now this is an

98
00:04:05,560 --> 00:04:03,840
important number for 1.5 because I'm

99
00:04:08,270 --> 00:04:05,570
going to compare the Sun to other stars

100
00:04:10,220 --> 00:04:08,280
now if you're chemists this is your

101
00:04:11,720 --> 00:04:10,230
periodic table and if you're an

102
00:04:14,319 --> 00:04:11,730
astronomer this is your periodic table

103
00:04:17,000 --> 00:04:14,329
it's much simpler and easier to remember

104
00:04:18,469 --> 00:04:17,010
hydrogen helium in metals and if you

105
00:04:21,380 --> 00:04:18,479
want to know a little bit more about

106
00:04:23,360 --> 00:04:21,390
astronomy metals means Fe on H because

107
00:04:25,700 --> 00:04:23,370
we use iron abundance to represent all

108
00:04:27,320 --> 00:04:25,710
of these things all of these things so

109
00:04:29,480 --> 00:04:27,330
that means neon and nitrogen or

110
00:04:31,520 --> 00:04:29,490
medals for example to ensure Oliver now

111
00:04:33,860 --> 00:04:31,530
why is that important well that we use

112
00:04:36,860 --> 00:04:33,870
this Fei yan hou in the next plot this

113
00:04:38,330 --> 00:04:36,870

is a paper i published in 2001 on the

114
00:04:40,490 --> 00:04:38,340
here is the big bang and here's today

115
00:04:42,529 --> 00:04:40,500
notice this was published in 2001 so

116
00:04:44,990 --> 00:04:42,539
it's like 15 years ago and the universe

117
00:04:48,830 --> 00:04:45,000
has gotten 400 million years older in

118
00:04:50,510 --> 00:04:48,840
about 15 years but so this is time here

119
00:04:53,179 --> 00:04:50,520
here's a star formation rate of the

120
00:04:54,740 --> 00:04:53,189
universe here's today in the past it was

121
00:04:56,990 --> 00:04:54,750
higher higher higher higher and then

122
00:04:59,089 --> 00:04:57,000
there was no star formation now what

123
00:05:01,040 --> 00:04:59,099
that means is that if you start here at

124
00:05:03,140 --> 00:05:01,050
the Big Bang the metallicity of the

125
00:05:04,790 --> 00:05:03,150
universe the non hydrogen helium builds

126
00:05:06,529 --> 00:05:04,800
up builds up very quickly because of the

127
00:05:07,850 --> 00:05:06,539
high star-formation rate and then as the

128
00:05:10,369 --> 00:05:07,860
star-formation rate goes down the

129
00:05:11,839 --> 00:05:10,379
increase in the metals slows down but

130
00:05:13,459 --> 00:05:11,849
it's a monotonically increasing function

131
00:05:15,409 --> 00:05:13,469
so you're getting more and more garbage

132
00:05:16,790 --> 00:05:15,419
in the universe why is that important

133
00:05:19,149 --> 00:05:16,800
because the earth is made out of garbage

134
00:05:21,980 --> 00:05:19,159
it's made out of metal here is the

135
00:05:23,779 --> 00:05:21,990
approximate distribution of the metals

136
00:05:25,040 --> 00:05:23,789
that you need to form an earth this

137
00:05:27,290 --> 00:05:25,050
earth that we're standing on is made out

138
00:05:29,749 --> 00:05:27,300

of SI and o and a whole bunch of non

139
00:05:31,519 --> 00:05:29,759
hydrogen helium and this is the regime

140
00:05:33,909 --> 00:05:31,529
there you where you need in order to

141
00:05:37,040 --> 00:05:33,919
form an earth notice that in the first

142
00:05:39,649 --> 00:05:37,050
billion or two years these stars these

143
00:05:41,629 --> 00:05:39,659
stars that are forming do not have high

144
00:05:44,059 --> 00:05:41,639
metallicity and therefore could not have

145
00:05:45,559 --> 00:05:44,069
formed rocking planets you could not

146
00:05:49,369 --> 00:05:45,569
have life because you don't have any Oh

147
00:05:50,869 --> 00:05:49,379
to make the water or carbon monoxide now

148
00:05:53,779 --> 00:05:50,879
what that means is if you take the

149
00:05:55,909 --> 00:05:53,789
distribution of stars cut off the first

150
00:05:57,769 --> 00:05:55,919
two billion years or so you're left with

151
00:06:00,350 --> 00:05:57,779
this distribution with big error bars

152
00:06:02,779 --> 00:06:00,360
and that was published as the earth

153
00:06:05,839 --> 00:06:02,789
formation rate or the age distribution

154
00:06:07,339 --> 00:06:05,849
of Earth's in the universe why that's

155
00:06:09,439 --> 00:06:07,349
interesting is because here's where the

156
00:06:11,029 --> 00:06:09,449
Sun and Earth form and here is

157
00:06:12,439 --> 00:06:11,039
approximately where we think life

158
00:06:15,469 --> 00:06:12,449
started we're not quite sure whether it

159
00:06:18,050 --> 00:06:15,479
was here or here but that's interesting

160
00:06:19,760 --> 00:06:18,060
so if life is common in the universe as

161
00:06:22,519 --> 00:06:19,770
suggested by the rapid appearance of

162
00:06:23,930 --> 00:06:22,529
life on Earth I should say the rapid

163
00:06:25,820 --> 00:06:23,940

appearance of life owners is a very very

164
00:06:27,879 --> 00:06:25,830
important number because from it you can

165
00:06:30,800 --> 00:06:27,889
conclude quite a few things for example

166
00:06:33,680 --> 00:06:30,810
how often we should expect life

167
00:06:35,209 --> 00:06:33,690
elsewhere kind of a weird inverse

168
00:06:36,740 --> 00:06:35,219
probability calculation that you can

169
00:06:39,139 --> 00:06:36,750
look up in a paper that I wrote about 10

170
00:06:41,030 --> 00:06:39,149
years ago anyway we have that many at

171
00:06:43,310 --> 00:06:41,040
all recent paper came with

172
00:06:45,980 --> 00:06:43,320
Vickie Bennett contributing to that Anu

173
00:06:47,900 --> 00:06:45,990
and we have these stromatolites the

174
00:06:51,950 --> 00:06:47,910
oldest macroscopic evidence for life

175
00:06:54,590 --> 00:06:51,960
reported just few months ago 3.75 and

176
00:06:58,390 --> 00:06:54,600
then bell at all based on carbon 12 13

177
00:07:00,650 --> 00:06:58,400
like carbon in evidence for isotopic

178
00:07:03,170 --> 00:07:00,660
controversial evidence for early life of

179
00:07:04,790 --> 00:07:03,180
4.1 the whole point is that these dates

180
00:07:06,530 --> 00:07:04,800
have been getting earlier and earlier

181
00:07:08,120 --> 00:07:06,540
and so this green arrow is getting

182
00:07:10,850 --> 00:07:08,130
closer and closer and the closer it gets

183
00:07:12,680 --> 00:07:10,860
to the formation of the earth the easier

184
00:07:15,740 --> 00:07:12,690
it is to conclude that the probability

185
00:07:18,530 --> 00:07:15,750
of life elsewhere is higher in any case'

186
00:07:21,020 --> 00:07:18,540
it gives you an this age distribution

187
00:07:22,940 --> 00:07:21,030
gives us an idea about how we compared

188
00:07:26,480 --> 00:07:22,950

to other life that may exist in the

189
00:07:29,540 --> 00:07:26,490
universe now half a bit nas's a to mass

190
00:07:32,410 --> 00:07:29,550
image here's a milky way here's the

191
00:07:34,880 --> 00:07:32,420
large and small Magellanic Clouds and

192
00:07:36,230 --> 00:07:34,890
it's a half a billion stars of the about

193
00:07:38,330 --> 00:07:36,240
three hundred billion stars in our

194
00:07:41,540 --> 00:07:38,340
galaxy and the question is what fraction

195
00:07:43,190 --> 00:07:41,550
of those have planets well this is a

196
00:07:47,180 --> 00:07:43,200
historical subject which has been going

197
00:07:49,190 --> 00:07:47,190
on for about 20 years now so 1995 notice

198
00:07:51,440 --> 00:07:49,200
on the y-axis here is the lower limit on

199
00:07:53,960 --> 00:07:51,450
the percentage of stars with planets so

200
00:07:56,660 --> 00:07:53,970
in 1995 we found one and it would be

201
00:07:59,330 --> 00:07:56,670
consistent with hey 0% have planets but

202
00:08:02,000 --> 00:07:59,340
then we know at least 50 at least 10 and

203
00:08:03,890 --> 00:08:02,010
then our great paper in 2003 said oh at

204
00:08:05,900 --> 00:08:03,900
least twenty five percent and then this

205
00:08:07,610 --> 00:08:05,910
number has been going out Oh at least 50

206
00:08:10,460 --> 00:08:07,620
at least 60 at least and now here we are

207
00:08:13,850 --> 00:08:10,470
in 2017 over here and so this number is

208
00:08:15,860 --> 00:08:13,860
essentially a hundred percent and so the

209
00:08:18,890 --> 00:08:15,870
default the new default that has changed

210
00:08:21,320 --> 00:08:18,900
in 20 years is you look up at the sky

211
00:08:23,210 --> 00:08:21,330
and see a star and the default is that

212
00:08:25,460 --> 00:08:23,220
it had some type of planetary system

213
00:08:28,520 --> 00:08:25,470

around it and share some of the details

214
00:08:30,320 --> 00:08:28,530
of how that was made now here's a nice

215
00:08:32,750 --> 00:08:30,330
plot here's the orbital period of a

216
00:08:35,300 --> 00:08:32,760
planet here's the mass of the planet and

217
00:08:36,830 --> 00:08:35,310
if there's a whole bunch of techniques

218
00:08:38,450 --> 00:08:36,840
that have been used to discover there's

219
00:08:40,010 --> 00:08:38,460
radial velocity or Doppler technique

220
00:08:42,740 --> 00:08:40,020
transit technique from the ground

221
00:08:44,180 --> 00:08:42,750
transit if I'm Kepler in our solar

222
00:08:46,760 --> 00:08:44,190
system here's our solar system right

223
00:08:48,530 --> 00:08:46,770
here Jupiter here's earth this thing is

224
00:08:51,440 --> 00:08:48,540
like Earth like here's like Jupiter like

225
00:08:53,480 --> 00:08:51,450
then there's debris disks direct imaging

226
00:08:54,769 --> 00:08:53,490
over here and this pulse our timing here

227
00:08:56,900 --> 00:08:54,779
and here and here so there's

228
00:08:58,790 --> 00:08:56,910
many wonderful techniques of to detect

229
00:09:00,350 --> 00:08:58,800
these exoplanets and you can see that

230
00:09:02,389 --> 00:09:00,360
most of them are over here and very

231
00:09:04,400 --> 00:09:02,399
fewer over here well that's a selection

232
00:09:06,199 --> 00:09:04,410
effect do not go home thinking that

233
00:09:07,610 --> 00:09:06,209
there are no planets here because we

234
00:09:09,769 --> 00:09:07,620
know that the selection effects for

235
00:09:13,119 --> 00:09:09,779
these things are very steeply declining

236
00:09:18,079 --> 00:09:13,129
as you go towards the lower right here

237
00:09:22,220 --> 00:09:18,089
now that's 2012 oops that's 2012 here's

238
00:09:24,730 --> 00:09:22,230

2015 so as Kepler made more and more

239
00:09:28,699 --> 00:09:24,740
detections this thing change is this a

240
00:09:32,449 --> 00:09:28,709
red cloud move to the right as in this

241
00:09:34,460 --> 00:09:32,459
arrow and you can see now there are war

242
00:09:36,590 --> 00:09:34,470
they're kind of a few a handful of

243
00:09:39,470 --> 00:09:36,600
earth-like planets boasts and both in

244
00:09:41,269 --> 00:09:39,480
terms of its period and the mass and a

245
00:09:42,980 --> 00:09:41,279
couple of Jupiter like ones as well but

246
00:09:44,960 --> 00:09:42,990
you can see that we're still the Earth

247
00:09:47,509 --> 00:09:44,970
and Jupiter are still on the edge of

248
00:09:49,220 --> 00:09:47,519
this diagram so the earth-like planets

249
00:09:51,499 --> 00:09:49,230
and Jupiter like plants are very still

250
00:09:53,720 --> 00:09:51,509
very hard to detect and keep that in the

251
00:09:55,610 --> 00:09:53,730
back of your mind now one way to show

252
00:09:58,220 --> 00:09:55,620
that is a nice favorite biped agoura in

253
00:10:00,350 --> 00:09:58,230
2014 in which again orbital period but

254
00:10:03,199 --> 00:10:00,360
here not mass but planetary size and

255
00:10:05,299 --> 00:10:03,209
here's the completeness of this Kepler

256
00:10:07,189 --> 00:10:05,309
survey and you can see here 0 can't see

257
00:10:08,840 --> 00:10:07,199
it much here at all and then you can see

258
00:10:11,780 --> 00:10:08,850
oh these are all complete and so you go

259
00:10:15,079 --> 00:10:11,790
from complete to very very very very

260
00:10:16,579 --> 00:10:15,089
little very completeness and so here is

261
00:10:18,799 --> 00:10:16,589
where the earth is so you can see at

262
00:10:21,860 --> 00:10:18,809
this early stage before the final Kepler

263
00:10:24,019 --> 00:10:21,870

data was out that the earth was not even

264
00:10:25,730 --> 00:10:24,029
we couldn't see it very well and so it's

265
00:10:28,970 --> 00:10:25,740
in the DA there's one hundred percent

266
00:10:30,379 --> 00:10:28,980
incomplete area so that's the kind of

267
00:10:33,470 --> 00:10:30,389
selection effect that we're dealing with

268
00:10:36,110 --> 00:10:33,480
now unfortunately the new testing the

269
00:10:38,569 --> 00:10:36,120
new tests observatory will not do very

270
00:10:40,730 --> 00:10:38,579
well in here either because it takes

271
00:10:42,470 --> 00:10:40,740
such short instinct an image here an

272
00:10:46,240 --> 00:10:42,480
image here an image here and it doesn't

273
00:10:49,549 --> 00:10:46,250
look long enough to probe this long

274
00:10:52,100 --> 00:10:49,559
region of orbital period ok so the new

275
00:10:53,449 --> 00:10:52,110
default is this artist period every star

276
00:10:57,049 --> 00:10:53,459
you look at has some type of planetary

277
00:11:00,259 --> 00:10:57,059
system around it so in the last few

278
00:11:01,730 --> 00:11:00,269
decades we've discovered their

279
00:11:03,439 --> 00:11:01,740
extraterrestrial environments known to

280
00:11:05,360 --> 00:11:03,449
exist has go on just enormous probably

281
00:11:06,740 --> 00:11:05,370
much much bigger than this so lots and

282
00:11:08,540 --> 00:11:06,750
lots of extra stressful environments

283
00:11:09,740 --> 00:11:08,550
have been found and tricks to try

284
00:11:11,960 --> 00:11:09,750
steel environments known to harbor life

285
00:11:14,480 --> 00:11:11,970
has also increased so the hope is that

286
00:11:17,470 --> 00:11:14,490
these two will overlap as they get

287
00:11:21,380 --> 00:11:17,480
bigger and continue to get bigger now

288
00:11:22,910 --> 00:11:21,390

one thing about this diagram is for each

289
00:11:25,069 --> 00:11:22,920
one of these planets we know what the

290
00:11:26,960 --> 00:11:25,079
star luminosity is and we know how far

291
00:11:29,060 --> 00:11:26,970
the planet is from the host star so we

292
00:11:31,370 --> 00:11:29,070
can turn it into a effective temperature

293
00:11:34,100 --> 00:11:31,380
on these planets so using the

294
00:11:36,259 --> 00:11:34,110
information of the period of and the

295
00:11:38,600 --> 00:11:36,269
luminosity of the star it turns into

296
00:11:40,670 --> 00:11:38,610
this so we've changed this to planetary

297
00:11:42,740 --> 00:11:40,680
effective temperature and here is mass

298
00:11:44,480 --> 00:11:42,750
and so here's where you might call the

299
00:11:45,980 --> 00:11:44,490
habitable zone and I agree with mark

300
00:11:47,990 --> 00:11:45,990
jelinek that atmosphere is very

301
00:11:50,690 --> 00:11:48,000
important for determining where this is

302
00:11:52,250 --> 00:11:50,700
if you can add gas and again in the

303
00:11:55,310 --> 00:11:52,260
habitable zone can get further out you

304
00:11:56,630 --> 00:11:55,320
decrease it it gets further in and later

305
00:11:58,730 --> 00:11:56,640
on in this talk I'll talk about not only

306
00:12:01,490 --> 00:11:58,740
is that Monsieur important but biology

307
00:12:03,139 --> 00:12:01,500
old self maybe even more important in

308
00:12:04,610 --> 00:12:03,149
any case here's that where you might

309
00:12:06,590 --> 00:12:04,620
have habit blue moons you're a brown

310
00:12:07,940 --> 00:12:06,600
dwarfs up here and here's the earth and

311
00:12:11,300 --> 00:12:07,950
you can see that we haven't found many

312
00:12:13,569 --> 00:12:11,310
here but this was 2012 if you do 2015

313
00:12:16,190 --> 00:12:13,579

data it'll be a few points around here

314
00:12:18,350 --> 00:12:16,200
okay but one of the things that guests

315
00:12:20,269 --> 00:12:18,360
will be able to do is this plot here

316
00:12:23,360 --> 00:12:20,279
here's planetary mass here's planetary

317
00:12:25,370 --> 00:12:23,370
radius and here's if if it's just like a

318
00:12:27,199 --> 00:12:25,380
radius density plot right and so we have

319
00:12:28,610 --> 00:12:27,209
height if the planet is pure hydrogen is

320
00:12:30,139 --> 00:12:28,620
where it would be if it were pure water

321
00:12:31,880 --> 00:12:30,149
here's where it would be your rock here

322
00:12:34,040 --> 00:12:31,890
and pure iron here you can see the Earth

323
00:12:36,829 --> 00:12:34,050
and Venus are here they are mixture of

324
00:12:38,150 --> 00:12:36,839
iron and rock and water right here you

325
00:12:39,590 --> 00:12:38,160
can see that these guys are just

326
00:12:41,090 --> 00:12:39,600
hydrogen consist with you and hydrogen

327
00:12:42,920 --> 00:12:41,100
and then as you go down here and get

328
00:12:45,800 --> 00:12:42,930
smaller and smaller planet mass or

329
00:12:47,990 --> 00:12:45,810
smaller radius it adds some totes to

330
00:12:49,400 --> 00:12:48,000
this region here now there's a little

331
00:12:51,019 --> 00:12:49,410
bit of an old plot three years ago we

332
00:12:53,930 --> 00:12:51,029
have much not not much but we have

333
00:12:56,120 --> 00:12:53,940
better data here and this is where this

334
00:13:00,380 --> 00:12:56,130
curve comes in to the Earth and Venus

335
00:13:02,510 --> 00:13:00,390
line is about 1.6 Earth radii so right

336
00:13:04,699 --> 00:13:02,520
where this green arrow is and when you

337
00:13:08,090 --> 00:13:04,709
cube 1.6 you get about fourth masses so

338
00:13:11,980 --> 00:13:08,100

for or for Earth masses and 1.6 Earth

339
00:13:15,829 --> 00:13:11,990
radii is where this add some totes to a

340
00:13:17,540 --> 00:13:15,839
Venus and Earth like composition pets

341
00:13:20,630 --> 00:13:17,550
will do wonderful things in this region

342
00:13:22,340 --> 00:13:20,640
right here between let's say 1 and 5 to

343
00:13:24,080 --> 00:13:22,350
get that much more accurate about

344
00:13:25,790 --> 00:13:24,090
how big does a planet have to be to

345
00:13:29,870 --> 00:13:25,800
become rocky and then transition to

346
00:13:31,550 --> 00:13:29,880
being gaseous okay how about these

347
00:13:33,020 --> 00:13:31,560
centricity this is something all for the

348
00:13:34,460 --> 00:13:33,030
past 20 years these centricity

349
00:13:36,320 --> 00:13:34,470
distribution of these exoplanets has

350
00:13:38,690 --> 00:13:36,330
been all just they're just highly

351
00:13:41,210 --> 00:13:38,700
eccentric not kind of circular like ours

352
00:13:42,830 --> 00:13:41,220
well is a very newspaper and the answer

353
00:13:44,750 --> 00:13:42,840
is is the eccentricity of our solar

354
00:13:46,580 --> 00:13:44,760
system you unusually low the answer's no

355
00:13:49,310 --> 00:13:46,590
here's a new paper it's not even out yet

356
00:13:51,740 --> 00:13:49,320
but he presented this result about a

357
00:13:53,900 --> 00:13:51,750
month ago in the Sol G conference and I

358
00:13:56,900 --> 00:13:53,910
was pretty impressed by it and the

359
00:13:58,670 --> 00:13:56,910
answer is that no decent tricity the

360
00:14:01,060 --> 00:13:58,680
lowest centricity zuv our solar system

361
00:14:03,520 --> 00:14:01,070
are not a typical and that the

362
00:14:06,680 --> 00:14:03,530
previously thought eccentricity

363
00:14:08,120 --> 00:14:06,690

distributions was due to a selection

364
00:14:09,860 --> 00:14:08,130
effect associated with the type of

365
00:14:12,500 --> 00:14:09,870
planets we are seeing namely hot

366
00:14:15,110 --> 00:14:12,510
Jupiters which only make up 5 10 most

367
00:14:16,910 --> 00:14:15,120
twelve percent of the population that

368
00:14:18,740 --> 00:14:16,920
we're seeing okay how about the

369
00:14:21,020 --> 00:14:18,750
abundances the abundances in the Sun

370
00:14:23,480 --> 00:14:21,030
this was shown before but it was also

371
00:14:25,820 --> 00:14:23,490
said and I repeat this is also the

372
00:14:28,910 --> 00:14:25,830
abundances in the universe so the Sun is

373
00:14:30,650 --> 00:14:28,920
not a bad proxy for the distribution of

374
00:14:32,680 --> 00:14:30,660
elements in the universe it's not just

375
00:14:35,060 --> 00:14:32,690
our solar system but the universe and

376
00:14:36,980 --> 00:14:35,070
here's hydrogen helium and you can see

377
00:14:38,800 --> 00:14:36,990
this is a log plot so these are much

378
00:14:41,510 --> 00:14:38,810
more abundant and here the metals

379
00:14:43,250 --> 00:14:41,520
everything here and there that I guess

380
00:14:45,950 --> 00:14:43,260
they called major elements in earth

381
00:14:48,050 --> 00:14:45,960
science talk now here's a molecular

382
00:14:49,940 --> 00:14:48,060
cloud here's a new region of this about

383
00:14:51,620 --> 00:14:49,950
a thousand stars that have just formed

384
00:14:53,630 --> 00:14:51,630
out of this molecular cloud and they are

385
00:14:55,280 --> 00:14:53,640
formed out of this material so it's just

386
00:14:57,140 --> 00:14:55,290
kind of like a baby being formed that

387
00:15:01,610 --> 00:14:57,150
baby is made out of the stuff from which

388
00:15:05,660 --> 00:15:01,620

it comes to this placenta and now how

389
00:15:07,550 --> 00:15:05,670
variable is the metallicity or how

390
00:15:10,460 --> 00:15:07,560
variable are the elemental abundances of

391
00:15:12,560 --> 00:15:10,470
these other stars in the universe well

392
00:15:14,810 --> 00:15:12,570
here's this is a fraction of solar

393
00:15:17,810 --> 00:15:14,820
abundance the Sun is here in this gray

394
00:15:19,490 --> 00:15:17,820
line here so here about sixty two stars

395
00:15:21,140 --> 00:15:19,500
and you can see some have high

396
00:15:23,240 --> 00:15:21,150
metallicity they go did you did you did

397
00:15:25,700 --> 00:15:23,250
some have low metallicity about one

398
00:15:28,670 --> 00:15:25,710
tenth of solar here but you can see that

399
00:15:30,980 --> 00:15:28,680
they have those similar shapes but they

400
00:15:33,950 --> 00:15:30,990
go up and down by ten twenty thirty

401
00:15:35,650 --> 00:15:33,960
forty percent and sometimes they go down

402
00:15:36,610 --> 00:15:35,660
in similar ways but some not

403
00:15:39,130 --> 00:15:36,620
all the time from here to here for

404
00:15:43,690 --> 00:15:39,140
example so that's the type of variation

405
00:15:46,510 --> 00:15:43,700
we expect that we can measure in stars

406
00:15:47,800 --> 00:15:46,520
in the galaxy and therefore in the

407
00:15:49,390 --> 00:15:47,810
universe we have no reason to expect

408
00:15:51,520 --> 00:15:49,400
that our galaxy is different from other

409
00:15:54,490 --> 00:15:51,530
galaxies so this represents the type of

410
00:15:57,730 --> 00:15:54,500
variability that we have in host stars

411
00:15:59,950 --> 00:15:57,740
that variability will be reflected in

412
00:16:01,720 --> 00:15:59,960
the composition of the rocky planets

413
00:16:04,270 --> 00:16:01,730

which are forming out of the same stuff

414
00:16:06,810 --> 00:16:04,280
but this but I just d volatilized

415
00:16:09,040 --> 00:16:06,820
versions of what you're seeing here

416
00:16:11,290 --> 00:16:09,050
caveat when you see or what by

417
00:16:13,120 --> 00:16:11,300
carbon-rich stars it's very important

418
00:16:15,280 --> 00:16:13,130
that we're talking about proxies that

419
00:16:17,530 --> 00:16:15,290
are representative of the bulk of the

420
00:16:19,690 --> 00:16:17,540
star not just dredge up from to the

421
00:16:21,570 --> 00:16:19,700
surface where it becomes visible so

422
00:16:24,460 --> 00:16:21,580
carbon starts for example are not

423
00:16:25,990 --> 00:16:24,470
carbon-rich accepted the photosphere

424
00:16:28,240 --> 00:16:26,000
when you measure them so they would not

425
00:16:29,980 --> 00:16:28,250
be candidates for saying oh the planets

426
00:16:32,830 --> 00:16:29,990
around that star would then be rich in

427
00:16:36,070 --> 00:16:32,840
carbon you have to be careful of things

428
00:16:38,530 --> 00:16:36,080
like that okay so here are a bunch of

429
00:16:41,260 --> 00:16:38,540
elements and here is the solar

430
00:16:42,850 --> 00:16:41,270
composition by number so ninety-one

431
00:16:45,670 --> 00:16:42,860
percent of the atoms in the Sun are

432
00:16:48,820 --> 00:16:45,680
hydrogen 8.8 or helium and then we have

433
00:16:52,780 --> 00:16:48,830
about this much oxygen and this much

434
00:16:55,030 --> 00:16:52,790
carbon now to first order if you're

435
00:16:57,370 --> 00:16:55,040
going to make an earth what you do with

436
00:16:59,530 --> 00:16:57,380
the carbon and oxygen is you take all of

437
00:17:01,660 --> 00:16:59,540
the carbon or almost all the carbon that

438
00:17:04,630 --> 00:17:01,670

isn't in graphite and then you combine

439
00:17:06,910 --> 00:17:04,640
it with the oxygen and then pump it goes

440
00:17:09,010 --> 00:17:06,920
away in the inner part of the system and

441
00:17:11,380 --> 00:17:09,020
then you're left with a bunch of oxygen

442
00:17:13,210 --> 00:17:11,390
in our case that oxygen then just

443
00:17:14,650 --> 00:17:13,220
combines with this and this and this and

444
00:17:17,380 --> 00:17:14,660
this and everything that I can combine

445
00:17:19,240 --> 00:17:17,390
with and that's how you make an earth if

446
00:17:22,270 --> 00:17:19,250
it were the other way around if the sea

447
00:17:24,940 --> 00:17:22,280
20 ratio were greater than 1 then this

448
00:17:26,800 --> 00:17:24,950
would be high this would be low almost

449
00:17:28,720 --> 00:17:26,810
all of the car all the oxygen would have

450
00:17:30,520 --> 00:17:28,730
been used up in the co we would have had

451
00:17:31,990 --> 00:17:30,530
lots of carbon which would then combined

452
00:17:35,470 --> 00:17:32,000
with this and this and this and we have

453
00:17:37,570 --> 00:17:35,480
a carbide planet most of the stars in

454
00:17:41,170 --> 00:17:37,580
the universe and the galaxies have 0

455
00:17:42,520 --> 00:17:41,180
bigger than C but there will be some at

456
00:17:44,860 --> 00:17:42,530
the tail of distribution which that's

457
00:17:47,770 --> 00:17:44,870
not the case and that's why there's a

458
00:17:49,500 --> 00:17:47,780
nice papers talk about carbon planet

459
00:17:51,270 --> 00:17:49,510
based on a CO ratio

460
00:17:55,230 --> 00:17:51,280
that's relatively high compared to the

461
00:17:57,600 --> 00:17:55,240
norm okay so this week saw yesterday in

462
00:18:01,710 --> 00:17:57,610
mark hirschmann stalk and essentially

463
00:18:04,170 --> 00:18:01,720

we're seeing the depletion of n volatile

464
00:18:06,150 --> 00:18:04,180
species in C in when you're close to the

465
00:18:07,500 --> 00:18:06,160
earth close to the Sun and then you're

466
00:18:09,030 --> 00:18:07,510
getting more and more of that volatile

467
00:18:10,830 --> 00:18:09,040
as you get further away until you reach

468
00:18:14,790 --> 00:18:10,840
about the Sun here and the same thing

469
00:18:16,350 --> 00:18:14,800
for carbon so what we did is we made a

470
00:18:17,850 --> 00:18:16,360
version of this now how young is a

471
00:18:20,070 --> 00:18:17,860
graduate student and can you raise your

472
00:18:21,540 --> 00:18:20,080
hand there there's my as my graduate

473
00:18:23,550 --> 00:18:21,550
student he's one who made this plot and

474
00:18:25,740 --> 00:18:23,560
what it is is condensation temperature

475
00:18:28,740 --> 00:18:25,750
here so really volatile things here and

476
00:18:31,770 --> 00:18:28,750
less volatile things here here's the Sun

477
00:18:33,270 --> 00:18:31,780
at one in yellow and then here's the

478
00:18:35,640 --> 00:18:33,280
earth joojoo joojoo the same same same

479
00:18:37,620 --> 00:18:35,650
same and improve like this so we have a

480
00:18:39,300 --> 00:18:37,630
devolatilization pattern which are we

481
00:18:41,340 --> 00:18:39,310
are trying to make precise enough to be

482
00:18:44,160 --> 00:18:41,350
useful as a tool which we would like to

483
00:18:45,660 --> 00:18:44,170
apply to other stars because we know the

484
00:18:48,480 --> 00:18:45,670
abundances of other stars from

485
00:18:50,460 --> 00:18:48,490
spectroscopy but we want to guess that

486
00:18:53,430 --> 00:18:50,470
using this devolatilization pattern

487
00:18:56,250 --> 00:18:53,440
predicting that it's semi early semi

488
00:18:58,320 --> 00:18:56,260

universal to say Oh rocky planets will

489
00:19:00,660 --> 00:18:58,330
also be a devolatilization not of our

490
00:19:03,510 --> 00:19:00,670
star but a ver star which we can measure

491
00:19:05,370 --> 00:19:03,520
and then we look at CI chondrites it's

492
00:19:07,350 --> 00:19:05,380
the same two gggggg and then it goes

493
00:19:09,000 --> 00:19:07,360
down comments go judges judges it and

494
00:19:11,010 --> 00:19:09,010
then go down and I think Jupiter is

495
00:19:13,560 --> 00:19:11,020
somewhere here too so the whole point is

496
00:19:16,380 --> 00:19:13,570
that things get bored d volatilize when

497
00:19:19,290 --> 00:19:16,390
they get closer to a hot source which i

498
00:19:21,570 --> 00:19:19,300
think is a universal feature of this

499
00:19:23,970 --> 00:19:21,580
it's even even beyond the observable

500
00:19:26,580 --> 00:19:23,980
universe that statement is true okay

501
00:19:28,230 --> 00:19:26,590
what about the Sun you might here is we

502
00:19:30,810 --> 00:19:28,240
wrote a paper a comprehensive comparison

503
00:19:32,700 --> 00:19:30,820
of the Sun to other stars searching for

504
00:19:34,560 --> 00:19:32,710
self selection effects the idea being

505
00:19:36,720 --> 00:19:34,570
well here we are we're kind of special

506
00:19:39,240 --> 00:19:36,730
or are we special we're we're we're

507
00:19:41,460 --> 00:19:39,250
alive it is our son particular is it

508
00:19:43,260 --> 00:19:41,470
particularly interesting different from

509
00:19:44,910 --> 00:19:43,270
other sons well when you put the Sun

510
00:19:46,740 --> 00:19:44,920
here's the Sun right here and compared

511
00:19:48,870 --> 00:19:46,750
to the metallicity of other stars it's

512
00:19:50,340 --> 00:19:48,880
kind of within 1 Sigma and metallicity

513
00:19:53,130 --> 00:19:50,350

so it's not particularly metal-rich or

514
00:19:54,570 --> 00:19:53,140
metal-poor it's within 1 Sigma here the

515
00:19:56,880 --> 00:19:54,580
thing that stands out the most about the

516
00:19:59,820 --> 00:19:56,890
Sun is its mass here's the distribution

517
00:20:01,470 --> 00:19:59,830
of the nearest 200 and 250 stars and you

518
00:20:03,320 --> 00:20:01,480
can see that the Sun right here at one

519
00:20:05,120 --> 00:20:03,330
solar mass is quite hot

520
00:20:07,040 --> 00:20:05,130
only five percent are here ninety-five

521
00:20:11,360 --> 00:20:07,050
percent are here so we're kind of a 2

522
00:20:13,310 --> 00:20:11,370
sigma massive star that we're orbiting

523
00:20:15,080 --> 00:20:13,320
that might have to do with more massive

524
00:20:16,700 --> 00:20:15,090
stars produce more UV and you need UV to

525
00:20:18,680 --> 00:20:16,710
get life started but that's not

526
00:20:21,230 --> 00:20:18,690
something that I can I'm very informed

527
00:20:23,480 --> 00:20:21,240
about now here's all the car all the

528
00:20:26,210 --> 00:20:23,490
things we looked at the Sun is typical

529
00:20:28,460 --> 00:20:26,220
so here we have that the middle of the

530
00:20:30,650 --> 00:20:28,470
median of the distributions of all the

531
00:20:33,260 --> 00:20:30,660
stars we could get a hold of in terms of

532
00:20:34,760 --> 00:20:33,270
stellar mass it's off here to Sigma in

533
00:20:36,950 --> 00:20:34,770
terms of host the mass of the host

534
00:20:38,330 --> 00:20:36,960
galaxy is about 1 Sigma galaxy lactic

535
00:20:40,700 --> 00:20:38,340
radius how far it is from the center

536
00:20:43,010 --> 00:20:40,710
here iron content oh it's a little bit

537
00:20:45,530 --> 00:20:43,020
metal-rich stellar aho to live a younger

538
00:20:47,180 --> 00:20:45,540

host group mass a little bit younger a

539
00:20:49,070 --> 00:20:47,190
little bit smaller rather height above

540
00:20:52,040 --> 00:20:49,080
the Galactic plane etc so you can you

541
00:20:54,260 --> 00:20:52,050
can compare the Sun to other stars in

542
00:20:56,240 --> 00:20:54,270
any parameter space you'd like to to see

543
00:20:57,590 --> 00:20:56,250
if it stands out to see if there's

544
00:20:59,540 --> 00:20:57,600
anything that might be associated with

545
00:21:02,960 --> 00:20:59,550
habitability that would be responsible

546
00:21:05,840 --> 00:21:02,970
for us being here possibly for example

547
00:21:08,150 --> 00:21:05,850
you can think if our if life were based

548
00:21:11,720 --> 00:21:08,160
on uranium and the Sun was the most

549
00:21:14,240 --> 00:21:11,730
uranium rich star in the galaxy with a

550
00:21:15,920 --> 00:21:14,250
whoa we would go then and look for the

551
00:21:17,270 --> 00:21:15,930
most uranium rich stars elsewhere and

552
00:21:19,520 --> 00:21:17,280
say that's probably where there's life

553
00:21:21,590 --> 00:21:19,530
there would be a correlation there and

554
00:21:23,240 --> 00:21:21,600
but that's not what we find we don't

555
00:21:25,250 --> 00:21:23,250
find anything that stands out like that

556
00:21:27,680 --> 00:21:25,260
there doesn't seem to be any selection

557
00:21:30,620 --> 00:21:27,690
effect for the Sun as far of any of the

558
00:21:32,420 --> 00:21:30,630
things we've looked at now co is very

559
00:21:33,940 --> 00:21:32,430
important and here's the Sun it's within

560
00:21:36,830 --> 00:21:33,950
about one sigma it's a little low

561
00:21:38,180 --> 00:21:36,840
compared to the mean median and why is

562
00:21:41,870 --> 00:21:38,190
that important that's important because

563
00:21:44,570 --> 00:21:41,880

C and O are the two most abundant

564
00:21:45,950 --> 00:21:44,580
element after hydrogen and helium these

565
00:21:47,540 --> 00:21:45,960
are the things that determine the

566
00:21:51,860 --> 00:21:47,550
chemistry of the disk that's going to

567
00:21:53,690 --> 00:21:51,870
form the planet and so how is that why

568
00:21:56,540 --> 00:21:53,700
that's so important look at this is co

569
00:21:58,760 --> 00:21:56,550
as soon as CEO gets above one hope you

570
00:22:00,650 --> 00:21:58,770
turn into a graphite titanium carbide

571
00:22:03,350 --> 00:22:00,660
silicon carbon you turn into an iron and

572
00:22:05,480 --> 00:22:03,360
carbide planet over here are all the

573
00:22:07,850 --> 00:22:05,490
rocky planets and say the word rocky

574
00:22:09,140 --> 00:22:07,860
this is what you mean Co less than this

575
00:22:11,990 --> 00:22:09,150
so that this is the condensation

576
00:22:13,430 --> 00:22:12,000
sequence that you get now up here we

577
00:22:15,140 --> 00:22:13,440
have distributions here's at eight

578
00:22:16,970 --> 00:22:15,150
kiloparsecs the sun is that distance

579
00:22:19,909 --> 00:22:16,980
from the center of the galaxy here's

580
00:22:21,260 --> 00:22:19,919
kiloparsecs the CEO ratio goes up as you

581
00:22:23,570 --> 00:22:21,270
get closer and closer to the center of

582
00:22:25,730 --> 00:22:23,580
the galaxy that what that's what happens

583
00:22:28,220 --> 00:22:25,740
when you get higher metallicity but only

584
00:22:30,260 --> 00:22:28,230
the tail end goes over here so that's

585
00:22:32,150 --> 00:22:30,270
why I said maybe the number of carbide

586
00:22:35,150 --> 00:22:32,160
planets will be all five percent or so

587
00:22:37,640 --> 00:22:35,160
and ninety-five percent of the small

588
00:22:41,330 --> 00:22:37,650

rocky planets are silly rocky rather

589
00:22:42,650 --> 00:22:41,340
than carbide rocky okay now you can go

590
00:22:44,150 --> 00:22:42,660
further than that because you have all

591
00:22:45,890 --> 00:22:44,160
these elements from these stars and you

592
00:22:47,930 --> 00:22:45,900
can say okay what's the seed oil ratio

593
00:22:50,150 --> 00:22:47,940
of this post are and what's the mg on SI

594
00:22:51,830 --> 00:22:50,160
ratio and we can start to play many many

595
00:22:55,310 --> 00:22:51,840
games in a much higher parameter space

596
00:22:57,320 --> 00:22:55,320
to make guesses after UD volatilize

597
00:23:00,500 --> 00:22:57,330
these elements to make guesses about the

598
00:23:02,390 --> 00:23:00,510
mineralogy of the of the planets the

599
00:23:04,250 --> 00:23:02,400
terrestrial planets which we have a hard

600
00:23:07,370 --> 00:23:04,260
time seeing and that will be true for

601
00:23:10,400 --> 00:23:07,380
the next ten years or so so there's this

602
00:23:11,600 --> 00:23:10,410
book rare earth and i read it and i

603
00:23:13,190 --> 00:23:11,610
thought this shouldn't be called rare

604
00:23:14,840 --> 00:23:13,200
earth it should be called rare animal

605
00:23:18,409 --> 00:23:14,850
because it had to deal with all of the

606
00:23:21,049 --> 00:23:18,419
details in our history that led to the

607
00:23:24,020 --> 00:23:21,059
emergence of animals for example the KT

608
00:23:26,000 --> 00:23:24,030
in the impact at Chicxulub alright well

609
00:23:28,100 --> 00:23:26,010
that was a that's kind of rare but it's

610
00:23:29,270 --> 00:23:28,110
a very particular kind of thing that you

611
00:23:32,060 --> 00:23:29,280
know wiped out the dinosaurs and allowed

612
00:23:33,620 --> 00:23:32,070
mammalian radiation but that's not the

613
00:23:35,980 --> 00:23:33,630

type of thing that I think we should be

614
00:23:38,570 --> 00:23:35,990
talking about when we talk about the D I

615
00:23:41,090 --> 00:23:38,580
guess the important features that lead

616
00:23:42,500 --> 00:23:41,100
to the origin of life now this book does

617
00:23:44,840 --> 00:23:42,510
talk about the important features that

618
00:23:47,390 --> 00:23:44,850
lead to the origin of life and are we

619
00:23:49,159 --> 00:23:47,400
talking about rare geochemistry well I

620
00:23:50,750 --> 00:23:49,169
didn't read the whole book yet I haven't

621
00:23:52,820 --> 00:23:50,760
read it whole book yet but as far as I

622
00:23:55,580 --> 00:23:52,830
can tell there's no unobtainium

623
00:23:57,289 --> 00:23:55,590
unobtanium in this book so I was hard

624
00:23:59,930 --> 00:23:57,299
pressed to find something that is unique

625
00:24:02,600 --> 00:23:59,940
to terrestrial geochemistry so if you

626
00:24:05,690 --> 00:24:02,610
want to claim somehow that life is so

627
00:24:07,340 --> 00:24:05,700
wonderfully unique here on earth and at

628
00:24:09,830 --> 00:24:07,350
the same time you believe strongly that

629
00:24:11,630 --> 00:24:09,840
life emerged from geochemistry in the

630
00:24:14,180 --> 00:24:11,640
continuous way that Eric spit so

631
00:24:15,890 --> 00:24:14,190
eloquently described yesterday then you

632
00:24:18,650 --> 00:24:15,900
have to find something about the

633
00:24:20,690 --> 00:24:18,660
geochemistry of earth that would be

634
00:24:22,909 --> 00:24:20,700
different from the geochemistry of these

635
00:24:26,630 --> 00:24:22,919
other billions and billions of billions

636
00:24:28,190 --> 00:24:26,640
of earth-like planets now here's a just

637
00:24:30,710 --> 00:24:28,200
trying to make contact with geochemistry

638
00:24:32,419 --> 00:24:30,720

biogeochemistry is this book this

639
00:24:36,950 --> 00:24:32,429
paper that we should somebody else

640
00:24:38,720 --> 00:24:36,960
showed yesterday and here is this you

641
00:24:40,370 --> 00:24:38,730
know nice little hey these are the core

642
00:24:42,770 --> 00:24:40,380
metabolisms but what I'm trying to talk

643
00:24:45,200 --> 00:24:42,780
about is this production of h 2 co 2 h 2

644
00:24:48,200 --> 00:24:45,210
s the geochemistry from which these

645
00:24:50,510 --> 00:24:48,210
things seem to emerge spontaneously we

646
00:24:52,700 --> 00:24:50,520
have no reason to believe that rock

647
00:24:55,279 --> 00:24:52,710
rocky planets would not produce the same

648
00:24:58,690 --> 00:24:55,289
type of highly diverse geochemical

649
00:25:02,049 --> 00:24:58,700
environments that we see on earth and

650
00:25:04,760 --> 00:25:02,059
also by the way don't forget that the

651
00:25:06,890 --> 00:25:04,770
building blocks of life in these

652
00:25:08,720 --> 00:25:06,900
carbonaceous chondrites the Vino acids

653
00:25:11,680 --> 00:25:08,730
are falling from the sky and that's not

654
00:25:13,850 --> 00:25:11,690
just amino acids but that type of

655
00:25:16,430 --> 00:25:13,860
bombardment particularly the early

656
00:25:18,230 --> 00:25:16,440
bombardment that we expect that we think

657
00:25:20,899 --> 00:25:18,240
we happen on earth is something that's

658
00:25:22,310 --> 00:25:20,909
fully extrapolate able to the formation

659
00:25:25,700 --> 00:25:22,320
of rocky planets anywhere in the

660
00:25:28,250 --> 00:25:25,710
universe so I changed up the skies all

661
00:25:30,529 --> 00:25:28,260
right here's a picture of the whole

662
00:25:32,060 --> 00:25:30,539
history of the universe and here's the

663
00:25:33,740 --> 00:25:32,070

BIGBANG hydrogen helium are producing

664
00:25:35,750 --> 00:25:33,750
stars that produced this is all physics

665
00:25:37,430 --> 00:25:35,760
this is all deterministic science and

666
00:25:39,049 --> 00:25:37,440
then this conference is talking about

667
00:25:40,789 --> 00:25:39,059
the origin of life and then here's where

668
00:25:44,320 --> 00:25:40,799
you get this these living forms here

669
00:25:46,539 --> 00:25:44,330
that you can get from phylogenetic trees

670
00:25:48,230 --> 00:25:46,549
but another way to say that is a

671
00:25:50,120 --> 00:25:48,240
four-and-a-half billion years ago this

672
00:25:52,640 --> 00:25:50,130
was the Sun look like and today it

673
00:25:54,320 --> 00:25:52,650
turned into that now the question is

674
00:25:56,270 --> 00:25:54,330
we're not trying to find this is kind of

675
00:25:58,789 --> 00:25:56,280
a quirky thing and we shouldn't expect

676
00:26:01,279 --> 00:25:58,799
that elsewhere but that's what happened

677
00:26:02,330 --> 00:26:01,289
on our planet but I think in the origin

678
00:26:03,409 --> 00:26:02,340
of life community we're not interested

679
00:26:07,730 --> 00:26:03,419
in this we're interested in those

680
00:26:10,130 --> 00:26:07,740
previous core metabolisms one other

681
00:26:12,440 --> 00:26:10,140
thing is a faint early Sun paradox is a

682
00:26:14,390 --> 00:26:12,450
faint early host star problems it's not

683
00:26:17,060 --> 00:26:14,400
just a sudden problem it's a problem of

684
00:26:18,770 --> 00:26:17,070
any star why because when you saw a

685
00:26:20,750 --> 00:26:18,780
start on the zero-age main sequence and

686
00:26:22,940 --> 00:26:20,760
you can see in this regime what happens

687
00:26:25,159 --> 00:26:22,950
to them they go up up up up up up up so

688
00:26:26,600 --> 00:26:25,169

they start faint that's as luminosity

689
00:26:30,980 --> 00:26:26,610
over here they start faint and then

690
00:26:33,230 --> 00:26:30,990
increase so faint faint early host star

691
00:26:35,750 --> 00:26:33,240
problem is something that's universal it

692
00:26:38,440 --> 00:26:35,760
has to do with your evolving off the

693
00:26:41,060 --> 00:26:38,450
main sequence that's every star does

694
00:26:44,360 --> 00:26:41,070
then there's this orbit matters problem

695
00:26:47,900 --> 00:26:44,370
so here's the habitable zone here and

696
00:26:50,030 --> 00:26:47,910
I and we wrote a paper called the case

697
00:26:52,760 --> 00:26:50,040
for a guy in bottleneck biology /

698
00:26:54,950 --> 00:26:52,770
habitability and in it essentially when

699
00:26:56,390 --> 00:26:54,960
you see these habitable zone plots this

700
00:26:58,400 --> 00:26:56,400
as though from here to here is kind of

701
00:27:00,920 --> 00:26:58,410
habitable what does that mean in your

702
00:27:02,750 --> 00:27:00,930
head you're doing this we have here's

703
00:27:04,400 --> 00:27:02,760
the habitable zone here's our planet

704
00:27:06,920 --> 00:27:04,410
it's in a habitable zone and then we

705
00:27:08,900 --> 00:27:06,930
have some type of supporting our

706
00:27:11,480 --> 00:27:08,910
negative feedback that maintains this

707
00:27:13,100 --> 00:27:11,490
planet up here in high habitability if

708
00:27:14,810 --> 00:27:13,110
you go over here you get rotary

709
00:27:17,080 --> 00:27:14,820
glaciation you're too cold too far away

710
00:27:21,200 --> 00:27:17,090
here is runaway greenhouse too hot and

711
00:27:23,180 --> 00:27:21,210
because of the walker paper 1981 we have

712
00:27:25,160 --> 00:27:23,190
we invoke silicate weathering negative

713
00:27:27,620 --> 00:27:25,170

feedback the strength of that negative

714
00:27:29,840 --> 00:27:27,630
feedback is what produces these ridges

715
00:27:32,630 --> 00:27:29,850
here and produces the width of that

716
00:27:33,919 --> 00:27:32,640
habitable zone now it's also something

717
00:27:36,230 --> 00:27:33,929
like everybody's body hidden here is

718
00:27:38,330 --> 00:27:36,240
like 37 degrees plus or minus point five

719
00:27:39,950 --> 00:27:38,340
or so and that thermal regulation is

720
00:27:41,690 --> 00:27:39,960
something that has evolved and it's the

721
00:27:43,310 --> 00:27:41,700
same type of thing here's 37 you get too

722
00:27:44,900 --> 00:27:43,320
high we got pull it back get too low

723
00:27:46,310 --> 00:27:44,910
pull it back but then if it gets really

724
00:27:48,380 --> 00:27:46,320
really too hot Brooke you're turning the

725
00:27:50,930 --> 00:27:48,390
meat here you turn to meet as well so

726
00:27:53,180 --> 00:27:50,940
you die now it might be the case that in

727
00:27:55,010 --> 00:27:53,190
the first billion years I could not find

728
00:27:56,810 --> 00:27:55,020
any justification for negative feedback

729
00:27:58,970 --> 00:27:56,820
from silicate weathering if that's the

730
00:28:01,610 --> 00:27:58,980
case then instead of this picture you

731
00:28:04,700 --> 00:28:01,620
have this picture where there is no

732
00:28:06,950 --> 00:28:04,710
stability there at all you have runaway

733
00:28:08,720 --> 00:28:06,960
greenhouse runaway glaciation too hot

734
00:28:10,490 --> 00:28:08,730
too cold there is no negative feedback

735
00:28:13,280 --> 00:28:10,500
and you have no width at all of the

736
00:28:15,140 --> 00:28:13,290
habitable zone so instead of saying that

737
00:28:18,160 --> 00:28:15,150
not only is the apples on strongly

738
00:28:20,720 --> 00:28:18,170

atmosphere dependent it may very well be

739
00:28:23,240 --> 00:28:20,730
biology dependent because biology is

740
00:28:25,730 --> 00:28:23,250
something that does create these types

741
00:28:29,060 --> 00:28:25,740
of wells as your body is doing right now

742
00:28:30,440 --> 00:28:29,070
in this room okay cars don't stay on the

743
00:28:33,620 --> 00:28:30,450
road without a driver planets don't

744
00:28:36,290 --> 00:28:33,630
remain habitable without life so here's

745
00:28:38,180 --> 00:28:36,300
these no lovely trees and I guess I

746
00:28:39,770 --> 00:28:38,190
wanted to say is you go back in time but

747
00:28:41,840 --> 00:28:39,780
you go back further and further towards

748
00:28:43,340 --> 00:28:41,850
these roots the tree of life you are

749
00:28:44,630 --> 00:28:43,350
talking about things that are coming

750
00:28:46,790 --> 00:28:44,640
more and more closely related to

751
00:28:49,220 --> 00:28:46,800
geochemistry and that geochemistry as

752
00:28:51,350 --> 00:28:49,230
far as I can tell is not different from

753
00:28:53,240 --> 00:28:51,360
the geochemistry of rocky planets that

754
00:28:56,240 --> 00:28:53,250
seemed to be everywhere in the universe

755
00:28:57,919 --> 00:28:56,250
so conclusions lots of Earth but not a

756
00:29:00,649 --> 00:28:57,929
lot of Japan's or kangaroo

757
00:29:03,350 --> 00:29:00,659
to the parameter space of geochemistry

758
00:29:05,419 --> 00:29:03,360
that led to life on Earth to the extent

759
00:29:08,029 --> 00:29:05,429
to which we understand it does not look

760
00:29:11,810 --> 00:29:08,039
like a sparsely populated region of EXO

761
00:29:13,159 --> 00:29:11,820
geochemistry 3r as we understand more

762
00:29:15,169 --> 00:29:13,169
about Luca and the origin of life on

763
00:29:17,060 --> 00:29:15,179

Earth our biology is linking up the

764
00:29:19,340 --> 00:29:17,070
geochemistry and is becoming more

765
00:29:21,680 --> 00:29:19,350
extrapolate able to the origin of life

766
00:29:23,539 --> 00:29:21,690
elsewhere one way to say that as early

767
00:29:26,690 --> 00:29:23,549
biogeochemistry is more Universal than

768
00:29:28,669 --> 00:29:26,700
current biogeochemistry ie kangaroos we

769
00:29:30,769 --> 00:29:28,679
should expect life elsewhere but it is

770
00:29:33,889 --> 00:29:30,779
probably dead according to the guy in

771
00:29:35,570 --> 00:29:33,899
bottleneck hypothesis and here's the

772
00:29:37,159 --> 00:29:35,580
chicken and egg problem is that this is

773
00:29:40,279 --> 00:29:37,169
the oxygen problem for this is a blow-up

774
00:29:42,619 --> 00:29:40,289
of a chicken egg and you could see it

775
00:29:44,480 --> 00:29:42,629
can let oxygen in and out that's it the

776
00:29:45,560 --> 00:29:44,490
egg problem here's the chicken problem

777
00:29:50,019 --> 00:29:45,570
trying to get that egg through the

778
00:29:53,239 --> 00:29:50,029
pelvis and chicken the egg problem now

779
00:29:54,950 --> 00:29:53,249
with one more commented that Eric Smith

780
00:29:56,899 --> 00:29:54,960
talked about rampant inappropriate

781
00:29:59,779 --> 00:29:56,909
dichotomies that's probably a Miss

782
00:30:02,149 --> 00:29:59,789
misquote but anyway I feel to that where

783
00:30:04,159 --> 00:30:02,159
we have we suffer from rampant

784
00:30:05,690 --> 00:30:04,169
inappropriate dichotomies in I guess the

785
00:30:07,369 --> 00:30:05,700
reason for that is this brain we have

786
00:30:09,109 --> 00:30:07,379
you can see it's bilaterally symmetric

787
00:30:10,999 --> 00:30:09,119
so we got dichotomy right here with the

788
00:30:12,919 --> 00:30:11,009

organ that we're using to find it and I

789
00:30:14,450 --> 00:30:12,929
also you can see that is why we can't

790
00:30:16,700 --> 00:30:14,460
smell little because a tiny tiny

791
00:30:19,399 --> 00:30:16,710
olfactory lobes that we have compared to

792
00:30:21,350 --> 00:30:19,409
most everything else and thank you very

793
00:30:22,820 --> 00:30:21,360
much and I think the big bang for making

794
00:30:28,440 --> 00:30:22,830
this research puzzle

795
00:30:37,930 --> 00:30:33,550
alright so time for questions nobody's

796
00:30:47,080 --> 00:30:37,940
stirred up by yet by the book right Eric

797
00:30:50,680 --> 00:30:47,090
by the book it's good books yes Charlie

798
00:30:52,870 --> 00:30:50,690
I'm glad you're still having fun all

799
00:30:56,350 --> 00:30:52,880
right these are you Joel aren't you yes

800
00:30:58,540 --> 00:30:56,360
I am actually the real question is okay

801
00:31:02,380 --> 00:30:58,550
for Arjun of life that's fun that means

802
00:31:05,380 --> 00:31:02,390
slime or something you think that the

803
00:31:08,740 --> 00:31:05,390
rest of the life is dead then why aren't

804
00:31:12,520 --> 00:31:08,750
we right so the question therefore so in

805
00:31:15,220 --> 00:31:12,530
this in this paper we have said you know

806
00:31:17,560 --> 00:31:15,230
what without without this negative

807
00:31:21,100 --> 00:31:17,570
feedback the earth and every other rocky

808
00:31:22,150 --> 00:31:21,110
planets this is what we expect now it's

809
00:31:24,280 --> 00:31:22,160
the reason it's called the guy in

810
00:31:26,860 --> 00:31:24,290
bottleneck is because we're saying well

811
00:31:29,200 --> 00:31:26,870
how do we get out of that and the ant we

812
00:31:31,960 --> 00:31:29,210
think the answer is that occasionally

813
00:31:34,150 --> 00:31:31,970

there is a planet that has life that

814
00:31:36,550 --> 00:31:34,160
figures out how to control the albedo or

815
00:31:38,890 --> 00:31:36,560
how to control the greenhouse gases and

816
00:31:40,000 --> 00:31:38,900
when it does that successfully it sound

817
00:31:42,130 --> 00:31:40,010
like random variation when it does that

818
00:31:44,680 --> 00:31:42,140
successfully bump outcomes life and it

819
00:31:46,720 --> 00:31:44,690
starts to build these things and then we

820
00:31:49,180 --> 00:31:46,730
have a habitable zone so habitability

821
00:31:50,500 --> 00:31:49,190
kind of like you just like any

822
00:31:51,610 --> 00:31:50,510
life-forms anything how do you get an

823
00:31:53,170 --> 00:31:51,620
eyeball you have a whole bunch of people

824
00:31:54,970 --> 00:31:53,180
most of them can't see but one that

825
00:31:55,930 --> 00:31:54,980
survives the one that can see you get a

826
00:31:59,260 --> 00:31:55,940
whole bunch of planets that are like

827
00:32:01,030 --> 00:31:59,270
this randomly you have some biology that

828
00:32:04,960 --> 00:32:01,040
figures that doesn't figure it out but

829
00:32:06,820 --> 00:32:04,970
it happens to control the greenhouse in

830
00:32:11,560 --> 00:32:06,830
a way that that makes this little flat

831
00:32:16,180 --> 00:32:11,570
and then Darwinian selection that's how

832
00:32:18,550 --> 00:32:16,190
I would say it's not something that yeah

833
00:32:20,260 --> 00:32:18,560
debt before the first billion years or

834
00:32:22,540 --> 00:32:20,270
so or maybe the first half a billion

835
00:32:24,010 --> 00:32:22,550
m-pin because glaciation goes sound like

836
00:32:30,700 --> 00:32:24,020
everything becomes a venusaur everything

837
00:32:40,509 --> 00:32:30,710
becomes a Mars that's right but the

838
00:32:47,210 --> 00:32:43,669

so I want to ask a kind of a Larry

839
00:32:50,539 --> 00:32:47,220
Henderson question charlie not as he

840
00:32:53,720 --> 00:32:50,549
would ask it but so Henderson starts out

841
00:32:55,549 --> 00:32:53,730
by saying that blood pH would have to be

842
00:32:57,529 --> 00:32:55,559
a lot more heavily actively regulated

843
00:32:59,149 --> 00:32:57,539
than it is except that it happens to

844
00:33:01,759 --> 00:32:59,159
occupy region where you have a carbonate

845
00:33:04,190 --> 00:33:01,769
buffer or a bicarbonate buffer so in

846
00:33:08,060 --> 00:33:04,200
some sense the fact that blood is where

847
00:33:10,430 --> 00:33:08,070
it is should have enabled us to look in

848
00:33:12,590 --> 00:33:10,440
the phase space of dissolved gases and

849
00:33:14,060 --> 00:33:12,600
fluids for the places where buffering

850
00:33:16,759 --> 00:33:14,070
was easy because that would be a kind of

851
00:33:19,610 --> 00:33:16,769
a path of least resistance if I think

852
00:33:21,919 --> 00:33:19,620
about this question of Runaways and

853
00:33:25,899 --> 00:33:21,929
whether the hill really is an inverted

854
00:33:28,430 --> 00:33:25,909
parabola that way is there a kind of an

855
00:33:30,799 --> 00:33:28,440
anthropic argument that where you see a

856
00:33:33,320 --> 00:33:30,809
biosphere there may have been

857
00:33:35,080 --> 00:33:33,330
stabilizing effect on the planet even if

858
00:33:37,250 --> 00:33:35,090
your current modeling sophistication

859
00:33:40,399 --> 00:33:37,260
doesn't make you aware of where they are

860
00:33:41,930 --> 00:33:40,409
sure sure in other words just like hey

861
00:33:44,960 --> 00:33:41,940
Charlie these parabola they probably

862
00:33:46,850 --> 00:33:44,970
have different shapes yeah sure but

863
00:33:48,379 --> 00:33:46,860

there's what my whole point is that

864
00:33:49,940 --> 00:33:48,389
people have just swallowed this

865
00:33:51,169 --> 00:33:49,950
canonical model up hey there's a

866
00:33:53,269 --> 00:33:51,179
habitable zone when your the right

867
00:33:56,690 --> 00:33:53,279
distance and not only is it the

868
00:33:59,509 --> 00:33:56,700
atmosphere but i think the inhabitants

869
00:34:02,600 --> 00:33:59,519
may play a very important role in how

870
00:34:05,000 --> 00:34:02,610
wide that is or where it is certainly

871
00:34:07,279 --> 00:34:05,010
but lots of variability i mean i'm not

872
00:34:08,659 --> 00:34:07,289
claiming that i can know where this is

873
00:34:09,800 --> 00:34:08,669
I'm just saying I that's some type of

874
00:34:11,990 --> 00:34:09,810
instability this way some type of

875
00:34:13,430 --> 00:34:12,000
instability this way the canonical view

876
00:34:15,680 --> 00:34:13,440
has been oh there's a region of

877
00:34:17,480 --> 00:34:15,690
stability here I said well is that true

878
00:34:20,480 --> 00:34:17,490
do we need to have that do we have that

879
00:34:22,849 --> 00:34:20,490
and maybe not and that stability is

880
00:34:24,889 --> 00:34:22,859
usually based on this which we are

881
00:34:26,270 --> 00:34:24,899
pretty sure is not very strong in the

882
00:34:29,210 --> 00:34:26,280
first billion years that's the argument

883
00:34:30,770 --> 00:34:29,220
there I mean Adi chopra the lead author

884
00:34:33,829 --> 00:34:30,780
of this paper will be talking about this

885
00:34:39,749 --> 00:34:33,839
I guess on Tuesday or something in a

886
00:35:00,160 --> 00:34:42,909
more comments questions we've got plenty

887
00:35:03,039 --> 00:35:00,170
of time yes just a why do you think

888
00:35:05,200 --> 00:35:03,049

because life appear rapidly on earth

889
00:35:06,279 --> 00:35:05,210
then this should be life every way just

890
00:35:08,589 --> 00:35:06,289
means that the current when the

891
00:35:11,859 --> 00:35:08,599
conditions are there then life curiosity

892
00:35:13,690 --> 00:35:11,869
I I guess I've been semi convinced by

893
00:35:16,150 --> 00:35:13,700
Eric's argument to some extent that

894
00:35:18,339 --> 00:35:16,160
saying the origin of life is that in or

895
00:35:20,559 --> 00:35:18,349
what if a cascade of phase transitions

896
00:35:23,589 --> 00:35:20,569
which are very closely related to the

897
00:35:25,210 --> 00:35:23,599
sources of energy and that well for

898
00:35:28,059 --> 00:35:25,220
example is a redox potential that you

899
00:35:29,769 --> 00:35:28,069
have and I don't in reading this book as

900
00:35:32,309 --> 00:35:29,779
closely as I have I don't see any reason

901
00:35:34,930 --> 00:35:32,319
to think that the structure the

902
00:35:36,819 --> 00:35:34,940
mechanism that he has described have

903
00:35:38,470 --> 00:35:36,829
anything to do necessarily with earth

904
00:35:40,779 --> 00:35:38,480
the uniqueness of Earth that's why I

905
00:35:44,229 --> 00:35:40,789
said there's no unobtanium in that book

906
00:35:46,089 --> 00:35:44,239
so if that's the case and the origin of

907
00:35:49,839 --> 00:35:46,099
life is connected to geo chemistry's and

908
00:35:51,249 --> 00:35:49,849
we I think the the geochemical parameter

909
00:35:54,489 --> 00:35:51,259
space although could be very wide

910
00:35:56,170 --> 00:35:54,499
there's no reason why it should be that

911
00:35:59,650 --> 00:35:56,180
that space should be sparsely populated

912
00:36:01,660 --> 00:35:59,660
where the earth is if the earth had

913
00:36:03,819 --> 00:36:01,670

unobtainium and that was important for

914
00:36:06,579 --> 00:36:03,829
earth then we would I wouldn't be able

915
00:36:08,559 --> 00:36:06,589
to say that but air all the elements all

916
00:36:11,140 --> 00:36:08,569
of the redox potential all of the hey

917
00:36:14,410 --> 00:36:11,150
central heat cool lumination here

918
00:36:16,539 --> 00:36:14,420
phototrophs autotrophs that i don't see

919
00:36:18,670 --> 00:36:16,549
any reason why that should be perfectly

920
00:36:20,380 --> 00:36:18,680
extrapolate able to these other billions

921
00:36:25,930 --> 00:36:20,390
and billions and billions of other

922
00:36:32,670 --> 00:36:25,940
Earth's that's the reasoning yes we have

923
00:36:37,300 --> 00:36:35,050
try that was a really entertaining talk

924
00:36:41,230 --> 00:36:37,310
I couldn't tweet fast enough I was

925
00:36:43,210 --> 00:36:41,240
having fun so mark mentioned that plate

926
00:36:45,910 --> 00:36:43,220
mechanic hershman Marshall jellineck

927
00:36:48,160 --> 00:36:45,920
mentioned that plate tectonics enhances

928
00:36:49,720 --> 00:36:48,170
habitability and your presentation you

929
00:36:53,050 --> 00:36:49,730
mentioned that life enhances

930
00:36:55,450 --> 00:36:53,060
habitability so does life enhance plate

931
00:36:58,330 --> 00:36:55,460
tectonics well I think rosing is written

932
00:37:00,220 --> 00:36:58,340
a paper on that and I kind of a rosing

933
00:37:01,810 --> 00:37:00,230
kind of guy but I'm unqualified to

934
00:37:05,650 --> 00:37:01,820
comment on that beyond the literature

935
00:37:07,360 --> 00:37:05,660
that you can find elsewhere why not you

936
00:37:09,640 --> 00:37:07,370
know I think one another paper by

937
00:37:12,790 --> 00:37:09,650
Harding in and margules you know Lynn

938
00:37:15,280 --> 00:37:12,800

Margot's they mentioned how what is life

939
00:37:16,720 --> 00:37:15,290
what has life's role been in maintaining

940
00:37:18,490 --> 00:37:16,730
water at the surface of the planet

941
00:37:20,920 --> 00:37:18,500
something that's usually not invoked

942
00:37:22,660 --> 00:37:20,930
it's a kind of guy in paper it's not the

943
00:37:25,150 --> 00:37:22,670
greatest paper but it is one of the few

944
00:37:27,610 --> 00:37:25,160
spaces the only paper I've seen trying

945
00:37:29,530 --> 00:37:27,620
to connect the role of life in

946
00:37:32,500 --> 00:37:29,540
maintaining liquid on the surface of the

947
00:37:33,760 --> 00:37:32,510
earth if they're correct then it's a

948
00:37:34,810 --> 00:37:33,770
really important thing because we don't

949
00:37:37,450 --> 00:37:34,820
have to look for chemical disequilibrium

950
00:37:39,910 --> 00:37:37,460
to see life all we'd look for is like

951
00:37:42,190 --> 00:37:39,920
water on the surface no life did it I'm

952
00:37:43,900 --> 00:37:42,200
not sure how strong that connection is

953
00:37:50,980 --> 00:37:43,910
but it's certainly one that's plausible

954
00:37:52,690 --> 00:37:50,990
and I think it should be looked at I'm

955
00:37:54,160 --> 00:37:52,700
curious it's convenient that this slide

956
00:37:55,660 --> 00:37:54,170
is up I'm curious as to why you say that

957
00:37:57,970 --> 00:37:55,670
there's no silicate weathering in the

958
00:37:59,800 --> 00:37:57,980
first billion years I'm thinking about a

959
00:38:01,810 --> 00:37:59,810
set of observations that perhaps are

960
00:38:04,000 --> 00:38:01,820
underappreciated about the inclusions in

961
00:38:06,070 --> 00:38:04,010
the jack hill zircons where the most

962
00:38:08,550 --> 00:38:06,080
common minerals in the jack hills or

963
00:38:12,130 --> 00:38:08,560

comes included in them our courts

964
00:38:14,590 --> 00:38:12,140
muscovite and albeit feldspar and that's

965
00:38:16,000 --> 00:38:14,600
an assemblage that is something you have

966
00:38:17,500 --> 00:38:16,010
to take a couple steps backward but

967
00:38:19,450 --> 00:38:17,510
that's an assemblage that is

968
00:38:22,090 --> 00:38:19,460
characteristic of so-called s-type

969
00:38:23,950 --> 00:38:22,100
grants which are partial melts of a

970
00:38:25,330 --> 00:38:23,960
luminous rich sediments which are

971
00:38:27,190 --> 00:38:25,340
themselves the product of silicate

972
00:38:29,140 --> 00:38:27,200
weathering so I think within the jack

973
00:38:30,420 --> 00:38:29,150
hill zircons we have evidence and this

974
00:38:33,340 --> 00:38:30,430
goes all the way back to the most the

975
00:38:34,810 --> 00:38:33,350
oldest of the Jackals are comes we have

976
00:38:36,820 --> 00:38:34,820
evidence that in fact there was silicate

977
00:38:38,860 --> 00:38:36,830
weathering early on this planet right I

978
00:38:41,680 --> 00:38:38,870
guess the question should be really

979
00:38:44,920 --> 00:38:41,690
instead of yes or no it's how much and I

980
00:38:47,500 --> 00:38:44,930
think the literature says that

981
00:38:49,690 --> 00:38:47,510
continental when you look at the 20

982
00:38:52,390 --> 00:38:49,700
plots of the increase of continental

983
00:38:55,960 --> 00:38:52,400
crust you will see most of them going

984
00:38:57,849 --> 00:38:55,970
very low as you get to 3.5 3.7 billion

985
00:38:59,859 --> 00:38:57,859
years ago I'm sure you're right that

986
00:39:03,130 --> 00:38:59,869
there's some type of silicon weathering

987
00:39:04,720 --> 00:39:03,140
going on the question is the this the

988
00:39:06,819 --> 00:39:04,730

strengths of the negative feedback is

989
00:39:08,349 --> 00:39:06,829
proportional to I guess the strength of

990
00:39:10,720 --> 00:39:08,359
the facility weathering and that has to

991
00:39:13,329 --> 00:39:10,730
go down as you're getting much much less

992
00:39:15,339 --> 00:39:13,339
sub aerial erosion of those continental

993
00:39:17,740 --> 00:39:15,349
crust that's how I would argue and I

994
00:39:20,920 --> 00:39:17,750
shouldn't say no I should say very

995
00:39:22,329 --> 00:39:20,930
little it turns down the strength of the

996
00:39:24,700 --> 00:39:22,339
negative feedback and when you do that

997
00:39:27,160 --> 00:39:24,710
this habitable zone which gets smaller

998
00:39:39,309 --> 00:39:27,170
and probably these these hills get

999
00:39:41,819 --> 00:39:39,319
smaller to dr. Q civil comments or this

1000
00:39:44,680 --> 00:39:41,829
figure you say no silicate weathering

1001
00:39:48,130 --> 00:39:44,690
but you know that you must consider that

1002
00:39:50,710 --> 00:39:48,140
amount of auction so if no continent

1003
00:39:52,809 --> 00:39:50,720
available and then no way for silicate

1004
00:39:54,280 --> 00:39:52,819
weathering no sub aerial silicate

1005
00:39:56,470 --> 00:39:54,290
weathering Yeah right there is there are

1006
00:39:58,150 --> 00:39:56,480
some people have looked at sub aqueous

1007
00:39:59,500 --> 00:39:58,160
silicate weathering again the two

1008
00:40:01,420 --> 00:39:59,510
problems they are selfie although

1009
00:40:03,940 --> 00:40:01,430
mountains are smaller how strong is it

1010
00:40:06,400 --> 00:40:03,950
and plus remember it has to be cuddled

1011
00:40:07,480 --> 00:40:06,410
it has to be negative feedback you can

1012
00:40:10,089 --> 00:40:07,490
have weathering but if it's not

1013
00:40:12,640 --> 00:40:10,099

negatively fed back you do not get this

1014
00:40:14,710 --> 00:40:12,650
type of stabilization yeah but possible

1015
00:40:17,859 --> 00:40:14,720
for example that it is difficult to have

1016
00:40:20,230 --> 00:40:17,869
a okay oceanfront it's difficult have an

1017
00:40:22,089 --> 00:40:20,240
ocean planet viola maybe if you give up

1018
00:40:25,120 --> 00:40:22,099
a huge amount of carbon Direction a lot

1019
00:40:29,079 --> 00:40:25,130
you must transport atmospheric carbon

1020
00:40:31,180 --> 00:40:29,089
dioxide into the mantle and also but

1021
00:40:33,609 --> 00:40:31,190
anyway so that therefore the size of

1022
00:40:35,500 --> 00:40:33,619
random ass is another important key so

1023
00:40:38,200 --> 00:40:35,510
you can extend the idea and just I'm

1024
00:40:41,859 --> 00:40:38,210
going to give up to reconnect yeah so

1025
00:40:44,680 --> 00:40:41,869
then also the fate / h 2 or ocean

1026
00:40:47,440 --> 00:40:44,690
through time because there are pretty

1027
00:40:50,079 --> 00:40:47,450
astronics can deliver subtle change the

1028
00:40:52,780 --> 00:40:50,089
mantle even for the earth the mantle

1029
00:40:54,510 --> 00:40:52,790
transition from can occupy more than our

1030
00:40:57,630 --> 00:40:54,520
five times or portal all challenges are

1031
00:40:59,940 --> 00:40:57,640
so there it depends on the time

1032
00:41:01,799 --> 00:40:59,950
oh that and therefore i'm just going to

1033
00:41:04,200 --> 00:41:01,809
deliver a kind of otherwise to extend

1034
00:41:07,380 --> 00:41:04,210
you are idea how long habit i was going

1035
00:41:09,390 --> 00:41:07,390
continue yeah well the i think there is

1036
00:41:12,029 --> 00:41:09,400
no original habit was on the width of

1037
00:41:15,720 --> 00:41:12,039
the habitable zone in this plot should

1038
00:41:17,670 --> 00:41:15,730

go to 0 here is one way to look at what

1039
00:41:22,470 --> 00:41:17,680
i just said if this hypothesis is

1040
00:41:24,599 --> 00:41:22,480
correct again well since we actually are

1041
00:41:26,309 --> 00:41:24,609
ahead of schedule and mark who are their

1042
00:41:34,559 --> 00:41:26,319
previous speaker has a question go ahead

1043
00:41:36,690 --> 00:41:34,569
and get the nice oh here we go that's

1044
00:41:40,529 --> 00:41:36,700
more common about sea floor weathering

1045
00:41:42,059 --> 00:41:40,539
so the issue is whether weathering or

1046
00:41:44,309 --> 00:41:42,069
flow through hydrothermal systems

1047
00:41:48,059 --> 00:41:44,319
produces a net flux of alkalinity

1048
00:41:51,539 --> 00:41:48,069
cations and the current ocean it's not

1049
00:41:53,930 --> 00:41:51,549
that the question is whether that is is

1050
00:41:56,339 --> 00:41:53,940
when you increase the temperature it

1051
00:41:58,859 --> 00:41:56,349
increases right it's not only what the

1052
00:42:00,870 --> 00:41:58,869
process that has to be coupled oh yes

1053
00:42:02,789 --> 00:42:00,880
sir I mean coogan has shown that there

1054
00:42:06,749 --> 00:42:02,799
is a temperature coupling true than

1055
00:42:09,180 --> 00:42:06,759
Mesozoic certainly and about at least in

1056
00:42:12,180 --> 00:42:09,190
the modern notion about forty percent of

1057
00:42:14,309 --> 00:42:12,190
the current CEO too long long-term co2

1058
00:42:16,650 --> 00:42:14,319
budget is controlled by low temperature

1059
00:42:18,299 --> 00:42:16,660
by weathering and low temperature

1060
00:42:20,519 --> 00:42:18,309
hydrothermal systems but it has to be

1061
00:42:23,130 --> 00:42:20,529
coupled it does when you heat up the

1062
00:42:24,870 --> 00:42:23,140
surface by two degrees does that change

1063
00:42:26,309 --> 00:42:24,880

the surface the bottom of the ocean

1064
00:42:27,900 --> 00:42:26,319
temperature by two degrees oh yes so if

1065
00:42:29,819 --> 00:42:27,910
you look at the difference if you look

1066
00:42:32,579 --> 00:42:29,829
at the proxies for the Pacific and

1067
00:42:33,809 --> 00:42:32,589
Atlantic Basin bottom water temperatures

1068
00:42:36,480 --> 00:42:33,819
now and through the end into the

1069
00:42:37,769 --> 00:42:36,490
Mesozoic the Mesozoic was six or eight

1070
00:42:39,990 --> 00:42:37,779
degrees warmer than now for a hundred

1071
00:42:41,670 --> 00:42:40,000
million years the bottom water

1072
00:42:43,740 --> 00:42:41,680
temperature was about between two and

1073
00:42:45,569 --> 00:42:43,750
six degrees warmer than now and the

1074
00:42:49,349 --> 00:42:45,579
weathering efficiency was much much

1075
00:42:51,509 --> 00:42:49,359
higher and so about weathering officials

1076
00:42:52,950 --> 00:42:51,519
you mean carbonate deposit the prettiest

1077
00:42:54,690 --> 00:42:52,960
the production of carbonate but also the

1078
00:42:57,720 --> 00:42:54,700
net flux about validity back into the

1079
00:42:59,249 --> 00:42:57,730
ocean because you can unless you produce

1080
00:43:02,819 --> 00:42:59,259
the flux of alkalinity back into the

1081
00:43:04,920 --> 00:43:02,829
ocean it doesn't matter so there's a

1082
00:43:08,190 --> 00:43:04,930
temperature component and also the

1083
00:43:11,410 --> 00:43:08,200
strength of the of the flux of water

1084
00:43:16,630 --> 00:43:14,380
is higher it made the slow spreading

1085
00:43:18,819 --> 00:43:16,640
rates which are more likely early on

1086
00:43:22,120 --> 00:43:18,829
right so what we'd really like to

1087
00:43:24,700 --> 00:43:22,130
evaluate this is a plot of silicate

1088
00:43:26,920 --> 00:43:24,710

weathering sub aerial or sub aqueous or

1089
00:43:28,960 --> 00:43:26,930
wherever as a function of four and a

1090
00:43:32,230 --> 00:43:28,970
half billion years and then that would

1091
00:43:33,730 --> 00:43:32,240
be and make sure that we have then we

1092
00:43:36,460 --> 00:43:33,740
have a coupling constant that multiplies

1093
00:43:39,309 --> 00:43:36,470
that and then we could address this

1094
00:43:41,200 --> 00:43:39,319
issue I can show you one after your talk

1095
00:43:45,220 --> 00:43:41,210
if you want okay oh you have one that's

1096
00:43:48,309 --> 00:43:45,230
good now the co-author of the Sabre ID

1097
00:43:52,210 --> 00:43:48,319
back there would has a comment did I say

1098
00:43:55,930 --> 00:43:52,220
something wrong ID yeah can you wait for

1099
00:43:58,780 --> 00:43:55,940
the microphone thank you so I had a chat

1100
00:44:02,620 --> 00:43:58,790
to Lawrence Coogan about this exactly

1101
00:44:04,750 --> 00:44:02,630
and he wouldn't be comfortable invoking

1102
00:44:06,910 --> 00:44:04,760
the process that was that he's

1103
00:44:08,559 --> 00:44:06,920
identified in the Mesozoic going back

1104
00:44:10,120 --> 00:44:08,569
three billion years ago even four

1105
00:44:12,460 --> 00:44:10,130
billion years ago and part of the

1106
00:44:15,190 --> 00:44:12,470
challenges that communication between

1107
00:44:17,410 --> 00:44:15,200
the surface temperature of the oceans

1108
00:44:21,280 --> 00:44:17,420
down to bottom water temperature is not

1109
00:44:24,339 --> 00:44:21,290
a strong well understood one and the

1110
00:44:26,410 --> 00:44:24,349
other point he made was even if there's

1111
00:44:28,809 --> 00:44:26,420
active there's some communication going

1112
00:44:31,270 --> 00:44:28,819
on it's the total amount of weathering

1113
00:44:32,589 --> 00:44:31,280

he thinks is not going to be sufficient

1114
00:44:35,380 --> 00:44:32,599
to provide a big enough negative

1115
00:44:37,299 --> 00:44:35,390
feedback the other thing to consider is

1116
00:44:39,160 --> 00:44:37,309
you know back then because of impacts

1117
00:44:41,319 --> 00:44:39,170
and greater volcanism you could have the

1118
00:44:44,260 --> 00:44:41,329
earth going back and forth between you

1119
00:44:46,359 --> 00:44:44,270
know greenhouse dominated or glaciation

1120
00:44:51,190 --> 00:44:46,369
dominated events in the Hadean or

1121
00:44:52,960 --> 00:44:51,200
Canadian as well ok we'll do one more

1122
00:44:57,490 --> 00:44:52,970
question and then we'll start the flesh

1123
00:45:03,840 --> 00:44:57,500
talks so we need a okay come over here

1124
00:45:07,500 --> 00:45:05,970
and I just wanted to ask for the

1125
00:45:09,000 --> 00:45:07,510
temperature at the bottom of the ocean

1126
00:45:11,220 --> 00:45:09,010
do you take into consideration the

1127
00:45:14,160 --> 00:45:11,230
thermohaline circulation or something

1128
00:45:16,610 --> 00:45:14,170
that happens at that era so the buoyancy

1129
00:45:18,870 --> 00:45:16,620
driven part of the ocean circulation

1130
00:45:20,520 --> 00:45:18,880
that's the issue that Adi was just

1131
00:45:22,170 --> 00:45:20,530
talking about it he's much more formed

1132
00:45:26,040 --> 00:45:22,180
about it than I do so I recommend you go

1133
00:45:28,230 --> 00:45:26,050
talk to Eddie about that history ok with

1134
00:45:30,270 --> 00:45:28,240
that we will start our flash talk for

1135
00:45:31,470 --> 00:45:30,280
this session yeah but thank the speaker

1136
00:45:33,120 --> 00:45:31,480
again

1137
00:45:45,450 --> 00:45:33,130
[Applause]

1138
00:45:49,600 --> 00:45:48,320

[Music]

1139
00:46:21,750 --> 00:45:49,610
you