Panelists

Attendees (9)

- Hosts (1)
  - Mike Toillion
- Presenters (3)
  - Andy Burnett
  - Penny Boston
  - Rory Barnes
- Participants (5)
  - Alycia Weinberger & ...
  - ASU - Anbar
  - DanShim
  - Lindsay Hays
  - Pauli Laine

Open Chat (Everyone)

---------- (01/29/2014 10:54) ----------

Mike Toillion: Welcome! For audio, please dial into the teleconference line listed below. Thanks!

---------- (01/29/2014 11:12) ----------

Mike Toillion: Just a friendly reminder: when not speaking, please mute your phone by pushing * 6 on your dial pad. When you wish to speak, simply push * 6 again. Thanks!

---------- (01/29/2014 11:14) ----------

Penny Boston: Mike I'm back in but have no webcam button

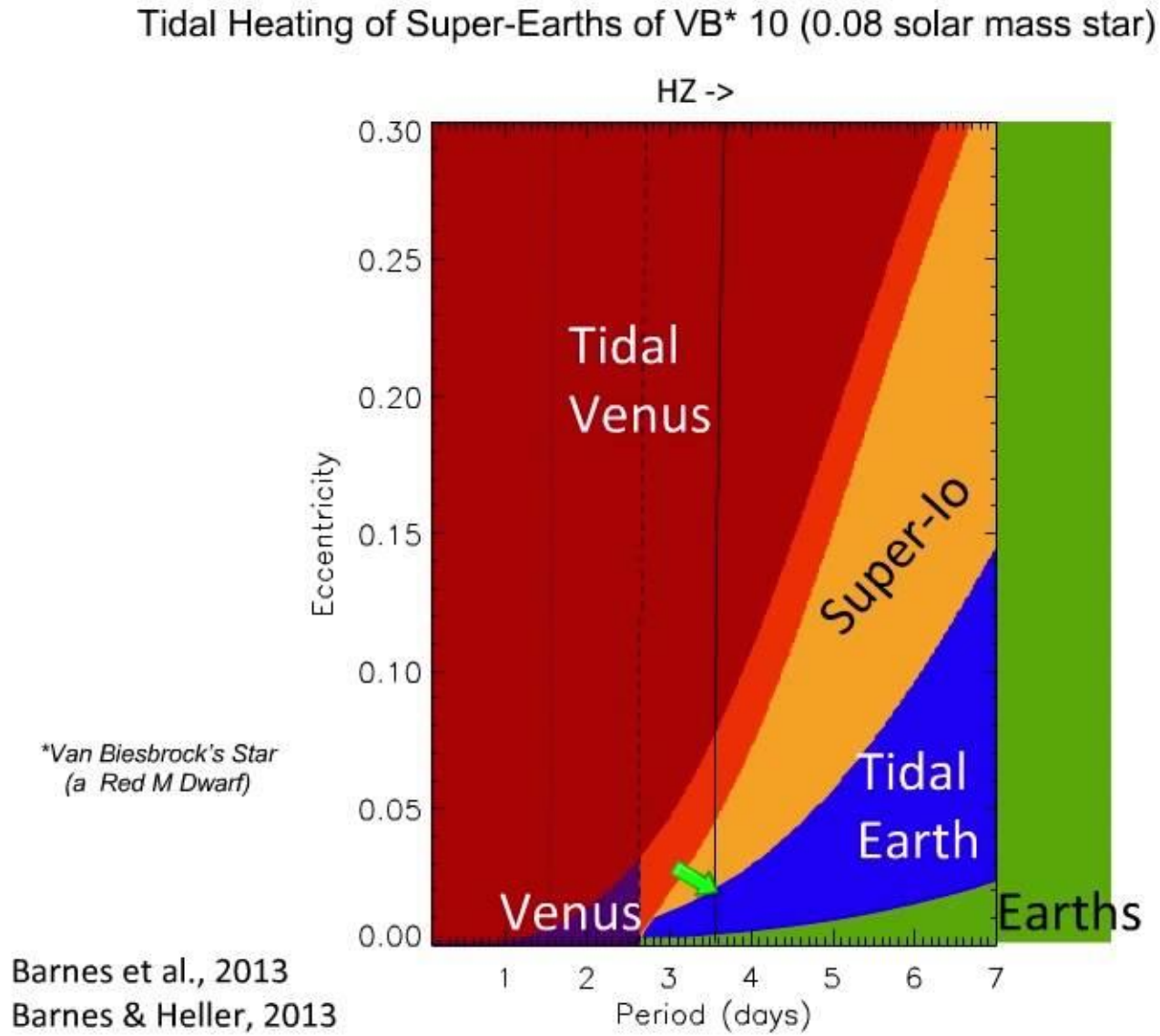
Mike Toillion: OK, you should now have webcam access.

Audio Instructions (Participants)

Teleconference Line: 866-692-3158
Passcode: 9109668#
Please use *6 (STAR, then 6) to **MUTE** your phone's mic when not speaking.
More info: https://astrobiologyfuture.org

What is the geophysical evolutionary history of terrestrial planets?

Full Screen



1
00:00:13,589 --> 00:00:10,790
hello everyone and welcome to our

2
00:00:15,270 --> 00:00:13,599
penultimate webinar we have one more

3
00:00:17,109 --> 00:00:15,280
tomorrow and then that will be the end

4
00:00:20,230 --> 00:00:17,119
of the current series

5
00:00:23,029 --> 00:00:20,240
uh for anyone who is joining just on

6
00:00:25,830 --> 00:00:23,039
audio the slides for this have been

7
00:00:28,070 --> 00:00:25,840
uploaded onto the website and you can

8
00:00:30,310 --> 00:00:28,080
download them straight from the link for

9
00:00:32,709 --> 00:00:30,320
today's event it's not too big the

10
00:00:34,790 --> 00:00:32,719
file's about three megs uh so that

11
00:00:37,350 --> 00:00:34,800
shouldn't take you long to pull down

12
00:00:41,190 --> 00:00:37,360
the document that this presentation is

13
00:00:44,310 --> 00:00:41,200

based on is now open for comments um

14
00:00:46,790 --> 00:00:44,320
and we have a slightly technically

15
00:00:49,670 --> 00:00:46,800
restricted event today penny boston who

16
00:00:52,069 --> 00:00:49,680
is one of our presenters is on a dodgy

17
00:00:55,110 --> 00:00:52,079
wi-fi connection so unless we get a

18
00:00:58,229 --> 00:00:55,120
sudden improvement uh she will be in

19
00:01:01,990 --> 00:00:58,239
voice only and rory will be here in

20
00:01:03,990 --> 00:01:02,000
sound and video um so the event is being

21
00:01:06,390 --> 00:01:04,000
recorded and will be placed on the

22
00:01:08,950 --> 00:01:06,400
internet so everything you type and say

23
00:01:11,270 --> 00:01:08,960
will be out there in public and with

24
00:01:12,630 --> 00:01:11,280
that let's see if we can make this work

25
00:01:15,429 --> 00:01:12,640
penny

26
00:01:17,910 --> 00:01:15,439
okay thanks uh everybody sorry i can't

27
00:01:19,830 --> 00:01:17,920
be visible on the screen um

28
00:01:22,710 --> 00:01:19,840
rory if you can advance slides for me as

29
00:01:25,109 --> 00:01:22,720
i go i'll call for them as i need them

30
00:01:27,590 --> 00:01:25,119
and uh i'm afraid you'll also have to

31
00:01:29,270 --> 00:01:27,600
field any questions for us and and if

32
00:01:31,910 --> 00:01:29,280
it's something that i need to address

33
00:01:33,510 --> 00:01:31,920
please let me know

34
00:01:36,149 --> 00:01:33,520
we felt

35
00:01:38,390 --> 00:01:36,159
during our face-to-face meeting back in

36
00:01:40,789 --> 00:01:38,400
june that there was a really important

37
00:01:43,109 --> 00:01:40,799
need to focus on

38
00:01:46,069 --> 00:01:43,119

aspects of geophysics

39
00:01:49,270 --> 00:01:46,079
and the geophysical evolution of uh

40
00:01:51,830 --> 00:01:49,280
terrestrial type planets whether they be

41
00:01:53,109 --> 00:01:51,840
primary planets or even terrestrial uh

42
00:01:54,870 --> 00:01:53,119
type bodies

43
00:01:58,310 --> 00:01:54,880
um circling

44
00:02:00,950 --> 00:01:58,320
uh gas giants and uh even though rory

45
00:02:03,670 --> 00:02:00,960
and i are neither of us experts in a lot

46
00:02:06,469 --> 00:02:03,680
of the areas that we felt were important

47
00:02:08,869 --> 00:02:06,479
we wanted it to be included and so

48
00:02:11,110 --> 00:02:08,879
several other people have assisted us in

49
00:02:14,070 --> 00:02:11,120
this kelsey singer who i believe is not

50
00:02:17,589 --> 00:02:14,080
able to participate today uh paulie lane

51
00:02:20,150 --> 00:02:17,599
in finland um and then most recently and

52
00:02:21,750 --> 00:02:20,160
very usefully uh peter driscoll who

53
00:02:23,430 --> 00:02:21,760
happens to be

54
00:02:25,110 --> 00:02:23,440
rory barnes's

55
00:02:28,790 --> 00:02:25,120
postdoc so

56
00:02:29,830 --> 00:02:28,800
we are open and welcoming of

57
00:02:32,150 --> 00:02:29,840
additional

58
00:02:33,910 --> 00:02:32,160
thoughts on this obviously as all the

59
00:02:35,750 --> 00:02:33,920
webinars have done but particularly in

60
00:02:37,589 --> 00:02:35,760
this area

61
00:02:39,270 --> 00:02:37,599
we have not had any real-life

62
00:02:40,390 --> 00:02:39,280
geophysicists

63
00:02:43,190 --> 00:02:40,400

on

64
00:02:47,350 --> 00:02:45,030
primarily of course these geophysical

65
00:02:48,550 --> 00:02:47,360
parameters are important for our

66
00:02:51,350 --> 00:02:48,560
consideration because of the

67
00:02:53,670 --> 00:02:51,360
consequences for astrobiology so we have

68
00:02:55,830 --> 00:02:53,680
tried to uh at least do the initial

69
00:02:57,830 --> 00:02:55,840
exercise of thinking through some of

70
00:03:00,710 --> 00:02:57,840
those uh consequences rory can you give

71
00:03:01,830 --> 00:03:00,720
me the next slide please

72
00:03:04,309 --> 00:03:01,840
so

73
00:03:05,430 --> 00:03:04,319
as with all of these we have uh tried to

74
00:03:08,470 --> 00:03:05,440
come up with

75
00:03:10,550 --> 00:03:08,480
uh an explanation of what the title

76
00:03:13,270 --> 00:03:10,560
means and what the content is

77
00:03:16,710 --> 00:03:13,280
um and then of course the justification

78
00:03:19,110 --> 00:03:16,720
uh the explanation is uh that the

79
00:03:21,430 --> 00:03:19,120
evolution geophysically of a of a planet

80
00:03:23,910 --> 00:03:21,440
will be a major control on a lot of it

81
00:03:26,949 --> 00:03:23,920
the other salient features including its

82
00:03:29,190 --> 00:03:26,959
uh climate and atmospheric composition

83
00:03:31,910 --> 00:03:29,200
uh and even its surface volatile

84
00:03:34,070 --> 00:03:31,920
inventory uh which is so critical as we

85
00:03:37,030 --> 00:03:34,080
think to astrobiology

86
00:03:37,990 --> 00:03:37,040
um we are expecting from our

87
00:03:40,710 --> 00:03:38,000
um

88
00:03:43,430 --> 00:03:40,720

forays so far into exoplanetary studies

89
00:03:45,430 --> 00:03:43,440
that there will be an enormous range

90
00:03:47,589 --> 00:03:45,440
of parameters that are relevant to the

91
00:03:48,710 --> 00:03:47,599
terrestrial planets

92
00:03:50,229 --> 00:03:48,720
that have

93
00:03:52,309 --> 00:03:50,239
strong implications of course for

94
00:03:55,030 --> 00:03:52,319
astrobiological concerns

95
00:03:57,350 --> 00:03:55,040
and because of course astrobiology is

96
00:04:00,630 --> 00:03:57,360
expected to play out over long time

97
00:04:02,229 --> 00:04:00,640
periods on bodies um how

98
00:04:03,830 --> 00:04:02,239
long and

99
00:04:06,070 --> 00:04:03,840
what is the duration

100
00:04:08,470 --> 00:04:06,080
and what is the sequence of events for

101
00:04:10,070 --> 00:04:08,480
different kinds of planets over uh the

102
00:04:12,070 --> 00:04:10,080
billions of years that we would expect

103
00:04:15,030 --> 00:04:12,080
them to be in existence

104
00:04:16,870 --> 00:04:15,040
and be potentially um habitable areas

105
00:04:19,509 --> 00:04:16,880
for uh for life

106
00:04:21,830 --> 00:04:19,519
and uh the justification we have boiled

107
00:04:23,030 --> 00:04:21,840
down to a single sentence trying to keep

108
00:04:24,629 --> 00:04:23,040
it succinct

109
00:04:26,469 --> 00:04:24,639
uh understanding the geophysical

110
00:04:29,030 --> 00:04:26,479
evolution the planets will allow us to

111
00:04:31,189 --> 00:04:29,040
understand critical aspects of potential

112
00:04:33,270 --> 00:04:31,199
habitability from a fundamental

113
00:04:34,550 --> 00:04:33,280

perspective so this is really trying to

114
00:04:36,390 --> 00:04:34,560
get at

115
00:04:39,110 --> 00:04:36,400
what are the fundamental ingredients

116
00:04:40,950 --> 00:04:39,120
that geophysics brings to the table that

117
00:04:43,510 --> 00:04:40,960
feeds into this whole notion of

118
00:04:45,830 --> 00:04:43,520
habitability rory can you advance to the

119
00:04:48,469 --> 00:04:45,840
next please for me

120
00:04:51,590 --> 00:04:48,479
um we've tried to corral a number of

121
00:04:54,070 --> 00:04:51,600
uber questions really uh to try to give

122
00:04:57,110 --> 00:04:54,080
a framework for our thinking

123
00:04:59,670 --> 00:04:57,120
obviously earth itself is

124
00:05:01,749 --> 00:04:59,680
uh the object about which we know uh

125
00:05:03,590 --> 00:05:01,759
most about is geophysics and of course

126
00:05:06,310 --> 00:05:03,600
we have this as a model

127
00:05:07,189 --> 00:05:06,320
um one of my own observations is that i

128
00:05:08,710 --> 00:05:07,199
have

129
00:05:11,749 --> 00:05:08,720
had

130
00:05:13,350 --> 00:05:11,759
very little success corralling

131
00:05:15,350 --> 00:05:13,360
uh conventional

132
00:05:17,990 --> 00:05:15,360
earth geophysicists

133
00:05:21,830 --> 00:05:18,000
into thinking about radically different

134
00:05:24,070 --> 00:05:21,840
bodies and how the geophysics might work

135
00:05:27,110 --> 00:05:24,080
and so i think there is a lot of room

136
00:05:29,350 --> 00:05:27,120
for trying to encourage um cross

137
00:05:30,550 --> 00:05:29,360
connectivity between planetary

138
00:05:33,590 --> 00:05:30,560

scientists

139
00:05:35,670 --> 00:05:33,600
um who work on other bodies and

140
00:05:37,749 --> 00:05:35,680
earth-centered geophysicists as much as

141
00:05:39,670 --> 00:05:37,759
possible

142
00:05:41,909 --> 00:05:39,680
obviously we are now in the era of

143
00:05:44,790 --> 00:05:41,919
comparative planetology not just within

144
00:05:47,110 --> 00:05:44,800
our own solar system uh but this

145
00:05:50,150 --> 00:05:47,120
tremendous and increasing

146
00:05:52,710 --> 00:05:50,160
um dance card of planets of every

147
00:05:55,350 --> 00:05:52,720
description and so this is a wonderful

148
00:05:57,590 --> 00:05:55,360
opportunity albeit challenging for us to

149
00:05:58,390 --> 00:05:57,600
expand our thinking in that direction

150
00:06:00,469 --> 00:05:58,400
um

151
00:06:03,430 --> 00:06:00,479
obviously astrobiology is very

152
00:06:05,909 --> 00:06:03,440
interested in habitable zones

153
00:06:09,270 --> 00:06:05,919
around stars as they are classically

154
00:06:11,270 --> 00:06:09,280
defined in terms of uh distance from the

155
00:06:14,550 --> 00:06:11,280
primary star and what the nature of that

156
00:06:15,350 --> 00:06:14,560
star is what stellar class it belongs to

157
00:06:17,350 --> 00:06:15,360
um

158
00:06:20,870 --> 00:06:17,360
and of course we know that there are not

159
00:06:23,510 --> 00:06:20,880
only perhaps uh earth-like bodies but uh

160
00:06:25,749 --> 00:06:23,520
also planets that are earth-like but in

161
00:06:29,749 --> 00:06:25,759
radically different mass classes

162
00:06:32,790 --> 00:06:29,759
both up and down from earth's mass

163
00:06:35,270 --> 00:06:32,800

we believe that thought about rocky

164
00:06:36,309 --> 00:06:35,280
terrestrial moons that circle around gas

165
00:06:38,790 --> 00:06:36,319
giants

166
00:06:40,550 --> 00:06:38,800
and habitable zones are really important

167
00:06:41,590 --> 00:06:40,560
and a whole other class of habitable

168
00:06:44,870 --> 00:06:41,600
zone

169
00:06:45,590 --> 00:06:44,880
and what can be learned from super ios

170
00:06:47,110 --> 00:06:45,600
or

171
00:06:50,230 --> 00:06:47,120
other similar

172
00:06:53,749 --> 00:06:52,870
bodies that are around other stars

173
00:06:55,510 --> 00:06:53,759
and

174
00:06:56,950 --> 00:06:55,520
really what are the geophysical

175
00:06:59,510 --> 00:06:56,960
consequences

176
00:07:01,430 --> 00:06:59,520
uh for planets around non-fall class

177
00:07:03,589 --> 00:07:01,440
stars and how does then

178
00:07:05,430 --> 00:07:03,599
that feed into the astrobiological

179
00:07:11,990 --> 00:07:05,440
considerations can we go to the next

180
00:07:17,189 --> 00:07:14,629
can we go to the next slide please

181
00:07:19,670 --> 00:07:17,199
i've advanced it penny so i get maybe

182
00:07:22,230 --> 00:07:19,680
delay okay all right thanks very sorry i

183
00:07:25,110 --> 00:07:22,240
can't see that

184
00:07:27,029 --> 00:07:25,120
i have to hear all right um

185
00:07:29,189 --> 00:07:27,039
the um

186
00:07:31,670 --> 00:07:29,199
the fundamental uh

187
00:07:34,150 --> 00:07:31,680
aspect of a lot of these bodies has to

188
00:07:36,790 --> 00:07:34,160

do with the various energy sources

189
00:07:38,629 --> 00:07:36,800
um that create processes that go on on

190
00:07:40,870 --> 00:07:38,639
planets and several of these are

191
00:07:42,830 --> 00:07:40,880
particularly salient of course to

192
00:07:46,629 --> 00:07:42,840
planetary interiors

193
00:07:49,589 --> 00:07:46,639
um we know that of course all bodies of

194
00:07:51,909 --> 00:07:49,599
any significant size

195
00:07:54,309 --> 00:07:51,919
presumably were endowed with your

196
00:07:55,589 --> 00:07:54,319
initial accretionary heating

197
00:07:57,830 --> 00:07:55,599
depending on the size of the body of

198
00:08:00,309 --> 00:07:57,840
course that accretionary heating uh can

199
00:08:04,469 --> 00:08:00,319
persist for very long periods of time

200
00:08:06,869 --> 00:08:04,479
um so that initial um amount of of

201
00:08:09,589 --> 00:08:06,879
heating is expected to be a common

202
00:08:12,230 --> 00:08:09,599
property of most bodies that are likely

203
00:08:15,589 --> 00:08:12,240
to be of astrobiological significance we

204
00:08:17,830 --> 00:08:15,599
know that those bodies that are endowed

205
00:08:20,790 --> 00:08:17,840
with enough metallicity in their solar

206
00:08:23,029 --> 00:08:20,800
system to possess

207
00:08:24,710 --> 00:08:23,039
radiogenic elements

208
00:08:27,830 --> 00:08:24,720
of high atomic

209
00:08:29,990 --> 00:08:27,840
mass are going to be also a major and

210
00:08:31,909 --> 00:08:30,000
long-term contributor to internal

211
00:08:34,149 --> 00:08:31,919
heating of the body

212
00:08:36,389 --> 00:08:34,159
there is of course a complex

213
00:08:38,709 --> 00:08:36,399

geochemistry

214
00:08:39,430 --> 00:08:38,719
that goes on as

215
00:08:41,350 --> 00:08:39,440
a

216
00:08:43,269 --> 00:08:41,360
will

217
00:08:45,030 --> 00:08:43,279
differentiate physically and chemically

218
00:08:47,750 --> 00:08:45,040
in its interior

219
00:08:49,990 --> 00:08:47,760
and a lot of those reactions are

220
00:08:51,509 --> 00:08:50,000
exergonic and also provide internal

221
00:08:54,070 --> 00:08:51,519
heating

222
00:08:56,630 --> 00:08:54,080
of course external factors are also

223
00:08:59,269 --> 00:08:56,640
important including the solar energy

224
00:09:02,150 --> 00:08:59,279
that a a body does or does not possess

225
00:09:04,870 --> 00:09:02,160
but that's perhaps less salient to a lot

226
00:09:07,269 --> 00:09:04,880
of these deep geophysical processes and

227
00:09:08,550 --> 00:09:07,279
of course as we have seen in around the

228
00:09:11,990 --> 00:09:08,560
solar system

229
00:09:15,030 --> 00:09:12,000
um early on in our history we had a very

230
00:09:17,430 --> 00:09:15,040
major impactor generated source of heat

231
00:09:20,150 --> 00:09:17,440
that certainly affected uh the surfaces

232
00:09:22,630 --> 00:09:20,160
of many of the bodies um the degree to

233
00:09:25,269 --> 00:09:22,640
which that penetrated the the surfaces

234
00:09:27,350 --> 00:09:25,279
of earth and other bodies is still a

235
00:09:28,790 --> 00:09:27,360
subject for debate and

236
00:09:31,990 --> 00:09:28,800
and study but nevertheless this is

237
00:09:33,350 --> 00:09:32,000
another another source

238
00:09:36,710 --> 00:09:33,360

with

239
00:09:37,829 --> 00:09:36,720
bodies that are orbiting particularly

240
00:09:42,949 --> 00:09:37,839
around

241
00:09:45,590 --> 00:09:42,959
resonances between the moons and the

242
00:09:48,470 --> 00:09:45,600
primary planets of course as we see on

243
00:09:50,389 --> 00:09:48,480
io and enceladus and et cetera

244
00:09:53,190 --> 00:09:50,399
are capable of providing a great deal of

245
00:09:55,110 --> 00:09:53,200
uh tidal heating and so these are the uh

246
00:09:58,150 --> 00:09:55,120
the primary mechanisms that we have at

247
00:10:01,590 --> 00:09:58,160
our disposal to think about these bodies

248
00:10:02,870 --> 00:10:01,600
from the geophysical position

249
00:10:05,110 --> 00:10:02,880
with respect to their fundamental

250
00:10:05,990 --> 00:10:05,120
properties okay rory and turn it over to

251
00:10:07,590 --> 00:10:06,000
you

252
00:10:09,190 --> 00:10:07,600
all right thanks penny so with that

253
00:10:11,190 --> 00:10:09,200
introduction i wanted to spend a few

254
00:10:13,030 --> 00:10:11,200
slides just uh discussing some of the

255
00:10:14,710 --> 00:10:13,040
more recent results that are pertinent

256
00:10:16,150 --> 00:10:14,720
to the today's discussion

257
00:10:17,590 --> 00:10:16,160
and one of the most fundamental things

258
00:10:19,350 --> 00:10:17,600
we might be interested in in a

259
00:10:20,710 --> 00:10:19,360
terrestrial exoplanet would be its

260
00:10:22,310 --> 00:10:20,720
composition

261
00:10:24,710 --> 00:10:22,320
and uh there's actually been a fair

262
00:10:27,190 --> 00:10:24,720
amount of work that's been uh tackled uh

263
00:10:29,829 --> 00:10:27,200

lately um a lot of it's been led by jade

264
00:10:31,750 --> 00:10:29,839
bond uh now jade carter bond uh and this

265
00:10:33,750 --> 00:10:31,760
is uh one of the her first results that

266
00:10:35,590 --> 00:10:33,760
i'm showing here in in this slide just

267
00:10:38,389 --> 00:10:35,600
some examples of it really

268
00:10:39,990 --> 00:10:38,399
and uh in this study what uh what jade

269
00:10:42,550 --> 00:10:40,000
and her colleagues did is they tried to

270
00:10:44,389 --> 00:10:42,560
basically map the composition of the

271
00:10:45,990 --> 00:10:44,399
star

272
00:10:47,910 --> 00:10:46,000
to the properties of a terrestrial

273
00:10:49,910 --> 00:10:47,920
planet that might have formed around it

274
00:10:52,069 --> 00:10:49,920
so they they basically they looked at

275
00:10:54,310 --> 00:10:52,079
the spectrum of the star identified the

276
00:10:56,470 --> 00:10:54,320
the abundances of the elements inside

277
00:10:58,630 --> 00:10:56,480
the atmosphere of the of the star and

278
00:10:59,910 --> 00:10:58,640
they assumed then that the uh the

279
00:11:01,910 --> 00:10:59,920
protoplanetary disk from which

280
00:11:04,630 --> 00:11:01,920
terrestrial planets would form uh was

281
00:11:07,030 --> 00:11:04,640
composed of similar uh elements and then

282
00:11:09,430 --> 00:11:07,040
they worked out sort of the evolution of

283
00:11:12,150 --> 00:11:09,440
that planetary disk at early times and

284
00:11:14,550 --> 00:11:12,160
basically identified a condensation

285
00:11:16,150 --> 00:11:14,560
sequence so to speak of where different

286
00:11:18,230 --> 00:11:16,160
elements and molecules might lie in the

287
00:11:20,870 --> 00:11:18,240
protoplanetary disk they then assumed

288
00:11:21,990 --> 00:11:20,880

that uh the precursors to the

289
00:11:24,630 --> 00:11:22,000
terrestrial planet we called them

290
00:11:27,990 --> 00:11:24,640
planetesimals were endowed with the

291
00:11:29,990 --> 00:11:28,000
local uh composition of the

292
00:11:31,990 --> 00:11:30,000
level composition of the of the of the

293
00:11:35,030 --> 00:11:32,000
disc and then they allowed gravity to

294
00:11:37,110 --> 00:11:35,040
take over and simulated just how uh the

295
00:11:38,870 --> 00:11:37,120
accretion process would proceed

296
00:11:41,030 --> 00:11:38,880
and at the end when they had just a

297
00:11:42,710 --> 00:11:41,040
handful of terrestrial planets that were

298
00:11:44,949 --> 00:11:42,720
somewhat similar in size to the earth

299
00:11:47,590 --> 00:11:44,959
they then examined what

300
00:11:50,310 --> 00:11:47,600
constituent planetesimals made up the

301
00:11:52,069 --> 00:11:50,320
entire planet at the end and there are a

302
00:11:54,710 --> 00:11:52,079
few different possibilities that they

303
00:11:56,630 --> 00:11:54,720
found and uh just to sort of highlight

304
00:11:59,269 --> 00:11:56,640
some of them

305
00:12:01,910 --> 00:11:59,279
if you look at this top panel up here

306
00:12:04,470 --> 00:12:01,920
this is a case of a star that has this

307
00:12:06,949 --> 00:12:04,480
telephone number hd17051

308
00:12:10,069 --> 00:12:06,959
which is a star that they found to have

309
00:12:12,629 --> 00:12:10,079
low a low carbon oxygen ratio

310
00:12:14,790 --> 00:12:12,639
compared to our sun and it they argue i

311
00:12:18,550 --> 00:12:14,800
think quite persuasively that the seed o

312
00:12:20,150 --> 00:12:18,560
ratio is a critical um value as far as

313
00:12:22,310 --> 00:12:20,160

trying to understand the composition of

314
00:12:23,829 --> 00:12:22,320
planets because it sets the the

315
00:12:25,110 --> 00:12:23,839
chemistry in the disc

316
00:12:26,150 --> 00:12:25,120
early on

317
00:12:28,629 --> 00:12:26,160
and uh

318
00:12:30,150 --> 00:12:28,639
just to point out here that the this is

319
00:12:32,230 --> 00:12:30,160
the earth's composition here and of

320
00:12:33,509 --> 00:12:32,240
course here's the uh the

321
00:12:35,030 --> 00:12:33,519
key where which you can look for your

322
00:12:36,829 --> 00:12:35,040
favorite element

323
00:12:39,509 --> 00:12:36,839
so in this in this system

324
00:12:40,949 --> 00:12:39,519
hd17051 what they found is that the the

325
00:12:42,949 --> 00:12:40,959
planets didn't look very similar to the

326
00:12:44,870 --> 00:12:42,959
earth and you might notice for example

327
00:12:48,150 --> 00:12:44,880
that there's a lot of white in a lot of

328
00:12:50,710 --> 00:12:48,160
these planets and that is calcium so

329
00:12:53,110 --> 00:12:50,720
this low co ratio transformed the

330
00:12:55,990 --> 00:12:53,120
chemistry in the disk and it then

331
00:12:57,269 --> 00:12:56,000
created planets that tended to be more

332
00:12:58,949 --> 00:12:57,279
calcium-rich than the earth although

333
00:13:01,829 --> 00:12:58,959
there are a couple of examples that look

334
00:13:03,990 --> 00:13:01,839
quite a bit like the earth

335
00:13:05,910 --> 00:13:04,000
if i go to another

336
00:13:08,470 --> 00:13:05,920
star that might host planets i think

337
00:13:09,750 --> 00:13:08,480
maybe it does in fact um we see that

338
00:13:13,269 --> 00:13:09,760

this this us

339
00:13:15,350 --> 00:13:13,279
says star had a similar co ratio as

340
00:13:17,750 --> 00:13:15,360
their sun and as they ran their their

341
00:13:19,269 --> 00:13:17,760
process forward they found that indeed

342
00:13:20,870 --> 00:13:19,279
they formed planets that did look quite

343
00:13:21,590 --> 00:13:20,880
a bit like the the earth you can see

344
00:13:23,430 --> 00:13:21,600
that

345
00:13:25,910 --> 00:13:23,440
the each of these little discs here

346
00:13:27,829 --> 00:13:25,920
looks quite similar to the uh

347
00:13:30,629 --> 00:13:27,839
our model earth

348
00:13:32,629 --> 00:13:30,639
uh finally they looked at uh this star

349
00:13:35,030 --> 00:13:32,639
that had a very large co or relatively

350
00:13:37,269 --> 00:13:35,040
large c to o ratio

351
00:13:39,829 --> 00:13:37,279
and what they found was that in fact you

352
00:13:41,269 --> 00:13:39,839
didn't get silicon rich planets at all

353
00:13:45,110 --> 00:13:41,279
you tended to get these planets that

354
00:13:48,310 --> 00:13:45,120
were mainly uh carbon and iron so you

355
00:13:49,590 --> 00:13:48,320
can see that these planets all are quite

356
00:13:51,350 --> 00:13:49,600
quite black meaning they have a lot of

357
00:13:54,389 --> 00:13:51,360
carbon so these are very different

358
00:13:56,629 --> 00:13:54,399
worlds than we might imagine uh

359
00:13:58,870 --> 00:13:56,639
from just in our solar system and these

360
00:14:01,110 --> 00:13:58,880
we don't know necessarily that the host

361
00:14:02,389 --> 00:14:01,120
star's properties do map in this way

362
00:14:03,670 --> 00:14:02,399
there's planet formation is a

363
00:14:05,350 --> 00:14:03,680

complicated process that we don't

364
00:14:07,750 --> 00:14:05,360
understand and i know there's been

365
00:14:09,509 --> 00:14:07,760
other uh webinars on this series on that

366
00:14:11,269 --> 00:14:09,519
topic but nonetheless this i think kind

367
00:14:13,829 --> 00:14:11,279
of gives us a zeroth order

368
00:14:16,230 --> 00:14:13,839
example or a cut of just what might be

369
00:14:18,310 --> 00:14:16,240
out there and it's fascinating to think

370
00:14:19,990 --> 00:14:18,320
about just what are the geophysical

371
00:14:22,389 --> 00:14:20,000
implications of these different kinds of

372
00:14:24,550 --> 00:14:22,399
compositions

373
00:14:26,069 --> 00:14:24,560
moving a little closer to home i think

374
00:14:27,350 --> 00:14:26,079
there's an interesting feature of the

375
00:14:33,509 --> 00:14:27,360
earth

376
00:14:36,069 --> 00:14:33,519
uh solidified about a billion years ago

377
00:14:38,550 --> 00:14:36,079
for the first several giga years of the

378
00:14:40,310 --> 00:14:38,560
earth's uh evolution we actually did not

379
00:14:43,910 --> 00:14:40,320
have a solid inner core

380
00:14:46,150 --> 00:14:43,920
and this transformation uh actually

381
00:14:49,430 --> 00:14:46,160
changed the geophysics and the

382
00:14:51,030 --> 00:14:49,440
geodynamo of our earth quite a bit and

383
00:14:53,269 --> 00:14:51,040
this is a figure that i've taken from

384
00:14:55,110 --> 00:14:53,279
from peter driscoll

385
00:14:58,389 --> 00:14:55,120
and uh i guess i can move my arrow out

386
00:15:00,150 --> 00:14:58,399
of the way here um and what he's plotted

387
00:15:02,790 --> 00:15:00,160
here is basically the evolution of the

388
00:15:04,389 --> 00:15:02,800

magnetic moment of the earth as a

389
00:15:05,189 --> 00:15:04,399
function of time

390
00:15:07,750 --> 00:15:05,199
and

391
00:15:09,990 --> 00:15:07,760
initially there's a little bit of growth

392
00:15:12,069 --> 00:15:10,000
here and as just the earth is accreting

393
00:15:14,949 --> 00:15:12,079
but then you see there is this long

394
00:15:16,550 --> 00:15:14,959
decrease in the uh and the power of our

395
00:15:18,710 --> 00:15:16,560
of our planet's magnetic field and

396
00:15:20,550 --> 00:15:18,720
that's just because the earth is cooling

397
00:15:21,670 --> 00:15:20,560
there's less energy around to drive the

398
00:15:23,110 --> 00:15:21,680
dynamo

399
00:15:24,629 --> 00:15:23,120
but then something quite dramatic

400
00:15:27,350 --> 00:15:24,639
happens in this case it happened about

401
00:15:29,670 --> 00:15:27,360
half a giga year ago when the inner core

402
00:15:31,829 --> 00:15:29,680
nucleated it started to solidify and

403
00:15:33,990 --> 00:15:31,839
this can radically changed the energy

404
00:15:36,710 --> 00:15:34,000
budget in our in our planet and it

405
00:15:38,310 --> 00:15:36,720
dramatically increased the the power of

406
00:15:40,790 --> 00:15:38,320
of our magnetic field

407
00:15:42,949 --> 00:15:40,800
and i find this a fascinating feature of

408
00:15:44,870 --> 00:15:42,959
our planet that it looks as though the

409
00:15:46,550 --> 00:15:44,880
about the lifetime of the sun is

410
00:15:48,310 --> 00:15:46,560
comparable to the time it took for an

411
00:15:50,069 --> 00:15:48,320
inner quarter form and whether or not

412
00:15:52,389 --> 00:15:50,079
this has any correlation with with

413
00:15:53,829 --> 00:15:52,399

habitability or not i have no idea but

414
00:15:55,110 --> 00:15:53,839
you know i think this is an interesting

415
00:15:56,550 --> 00:15:55,120
observation and it's a question that we

416
00:15:58,629 --> 00:15:56,560
need to think about as we as we look

417
00:16:02,389 --> 00:15:58,639
forward to uh actually trying to model

418
00:16:04,710 --> 00:16:02,399
some of these terrestrial exoplanets

419
00:16:07,030 --> 00:16:04,720
moving on

420
00:16:09,030 --> 00:16:07,040
uh there's also

421
00:16:10,710 --> 00:16:09,040
part of the energy budget for for

422
00:16:12,710 --> 00:16:10,720
planets as penny mentioned is the

423
00:16:15,110 --> 00:16:12,720
radiogenic inventory

424
00:16:17,110 --> 00:16:15,120
and we know pretty well what the earth's

425
00:16:19,590 --> 00:16:17,120
current energy flux is but we don't

426
00:16:21,350 --> 00:16:19,600
really know what the distribution of of

427
00:16:23,590 --> 00:16:21,360
energy sources

428
00:16:25,189 --> 00:16:23,600
don't know necessarily how much energy

429
00:16:28,069 --> 00:16:25,199
from the earth's interior is coming from

430
00:16:29,269 --> 00:16:28,079
radiogenic uh elements how much of it is

431
00:16:30,710 --> 00:16:29,279
coming from some of these other sources

432
00:16:33,269 --> 00:16:30,720
that fendi mentioned like a creationary

433
00:16:35,509 --> 00:16:33,279
heat or you know core formation these

434
00:16:36,629 --> 00:16:35,519
sorts of things so in this uh this

435
00:16:38,629 --> 00:16:36,639
figure

436
00:16:40,629 --> 00:16:38,639
that is in a paper submitted by patrick

437
00:16:42,470 --> 00:16:40,639
young at all to astrobiology uh they

438
00:16:45,910 --> 00:16:42,480

looked at the uh

439
00:16:47,990 --> 00:16:45,920
how can uh radiogenic uh heating vary on

440
00:16:50,870 --> 00:16:48,000
exoplanets and in this case uh we were

441
00:16:51,749 --> 00:16:50,880
primarily interested in higher levels of

442
00:16:53,509 --> 00:16:51,759
heat

443
00:16:55,350 --> 00:16:53,519
just assuming that the earth maybe is

444
00:16:57,269 --> 00:16:55,360
not typical or maybe the earth is

445
00:16:58,790 --> 00:16:57,279
difficult but there can be outliers what

446
00:17:00,470 --> 00:16:58,800
is sort of the range of possibilities

447
00:17:01,910 --> 00:17:00,480
out there so

448
00:17:03,189 --> 00:17:01,920
first of all

449
00:17:05,029 --> 00:17:03,199
there's this black curve here which is

450
00:17:07,990 --> 00:17:05,039
labeled the earth

451
00:17:10,630 --> 00:17:08,000
that is sort of a nominal model for the

452
00:17:13,270 --> 00:17:10,640
radiogenic heating of the earth which is

453
00:17:14,949 --> 00:17:13,280
labeled up here in terms of surface flux

454
00:17:16,789 --> 00:17:14,959
the surface energy flux through the the

455
00:17:18,870 --> 00:17:16,799
surface of the earth that's how it's

456
00:17:21,189 --> 00:17:18,880
being parameterized here

457
00:17:23,029 --> 00:17:21,199
and so this earth case is basically

458
00:17:24,150 --> 00:17:23,039
assuming that about 40 percent of the

459
00:17:26,069 --> 00:17:24,160
earth's

460
00:17:28,950 --> 00:17:26,079
energy current energy is coming from

461
00:17:31,270 --> 00:17:28,960
radioactive decay and you can you know

462
00:17:33,190 --> 00:17:31,280
that and we know from a geo neutrino

463
00:17:34,870 --> 00:17:33,200

experiments from around the world

464
00:17:36,870 --> 00:17:34,880
approximately what the proportions of

465
00:17:38,710 --> 00:17:36,880
the radiogenic elements are in in the

466
00:17:40,390 --> 00:17:38,720
earth their potassium thorium and

467
00:17:42,710 --> 00:17:40,400
uranium

468
00:17:44,470 --> 00:17:42,720
and so we these are

469
00:17:47,350 --> 00:17:44,480
elements that we know their half-lives

470
00:17:49,830 --> 00:17:47,360
very well and so we can actually project

471
00:17:51,590 --> 00:17:49,840
uh forward and model backwards what we

472
00:17:52,789 --> 00:17:51,600
think the energy production in the earth

473
00:17:54,950 --> 00:17:52,799
is going to be

474
00:17:56,950 --> 00:17:54,960
i've presented this as watts per square

475
00:17:58,230 --> 00:17:56,960
meter the surface flux

476
00:17:59,590 --> 00:17:58,240
that's a bit of a

477
00:18:02,870 --> 00:17:59,600
hand wavy argument there i'm not

478
00:18:05,590 --> 00:18:02,880
assuming any sort of uh thermal cooling

479
00:18:08,310 --> 00:18:05,600
in the interiors just as soon as a a an

480
00:18:09,909 --> 00:18:08,320
atom would or an isotope would decay its

481
00:18:12,070 --> 00:18:09,919
energy is immediately at the surface but

482
00:18:15,350 --> 00:18:12,080
it's sort of a zeroth order model for

483
00:18:18,470 --> 00:18:15,360
how the the planet might cool with time

484
00:18:20,230 --> 00:18:18,480
um this red curve here is a a bit more

485
00:18:23,590 --> 00:18:20,240
of an extreme case as if we were to

486
00:18:26,150 --> 00:18:23,600
assume that the entire earth's energy is

487
00:18:28,070 --> 00:18:26,160
being produced by radiogenic heating but

488
00:18:30,710 --> 00:18:28,080

with the same proportions of elements as

489
00:18:32,150 --> 00:18:30,720
we see today this is almost assuredly

490
00:18:33,510 --> 00:18:32,160
not possible

491
00:18:35,110 --> 00:18:33,520
but it's nonetheless sort of an

492
00:18:37,029 --> 00:18:35,120
interesting gauge maybe there's sort of

493
00:18:39,110 --> 00:18:37,039
a factor of a few what might happen is

494
00:18:42,070 --> 00:18:39,120
that a planet has the exact same

495
00:18:45,510 --> 00:18:42,080
abundances of potassium and uranium but

496
00:18:47,190 --> 00:18:45,520
maybe increased by about a factor of two

497
00:18:49,830 --> 00:18:47,200
one of the primary

498
00:18:51,029 --> 00:18:49,840
elements in the radiogenic inventory of

499
00:18:52,870 --> 00:18:51,039
the earth is

500
00:18:54,950 --> 00:18:52,880
40 potassium

501
00:18:57,190 --> 00:18:54,960
but potassium is a volatile and the

502
00:18:59,430 --> 00:18:57,200
earth is depleted quite significantly by

503
00:19:01,990 --> 00:18:59,440
a factor of maybe 25 or 30

504
00:19:05,590 --> 00:19:02,000
in potassium relative to chondrites and

505
00:19:07,350 --> 00:19:05,600
if if you were to add this uh additional

506
00:19:10,950 --> 00:19:07,360
uh source of energy to the earth you get

507
00:19:13,590 --> 00:19:10,960
a very different uh uh situation so this

508
00:19:15,750 --> 00:19:13,600
is basically taking this black curve and

509
00:19:18,390 --> 00:19:15,760
now bumping up potassium by a factor of

510
00:19:21,830 --> 00:19:18,400
25 or 30. so imagining and as if the

511
00:19:23,669 --> 00:19:21,840
earth were actually made of chondrites

512
00:19:25,990 --> 00:19:23,679
exclusively and you can see then that

513
00:19:28,230 --> 00:19:26,000

the uh the edge the energy evolution is

514
00:19:30,630 --> 00:19:28,240
quite quite different in fact for about

515
00:19:32,390 --> 00:19:30,640
the first two billion years of evolution

516
00:19:34,870 --> 00:19:32,400
we might expect the earth to behave more

517
00:19:36,310 --> 00:19:34,880
like io which is shown here by this dash

518
00:19:37,590 --> 00:19:36,320
line so

519
00:19:39,350 --> 00:19:37,600
very different kind of world very

520
00:19:41,350 --> 00:19:39,360
different evolution how

521
00:19:43,990 --> 00:19:41,360
does this change the picture does that

522
00:19:46,150 --> 00:19:44,000
actually prevent habitability in plate

523
00:19:48,230 --> 00:19:46,160
tectonics etc

524
00:19:50,310 --> 00:19:48,240
and then finally this green curve is an

525
00:19:53,270 --> 00:19:50,320
even more extreme example where now i'm

526
00:19:54,870 --> 00:19:53,280
basically taking the the red curve for

527
00:19:55,830 --> 00:19:54,880
assuming all the energy inside the earth

528
00:19:58,070 --> 00:19:55,840
is

529
00:20:00,310 --> 00:19:58,080
from radiogenic sources and then i'm

530
00:20:02,230 --> 00:20:00,320
making it not only just chondritic in

531
00:20:03,909 --> 00:20:02,240
abundance patterns but actually twice

532
00:20:06,470 --> 00:20:03,919
chondroitin as far as the radiogenic

533
00:20:07,750 --> 00:20:06,480
elements are concerned so this is i

534
00:20:09,750 --> 00:20:07,760
don't know maybe maybe i was going to

535
00:20:11,270 --> 00:20:09,760
say it's an extreme example maybe at the

536
00:20:12,789 --> 00:20:11,280
actual absolute upper limit but maybe

537
00:20:15,029 --> 00:20:12,799
not we don't really know what the

538
00:20:17,510 --> 00:20:15,039

distribution of of radioactive isotopes

539
00:20:19,830 --> 00:20:17,520
in the galaxy is we don't know how they

540
00:20:22,390 --> 00:20:19,840
can be uh how they are coalesced into

541
00:20:24,870 --> 00:20:22,400
planets do do certain processes tend to

542
00:20:27,190 --> 00:20:24,880
favor or disfavor uh the accretion of

543
00:20:28,789 --> 00:20:27,200
these elements into the earth so as we

544
00:20:29,990 --> 00:20:28,799
we look forward to these terrestrial

545
00:20:32,070 --> 00:20:30,000
exoplanets we're really going to have to

546
00:20:34,630 --> 00:20:32,080
think hard about just what really is the

547
00:20:36,549 --> 00:20:34,640
energy budget inside of these planets

548
00:20:38,549 --> 00:20:36,559
and at this point i'm going to turn it

549
00:20:40,789 --> 00:20:38,559
back over to penny so

550
00:20:43,190 --> 00:20:40,799
go ahead like all right well i'm

551
00:20:45,430 --> 00:20:43,200
temporarily back on the site we'll see a

552
00:20:46,390 --> 00:20:45,440
little bit less

553
00:20:49,990 --> 00:20:46,400
this

554
00:20:51,110 --> 00:20:50,000
slide is bringing up the issue of what

555
00:20:53,830 --> 00:20:51,120
is known

556
00:20:54,870 --> 00:20:53,840
as the rc to rp which is the ratio

557
00:20:57,750 --> 00:20:54,880
between

558
00:21:00,630 --> 00:20:57,760
the core radius of a planet

559
00:21:03,110 --> 00:21:00,640
and the outer diameter of that planet

560
00:21:06,310 --> 00:21:03,120
and it's been pointed out that

561
00:21:09,510 --> 00:21:06,320
this may uh be a significant factor in

562
00:21:12,390 --> 00:21:09,520
terms of what happens to an internal

563
00:21:14,870 --> 00:21:12,400

dynamo of a particular body

564
00:21:18,149 --> 00:21:14,880
it is not well understood it's a figure

565
00:21:21,350 --> 00:21:18,159
that is cited for a number of bodies um

566
00:21:23,590 --> 00:21:21,360
so this is an arena of uh research that

567
00:21:26,710 --> 00:21:23,600
has significance because there are uh

568
00:21:29,750 --> 00:21:26,720
major consequences uh in terms of what

569
00:21:32,789 --> 00:21:29,760
happens with uh an interior

570
00:21:34,630 --> 00:21:32,799
dynamo should a planet have one

571
00:21:36,390 --> 00:21:34,640
a generation of course of magnetic

572
00:21:38,070 --> 00:21:36,400
fields that we think comes from our own

573
00:21:41,430 --> 00:21:38,080
dynamo here

574
00:21:43,350 --> 00:21:41,440
producing magnetic field lines are

575
00:21:46,070 --> 00:21:43,360
a great astrobiological significance

576
00:21:48,789 --> 00:21:46,080
because they serve as a buffer

577
00:21:51,350 --> 00:21:48,799
from whatever ionizing radiation is

578
00:21:53,750 --> 00:21:51,360
being produced by a particular star

579
00:21:55,909 --> 00:21:53,760
around which they may be orbiting

580
00:21:58,230 --> 00:21:55,919
obviously for certain stellar classes

581
00:22:00,149 --> 00:21:58,240
this is perhaps even more important than

582
00:22:03,270 --> 00:22:00,159
it is for our own sun

583
00:22:06,230 --> 00:22:03,280
um red dwarfs for example are thought to

584
00:22:07,029 --> 00:22:06,240
uh sporadically emit a very strong blast

585
00:22:10,470 --> 00:22:07,039
of

586
00:22:14,149 --> 00:22:10,480
characteristics

587
00:22:17,190 --> 00:22:14,159
and so um the magnetic protection of a

588
00:22:19,430 --> 00:22:17,200

potential astrobiological object uh is

589
00:22:21,110 --> 00:22:19,440
really important the interior

590
00:22:23,110 --> 00:22:21,120
differentiation

591
00:22:24,789 --> 00:22:23,120
what actually goes on when the

592
00:22:27,350 --> 00:22:24,799
when the body is forming

593
00:22:30,470 --> 00:22:27,360
has profound implications for what

594
00:22:33,110 --> 00:22:30,480
materials are then ultimately available

595
00:22:35,990 --> 00:22:33,120
uh in the more surficial areas of that

596
00:22:38,950 --> 00:22:36,000
planet that can actually go into

597
00:22:41,669 --> 00:22:38,960
creating life in the first place

598
00:22:44,549 --> 00:22:41,679
differentiation and evolution of

599
00:22:47,590 --> 00:22:44,559
interiorly trapped volatiles for example

600
00:22:49,750 --> 00:22:47,600
um solid solution equations that go on

601
00:22:52,149 --> 00:22:49,760
and and many other uh fundamental things

602
00:22:54,630 --> 00:22:52,159
in terms of um perhaps perhaps even the

603
00:22:57,110 --> 00:22:54,640
depletion for example that uh rory was

604
00:23:00,149 --> 00:22:57,120
just mentioning um for potassium which

605
00:23:02,549 --> 00:23:00,159
is uh you know in our own biology is a a

606
00:23:03,909 --> 00:23:02,559
particularly significant element um and

607
00:23:06,070 --> 00:23:03,919
then really

608
00:23:08,870 --> 00:23:06,080
this also speaks to

609
00:23:12,310 --> 00:23:08,880
what is the potential longevity of

610
00:23:16,950 --> 00:23:12,320
internal heating sources um we all uh

611
00:23:20,310 --> 00:23:16,960
pretty much agree that some aspect of a

612
00:23:22,390 --> 00:23:20,320
highly active planetary interior where

613
00:23:25,110 --> 00:23:22,400

there is uh built-in recycling

614
00:23:27,830 --> 00:23:25,120
mechanisms is probably pretty important

615
00:23:31,590 --> 00:23:27,840
for the longevity of a biosphere on any

616
00:23:33,990 --> 00:23:31,600
planet and so uh this feeds into um into

617
00:23:37,430 --> 00:23:34,000
those considerations

618
00:23:39,590 --> 00:23:37,440
um we know that internal heat loss uh

619
00:23:42,549 --> 00:23:39,600
from the inside of the body is occurring

620
00:23:45,430 --> 00:23:42,559
by conduction and by convection

621
00:23:48,789 --> 00:23:45,440
and so contemplating what goes on here

622
00:23:50,630 --> 00:23:48,799
on our own planet um and the behavior of

623
00:23:53,430 --> 00:23:50,640
the complex

624
00:23:56,310 --> 00:23:53,440
plate tectonics that we have

625
00:23:59,350 --> 00:23:56,320
is something to give us pause how common

626
00:24:01,190 --> 00:23:59,360
are plate tectonics on planets

627
00:24:04,310 --> 00:24:01,200
it appears that we are

628
00:24:06,149 --> 00:24:04,320
alone or a rare body within our own

629
00:24:08,390 --> 00:24:06,159
solar system in terms of the particular

630
00:24:09,510 --> 00:24:08,400
style of plate tectonics that we appear

631
00:24:11,990 --> 00:24:09,520
to have

632
00:24:13,990 --> 00:24:12,000
there are obviously other extensional

633
00:24:16,710 --> 00:24:14,000
tectonics that go on on other bodies for

634
00:24:19,029 --> 00:24:16,720
example europa ganymede and so forth and

635
00:24:21,669 --> 00:24:19,039
clearly enceladus

636
00:24:25,190 --> 00:24:21,679
but we have very little um real

637
00:24:27,430 --> 00:24:25,200
understanding of uh what planetary

638
00:24:29,669 --> 00:24:27,440

regimes we are looking at where we would

639
00:24:32,710 --> 00:24:29,679
actually be able to set up something on

640
00:24:35,269 --> 00:24:32,720
that planet um i have attempted to

641
00:24:37,430 --> 00:24:35,279
induce people to talk to me about the

642
00:24:39,190 --> 00:24:37,440
issue of whether or not we could expect

643
00:24:42,070 --> 00:24:39,200
for example on a

644
00:24:44,230 --> 00:24:42,080
significantly chunky uh super earth uh

645
00:24:46,470 --> 00:24:44,240
would we actually get plate dynamics of

646
00:24:49,110 --> 00:24:46,480
the kinds that we have here would we get

647
00:24:52,310 --> 00:24:49,120
plates moving about would uh

648
00:24:54,950 --> 00:24:52,320
the much larger mass perhaps um really

649
00:24:57,269 --> 00:24:54,960
affect the behavior of the convection of

650
00:24:59,350 --> 00:24:57,279
the mantle and so forth um

651
00:25:01,430 --> 00:24:59,360
people are not even very willing to even

652
00:25:03,190 --> 00:25:01,440
speculate about that so this is

653
00:25:05,110 --> 00:25:03,200
something that has caught my attention

654
00:25:08,310 --> 00:25:05,120
in general people have suggested that

655
00:25:09,990 --> 00:25:08,320
the kind of relatively thin lithosphere

656
00:25:12,230 --> 00:25:10,000
that we have on earth

657
00:25:14,950 --> 00:25:12,240
in terms of the crustal material can

658
00:25:17,909 --> 00:25:14,960
produce a shallow convection

659
00:25:20,950 --> 00:25:17,919
and that these um crunchy lithospheric

660
00:25:22,710 --> 00:25:20,960
slabs on top are uh rapidly and

661
00:25:24,789 --> 00:25:22,720
continually created and consumed and we

662
00:25:28,390 --> 00:25:24,799
see that here on this planet

663
00:25:31,190 --> 00:25:28,400

but then extending that beyond our case

664
00:25:33,350 --> 00:25:31,200
um even to expand understanding

665
00:25:36,070 --> 00:25:33,360
tectonic regimes on other bodies in our

666
00:25:38,230 --> 00:25:36,080
solar system and then extending that to

667
00:25:39,990 --> 00:25:38,240
classes of bodies that we don't have

668
00:25:41,830 --> 00:25:40,000
here in our solar system

669
00:25:43,669 --> 00:25:41,840
we think is a really important for us

670
00:25:45,830 --> 00:25:43,679
for research with the profound

671
00:25:47,750 --> 00:25:45,840
astrobiology consequences and turn it

672
00:25:48,630 --> 00:25:47,760
back over to you rory

673
00:25:49,750 --> 00:25:48,640
thanks

674
00:25:51,909 --> 00:25:49,760
so uh

675
00:25:53,029 --> 00:25:51,919
the next slide here which looks to be a

676
00:25:55,510 --> 00:25:53,039
little bit

677
00:25:56,789 --> 00:25:55,520
modified somehow sorry about that but uh

678
00:25:58,149 --> 00:25:56,799
it's not quite what i put on here but

679
00:26:00,070 --> 00:25:58,159
anyway the point here is that now i want

680
00:26:01,830 --> 00:26:00,080
to think a little bit more about um

681
00:26:03,669 --> 00:26:01,840
terrestrial supplements again in the

682
00:26:06,070 --> 00:26:03,679
habit zones and in particular thinking

683
00:26:07,590 --> 00:26:06,080
about uh what other sources of energy

684
00:26:09,669 --> 00:26:07,600
are available in the tidal heating here

685
00:26:10,870 --> 00:26:09,679
and and more broadly

686
00:26:13,110 --> 00:26:10,880
looking at just how can we start to

687
00:26:15,830 --> 00:26:13,120
begin to classify these terrestrial

688
00:26:17,190 --> 00:26:15,840

exoplanets as we move forward

689
00:26:19,269 --> 00:26:17,200
in trying to envision a way in which we

690
00:26:21,190 --> 00:26:19,279
can sort of sample the atmospheres of

691
00:26:22,710 --> 00:26:21,200
these exoplanets we want to try and pick

692
00:26:24,870 --> 00:26:22,720
the planets that

693
00:26:25,750 --> 00:26:24,880
are the most likely to be be habitable

694
00:26:28,789 --> 00:26:25,760
um

695
00:26:30,789 --> 00:26:28,799
and this figure here is sort of meant to

696
00:26:32,310 --> 00:26:30,799
cause sort of a warning to people that

697
00:26:33,590 --> 00:26:32,320
you know it's not necessarily gonna be

698
00:26:35,590 --> 00:26:33,600
obvious that just because the planet is

699
00:26:38,149 --> 00:26:35,600
in the habitable zone that it is going

700
00:26:40,470 --> 00:26:38,159
to be potentially habitable because the

701
00:26:42,710 --> 00:26:40,480
geophysics can be quite important and

702
00:26:45,430 --> 00:26:42,720
quite dramatic and uh what this figure

703
00:26:47,830 --> 00:26:45,440
shows is a tidal heating from a rather

704
00:26:50,950 --> 00:26:47,840
simple model uh the in fact the model

705
00:26:54,310 --> 00:26:50,960
that predicted uh volcanism on io um how

706
00:26:55,350 --> 00:26:54,320
that title pd model will predict um

707
00:26:57,269 --> 00:26:55,360
what what it would predict for the

708
00:26:59,430 --> 00:26:57,279
heating rates would be on the uh on a

709
00:27:01,830 --> 00:26:59,440
planet in the uh habitable zone of a

710
00:27:05,029 --> 00:27:01,840
nearby very low mass star which is

711
00:27:07,830 --> 00:27:05,039
called vb10 um vb10 is sort of the

712
00:27:10,310 --> 00:27:07,840
archetypal low-mass sar star it's right

713
00:27:12,710 --> 00:27:10,320

at the hydrogen burning limit it's about

714
00:27:14,149 --> 00:27:12,720
six parsecs away so it's nearby and it's

715
00:27:15,350 --> 00:27:14,159
something that would probably be

716
00:27:18,149 --> 00:27:15,360
astronomers are probably going to be

717
00:27:21,110 --> 00:27:18,159
targeting to try and identify

718
00:27:23,750 --> 00:27:21,120
potentially habitable planets so uh what

719
00:27:25,669 --> 00:27:23,760
i in this figure first notice uh where

720
00:27:27,350 --> 00:27:25,679
it says habitable hz that stands for

721
00:27:29,750 --> 00:27:27,360
habitable zone so the habitable zone

722
00:27:31,669 --> 00:27:29,760
extends from this dashed line to the

723
00:27:33,750 --> 00:27:31,679
right

724
00:27:35,590 --> 00:27:33,760
now uh that the axes here are the

725
00:27:37,909 --> 00:27:35,600
orbital electricity and the orbital

726
00:27:39,430 --> 00:27:37,919
period so we're not normally used to

727
00:27:41,510 --> 00:27:39,440
seeing having zone plots in this way

728
00:27:43,269 --> 00:27:41,520
they're not it's not the uh the stellar

729
00:27:45,510 --> 00:27:43,279
mass versus the distance but it's

730
00:27:47,190 --> 00:27:45,520
slightly different uh and

731
00:27:48,470 --> 00:27:47,200
uh what i but what i want to point out

732
00:27:49,590 --> 00:27:48,480
here is that the eccentricity is

733
00:27:51,110 --> 00:27:49,600
actually going to be very important as

734
00:27:52,710 --> 00:27:51,120
far as identifying planets that might be

735
00:27:54,389 --> 00:27:52,720
habitable or not so let's first look

736
00:27:57,110 --> 00:27:54,399
down here at the bottom where it's

737
00:27:58,470 --> 00:27:57,120
purple and green these are sort of this

738
00:28:00,710 --> 00:27:58,480

would sort of be our classic picture of

739
00:28:02,070 --> 00:28:00,720
the habitable zone where interior to the

740
00:28:04,389 --> 00:28:02,080
habitable zone you have venus-like

741
00:28:06,389 --> 00:28:04,399
planets and in the habitable zone there

742
00:28:07,669 --> 00:28:06,399
are green planets um the outer edge of

743
00:28:09,750 --> 00:28:07,679
the hybalon is not shown it's probably

744
00:28:12,870 --> 00:28:09,760
about here though at the end of this

745
00:28:14,630 --> 00:28:12,880
spurious green field right there and

746
00:28:16,950 --> 00:28:14,640
notice that the eccentricity is down

747
00:28:19,990 --> 00:28:16,960
here where the green region is are very

748
00:28:21,909 --> 00:28:20,000
low sort of 0.01.02 this is similar to

749
00:28:24,070 --> 00:28:21,919
what the the earth's eccentricity is

750
00:28:26,070 --> 00:28:24,080
today and

751
00:28:27,750 --> 00:28:26,080
but if we go any any any larger than

752
00:28:30,789 --> 00:28:27,760
that we're going to move in to a very

753
00:28:32,310 --> 00:28:30,799
different kind of of planet this blue

754
00:28:35,430 --> 00:28:32,320
region right here is what i like to call

755
00:28:38,549 --> 00:28:35,440
title earth this is where uh the tidal

756
00:28:40,310 --> 00:28:38,559
energy inside a planet is likely to be

757
00:28:42,470 --> 00:28:40,320
similar to what the earth's current

758
00:28:43,909 --> 00:28:42,480
energy is today so these would be

759
00:28:44,630 --> 00:28:43,919
planets that

760
00:28:48,149 --> 00:28:44,640
in

761
00:28:49,350 --> 00:28:48,159
would have the same energy as the earth

762
00:28:50,950 --> 00:28:49,360
today but of course they probably do

763
00:28:52,549 --> 00:28:50,960

have more energy sources they have

764
00:28:54,070 --> 00:28:52,559
radiogenic heating and differentiation

765
00:28:55,590 --> 00:28:54,080
and things like that so it's a very

766
00:28:57,669 --> 00:28:55,600
different kind of world

767
00:29:00,710 --> 00:28:57,679
tidal heating is most likely deposited

768
00:29:02,470 --> 00:29:00,720
near the surface of a planet

769
00:29:04,310 --> 00:29:02,480
and so now you've completely changed the

770
00:29:06,149 --> 00:29:04,320
thermal profile of a planet if you have

771
00:29:08,630 --> 00:29:06,159
heat sources in a core and heat sources

772
00:29:10,950 --> 00:29:08,640
near the near the lithosphere and how

773
00:29:14,470 --> 00:29:10,960
does that change a planetary a planet's

774
00:29:15,750 --> 00:29:14,480
evolution is an unknown right now we we

775
00:29:18,070 --> 00:29:15,760
don't know if that really is going to

776
00:29:19,909 --> 00:29:18,080
suppress plate tectonics or geo uh the

777
00:29:22,149 --> 00:29:19,919
geodynamo but i think there's the things

778
00:29:24,149 --> 00:29:22,159
that we need to need to be exploring uh

779
00:29:25,510 --> 00:29:24,159
very soon to try and understand what

780
00:29:27,350 --> 00:29:25,520
might be going on on these planets i

781
00:29:29,269 --> 00:29:27,360
mean if you were to tell an astronomer

782
00:29:31,830 --> 00:29:29,279
that you found a planet right here at

783
00:29:33,350 --> 00:29:31,840
the at sort of the earth equivalent flux

784
00:29:35,590 --> 00:29:33,360
distance from its host star with an

785
00:29:37,830 --> 00:29:35,600
eccentricity of 0.02 they might be

786
00:29:39,029 --> 00:29:37,840
pretty excited but we have to remember

787
00:29:41,430 --> 00:29:39,039
then that there's this tidal heating

788
00:29:42,870 --> 00:29:41,440

effect here and in fact at 0.02 is where

789
00:29:44,950 --> 00:29:42,880
we'd actually transition into what i

790
00:29:47,830 --> 00:29:44,960
would call a super io these are planets

791
00:29:49,350 --> 00:29:47,840
in which tidal heating from the star i

792
00:29:51,830 --> 00:29:49,360
should say tidal heating due to

793
00:29:53,430 --> 00:29:51,840
deformations caused by the star

794
00:29:55,029 --> 00:29:53,440
will produce

795
00:29:57,669 --> 00:29:55,039
energy fluxes on the surface that are

796
00:29:59,750 --> 00:29:57,679
larger than we see on io so these

797
00:30:02,470 --> 00:29:59,760
planets in the habitable zone of vb10

798
00:30:04,070 --> 00:30:02,480
with an eccentricity of just 0.05

799
00:30:06,230 --> 00:30:04,080
they don't look like the earth they are

800
00:30:07,830 --> 00:30:06,240
going to be planets like

801
00:30:09,510 --> 00:30:07,840
like io

802
00:30:11,110 --> 00:30:09,520
and then finally which is what's

803
00:30:13,029 --> 00:30:11,120
dominating this figure is this red

804
00:30:14,950 --> 00:30:13,039
region which is what i call title

805
00:30:16,870 --> 00:30:14,960
venuses this is where tidal heating is

806
00:30:19,269 --> 00:30:16,880
strong enough to actually trigger the

807
00:30:20,549 --> 00:30:19,279
runaway group greenhouse which nominally

808
00:30:22,389 --> 00:30:20,559
represents the inner edge of the

809
00:30:25,190 --> 00:30:22,399
habitable zone so

810
00:30:26,950 --> 00:30:25,200
without any starlight at all planets in

811
00:30:28,950 --> 00:30:26,960
the habitable zone that are that are

812
00:30:30,070 --> 00:30:28,960
marked red in this figure

813
00:30:32,549 --> 00:30:30,080

they're not habitable they're in a

814
00:30:33,430 --> 00:30:32,559
runway greenhouse and they are their

815
00:30:35,510 --> 00:30:33,440
toast

816
00:30:37,430 --> 00:30:35,520
now that's of course using a very simple

817
00:30:40,230 --> 00:30:37,440
model though and we don't really know

818
00:30:42,950 --> 00:30:40,240
how uh tidal heating is going to behave

819
00:30:45,190 --> 00:30:42,960
on an exoplanet that is predicted to

820
00:30:48,789 --> 00:30:45,200
have two orders of magnitude

821
00:30:50,630 --> 00:30:48,799
more surface flux than on io so i find

822
00:30:52,549 --> 00:30:50,640
this to be a huge open question and we

823
00:30:54,470 --> 00:30:52,559
really need to have new and improved

824
00:30:56,549 --> 00:30:54,480
geophysical models that explore the

825
00:30:59,350 --> 00:30:56,559
relationship between tidal heating

826
00:31:01,190 --> 00:30:59,360
composition and other sources of energy

827
00:31:03,190 --> 00:31:01,200
if we're to understand the potential for

828
00:31:05,029 --> 00:31:03,200
identifying habitable plants around low

829
00:31:07,430 --> 00:31:05,039
mass stars

830
00:31:08,549 --> 00:31:07,440
and now it's back to penny

831
00:31:10,470 --> 00:31:08,559
okay

832
00:31:13,590 --> 00:31:10,480
thanks rory

833
00:31:16,230 --> 00:31:13,600
um the issue of um

834
00:31:17,110 --> 00:31:16,240
gravity on a planet how much it has of

835
00:31:20,149 --> 00:31:17,120
that

836
00:31:23,190 --> 00:31:20,159
is a fundamental and really critical uh

837
00:31:25,590 --> 00:31:23,200
critically important arena

838
00:31:26,470 --> 00:31:25,600

because we have focused for many decades

839
00:31:27,909 --> 00:31:26,480
on

840
00:31:30,149 --> 00:31:27,919
um

841
00:31:33,350 --> 00:31:30,159
space flight there have been

842
00:31:36,230 --> 00:31:33,360
many more studies on hypogravity

843
00:31:38,230 --> 00:31:36,240
microgravity no gravity and so forth

844
00:31:40,389 --> 00:31:38,240
then have occurred

845
00:31:42,389 --> 00:31:40,399
in the other direction with

846
00:31:44,230 --> 00:31:42,399
some sort of simulation or consideration

847
00:31:46,549 --> 00:31:44,240
of hypergravity

848
00:31:48,310 --> 00:31:46,559
but as we begin to see

849
00:31:51,590 --> 00:31:48,320
um these

850
00:31:54,389 --> 00:31:51,600
much uh larger than earth rocky

851
00:31:57,190 --> 00:31:54,399
terrestrials appear to be creeping into

852
00:32:00,549 --> 00:31:57,200
our list of exoplanets um

853
00:32:03,509 --> 00:32:00,559
it's time to begin to consider what that

854
00:32:06,549 --> 00:32:03,519
kind of environment might be like for

855
00:32:08,549 --> 00:32:06,559
uh for organisms and of course this is a

856
00:32:10,870 --> 00:32:08,559
very difficult thing to do

857
00:32:14,389 --> 00:32:10,880
it's much easier for us to even

858
00:32:16,389 --> 00:32:14,399
experimentally produce uh hypogravity

859
00:32:18,630 --> 00:32:16,399
and that has been done of course in the

860
00:32:22,149 --> 00:32:18,640
space station and space shuttle and

861
00:32:25,029 --> 00:32:22,159
other spacecraft uh we can also

862
00:32:27,430 --> 00:32:25,039
do that with hyperbolic uh term

863
00:32:29,269 --> 00:32:27,440

experiments on earth

864
00:32:30,870 --> 00:32:29,279
simulating hyper gravity is somewhat

865
00:32:32,630 --> 00:32:30,880
more difficult

866
00:32:34,870 --> 00:32:32,640
but there are specific geophysical

867
00:32:37,509 --> 00:32:34,880
considerations that go into creating

868
00:32:41,029 --> 00:32:37,519
whatever the gravitational value is for

869
00:32:43,590 --> 00:32:41,039
a body and the consequences of those um

870
00:32:45,509 --> 00:32:43,600
are really important so

871
00:32:50,070 --> 00:32:45,519
we have already discussed this whole

872
00:32:52,230 --> 00:32:50,080
issue of tectonics um what does a

873
00:32:54,470 --> 00:32:52,240
planet with a very different mass number

874
00:32:57,669 --> 00:32:54,480
and perhaps different density

875
00:32:59,590 --> 00:32:57,679
due to the potential for tectonic mixing

876
00:33:01,990 --> 00:32:59,600
of materials over time

877
00:33:03,029 --> 00:33:02,000
um can we even produce things like

878
00:33:05,110 --> 00:33:03,039
mountains

879
00:33:07,269 --> 00:33:05,120
uh above a

880
00:33:08,149 --> 00:33:07,279
terrestrial value that is close to our

881
00:33:08,950 --> 00:33:08,159
own

882
00:33:11,430 --> 00:33:08,960
um

883
00:33:13,350 --> 00:33:11,440
what does a much uh greater

884
00:33:16,070 --> 00:33:13,360
gravitational field do

885
00:33:19,110 --> 00:33:16,080
uh to weather patterns and thus the the

886
00:33:21,350 --> 00:33:19,120
climate of a given body so these are all

887
00:33:23,350 --> 00:33:21,360
primary things that can be considered in

888
00:33:25,269 --> 00:33:23,360

geophysical terms

889
00:33:28,230 --> 00:33:25,279
of course the consequences for any life

890
00:33:31,350 --> 00:33:28,240
forms on such bodies uh has to do with

891
00:33:33,269 --> 00:33:31,360
just about everything uh certainly

892
00:33:35,430 --> 00:33:33,279
any effects on the hydrology the

893
00:33:37,269 --> 00:33:35,440
hydrological cycle on the planet uh

894
00:33:39,350 --> 00:33:37,279
whether it's water as we think is

895
00:33:41,110 --> 00:33:39,360
currently important or perhaps more

896
00:33:43,350 --> 00:33:41,120
exotic

897
00:33:45,430 --> 00:33:43,360
solvents

898
00:33:47,110 --> 00:33:45,440
there are undoubtedly going to be major

899
00:33:49,909 --> 00:33:47,120
differences in the way

900
00:33:52,789 --> 00:33:49,919
geological materials will weather

901
00:33:53,990 --> 00:33:52,799
in response to a different

902
00:33:55,990 --> 00:33:54,000
energetic

903
00:33:57,029 --> 00:33:56,000
nature of weathering patterns and

904
00:33:59,190 --> 00:33:57,039
weather

905
00:34:00,230 --> 00:33:59,200
systems

906
00:34:03,269 --> 00:34:00,240
one of the

907
00:34:05,509 --> 00:34:03,279
things that is a concept within ecology

908
00:34:07,110 --> 00:34:05,519
here on our planet is known as the

909
00:34:09,109 --> 00:34:07,120
critical zone and

910
00:34:12,069 --> 00:34:09,119
um if you're not familiar with the term

911
00:34:14,950 --> 00:34:12,079
it really tries to capture the essence

912
00:34:18,629 --> 00:34:14,960
of this rather thin part of our own

913
00:34:19,909 --> 00:34:18,639

planet that is where we the organisms

914
00:34:22,790 --> 00:34:19,919
live here

915
00:34:25,109 --> 00:34:22,800
inhabit and where all of the

916
00:34:27,190 --> 00:34:25,119
relatively rapid and and perhaps even

917
00:34:29,990 --> 00:34:27,200
longer scale

918
00:34:33,430 --> 00:34:30,000
processes turnover

919
00:34:35,109 --> 00:34:33,440
processes that occur here that impact on

920
00:34:37,349 --> 00:34:35,119
the creation and sustenance of a

921
00:34:38,710 --> 00:34:37,359
biosphere are actually going on and

922
00:34:41,829 --> 00:34:38,720
extends from

923
00:34:44,470 --> 00:34:41,839
perhaps a few uh tens of kilometers

924
00:34:46,149 --> 00:34:44,480
within crossed up into

925
00:34:48,230 --> 00:34:46,159
perhaps the upper stratosphere this is

926
00:34:50,710 --> 00:34:48,240
sort of the hot zone if you will where

927
00:34:53,349 --> 00:34:50,720
um where life processes are are meeting

928
00:34:54,950 --> 00:34:53,359
nose-to-nose with the the geophysics the

929
00:34:57,670 --> 00:34:54,960
geochemistry and the atmospheric

930
00:35:01,430 --> 00:34:57,680
chemistry of the planet and then there

931
00:35:02,390 --> 00:35:01,440
is the simple question of the effect on

932
00:35:05,910 --> 00:35:02,400
organisms

933
00:35:09,349 --> 00:35:05,920
of the gravitational uh field itself

934
00:35:11,430 --> 00:35:09,359
um in some recent work that we're doing

935
00:35:13,829 --> 00:35:11,440
in my lab we're trying to look at

936
00:35:15,589 --> 00:35:13,839
hypergravity simulations as a kind of a

937
00:35:18,230 --> 00:35:15,599
test case and this is a

938
00:35:19,990 --> 00:35:18,240

very small project involving a couple of

939
00:35:22,630 --> 00:35:20,000
undergraduates doing their senior thesis

940
00:35:24,470 --> 00:35:22,640
on this but this is an arena in which we

941
00:35:27,030 --> 00:35:24,480
have not really given much consideration

942
00:35:27,990 --> 00:35:27,040
to these uh these kinds of issues so

943
00:35:30,950 --> 00:35:28,000
this

944
00:35:34,550 --> 00:35:30,960
really critical interaction of gravity

945
00:35:35,910 --> 00:35:34,560
with life is uh is another arena that we

946
00:35:37,990 --> 00:35:35,920
that we think

947
00:35:40,069 --> 00:35:38,000
should be folded into the

948
00:35:42,150 --> 00:35:40,079
research balance

949
00:35:43,750 --> 00:35:42,160
so this brings us to the last couple of

950
00:35:45,670 --> 00:35:43,760
slides where we

951
00:35:48,390 --> 00:35:45,680
have attempted to

952
00:35:51,349 --> 00:35:48,400
collect some of our thinking this is not

953
00:35:53,030 --> 00:35:51,359
meant to be um

954
00:35:54,950 --> 00:35:53,040
it's only meant to be illustrative it's

955
00:35:58,710 --> 00:35:54,960
certainly not exhaustive

956
00:36:00,790 --> 00:35:58,720
and we welcome input from others

957
00:36:03,349 --> 00:36:00,800
including those who are who are tuned in

958
00:36:04,550 --> 00:36:03,359
to this webinar and beyond

959
00:36:06,470 --> 00:36:04,560
so if you happen to have a pet

960
00:36:08,630 --> 00:36:06,480
geophysicist around i would suggest that

961
00:36:10,310 --> 00:36:08,640
you try to corral him or her for their

962
00:36:11,430 --> 00:36:10,320
thinking

963
00:36:13,349 --> 00:36:11,440

obviously

964
00:36:16,630 --> 00:36:13,359
fundamentally focusing on how the earth

965
00:36:18,470 --> 00:36:16,640
works that has implications for applying

966
00:36:19,829 --> 00:36:18,480
that to other planets and we show a few

967
00:36:20,870 --> 00:36:19,839
examples here

968
00:36:22,710 --> 00:36:20,880
uh

969
00:36:23,829 --> 00:36:22,720
plate tectonics how does the carbon

970
00:36:26,470 --> 00:36:23,839
cycle

971
00:36:28,470 --> 00:36:26,480
operate what is the balance between uh

972
00:36:32,069 --> 00:36:28,480
solid phases of the planet and liquid

973
00:36:34,310 --> 00:36:32,079
phases um how has earth gone from its

974
00:36:37,349 --> 00:36:34,320
original very different state uh through

975
00:36:39,430 --> 00:36:37,359
all the different geological epochs

976
00:36:40,950 --> 00:36:39,440
when did plate tectonics turn on this is

977
00:36:43,190 --> 00:36:40,960
quite controversial

978
00:36:45,510 --> 00:36:43,200
um what is the balance of course of

979
00:36:47,589 --> 00:36:45,520
internal heating

980
00:36:49,510 --> 00:36:47,599
what can we then take of our

981
00:36:52,710 --> 00:36:49,520
understanding of earth and the way we

982
00:36:54,950 --> 00:36:52,720
apply it to the solar system

983
00:36:57,030 --> 00:36:54,960
we have this long conundrum

984
00:36:59,829 --> 00:36:57,040
uh the three bears problem between earth

985
00:37:01,750 --> 00:36:59,839
venus and mars and their their different

986
00:37:04,069 --> 00:37:01,760
histories how different were there

987
00:37:06,230 --> 00:37:04,079
additional uh their uh initial rather

988
00:37:08,069 --> 00:37:06,240

endowments of materials

989
00:37:09,990 --> 00:37:08,079
why doesn't venus have a magnetic field

990
00:37:12,790 --> 00:37:10,000
when we do even though

991
00:37:15,109 --> 00:37:12,800
venus is very close to us in mass

992
00:37:17,349 --> 00:37:15,119
and many others

993
00:37:19,109 --> 00:37:17,359
can we get true tectonics on icy

994
00:37:21,030 --> 00:37:19,119
satellites and i we've mentioned that

995
00:37:24,150 --> 00:37:21,040
before very briefly

996
00:37:27,829 --> 00:37:24,160
what about these um exotic beasts that

997
00:37:31,109 --> 00:37:27,839
we have roaming about other stars um

998
00:37:34,630 --> 00:37:31,119
super ios as uh as rory has mentioned

999
00:37:36,310 --> 00:37:34,640
them i think of exo enceladuses and all

1000
00:37:38,150 --> 00:37:36,320
these other different examples that we

1001
00:37:39,990 --> 00:37:38,160
can extend um

1002
00:37:43,430 --> 00:37:40,000
beyond our own system

1003
00:37:45,670 --> 00:37:43,440
um if these objects are are outgassing

1004
00:37:48,710 --> 00:37:45,680
can we actually observe those volcanic

1005
00:37:50,630 --> 00:37:48,720
species can we actually detect whether

1006
00:37:53,270 --> 00:37:50,640
or not there are volcanic processes

1007
00:37:55,349 --> 00:37:53,280
going on on another uh body around a

1008
00:37:57,829 --> 00:37:55,359
distant star by looking at the

1009
00:37:59,430 --> 00:37:57,839
atmosphere and chemistry

1010
00:38:02,470 --> 00:37:59,440
there has been one attempt in the

1011
00:38:04,470 --> 00:38:02,480
literature uh that i will not fight here

1012
00:38:06,630 --> 00:38:04,480
uh it was a noble attempt

1013
00:38:07,829 --> 00:38:06,640

but apparently the authors never

1014
00:38:10,310 --> 00:38:07,839
actually talked to a real live

1015
00:38:11,670 --> 00:38:10,320
volcanologist um so it was an early

1016
00:38:13,589 --> 00:38:11,680
primitive attempt

1017
00:38:15,670 --> 00:38:13,599
but i think we can do better if we if we

1018
00:38:17,990 --> 00:38:15,680
cross those disciplinary lines

1019
00:38:19,670 --> 00:38:18,000
are there proxies for the planets in the

1020
00:38:22,069 --> 00:38:19,680
habitable zone

1021
00:38:23,910 --> 00:38:22,079
that we can use in order to make an

1022
00:38:25,910 --> 00:38:23,920
assessment of how habitable those

1023
00:38:28,069 --> 00:38:25,920
planets are

1024
00:38:30,790 --> 00:38:28,079
can we distinguish

1025
00:38:33,030 --> 00:38:30,800
between and evaporated and this is this

1026
00:38:33,910 --> 00:38:33,040
is rory's term for this that means

1027
00:38:36,710 --> 00:38:33,920
um

1028
00:38:37,750 --> 00:38:36,720
a rocky terrestrial that is essentially

1029
00:38:40,310 --> 00:38:37,760
a core

1030
00:38:42,550 --> 00:38:40,320
of a planet that was perhaps a gas giant

1031
00:38:45,430 --> 00:38:42,560
or a neptune-class planet earlier on in

1032
00:38:46,790 --> 00:38:45,440
this history can we distinguish those

1033
00:38:48,790 --> 00:38:46,800
from

1034
00:38:50,310 --> 00:38:48,800
bodies like we preserve earth to be

1035
00:38:51,910 --> 00:38:50,320
which is

1036
00:38:53,349 --> 00:38:51,920
a rocky terrestrial right from the

1037
00:38:55,910 --> 00:38:53,359
beginning

1038
00:38:57,910 --> 00:38:55,920

and then lastly this category of really

1039
00:39:01,270 --> 00:38:57,920
what are the geophysical properties of

1040
00:39:04,310 --> 00:39:01,280
planets in these exoplanetary habitable

1041
00:39:05,750 --> 00:39:04,320
zones as we define them

1042
00:39:07,910 --> 00:39:05,760
on their basis of their stellar

1043
00:39:09,750 --> 00:39:07,920
properties that may have consequences

1044
00:39:12,310 --> 00:39:09,760
for astrobiology

1045
00:39:14,230 --> 00:39:12,320
what is the fundamental chemistry

1046
00:39:16,550 --> 00:39:14,240
how does the balance between being a

1047
00:39:19,510 --> 00:39:16,560
carbonator silicate dominated body

1048
00:39:22,630 --> 00:39:19,520
really depends on the properties of the

1049
00:39:25,589 --> 00:39:22,640
actual disc and solar system formation

1050
00:39:27,589 --> 00:39:25,599
um how do metallic silicates

1051
00:39:29,030 --> 00:39:27,599
affect the evolution of super earth and

1052
00:39:31,589 --> 00:39:29,040
you have

1053
00:39:34,150 --> 00:39:31,599
metallic silicate poor bodies

1054
00:39:35,270 --> 00:39:34,160
in the same mass class that behave very

1055
00:39:36,950 --> 00:39:35,280
differently

1056
00:39:39,190 --> 00:39:36,960
we presume so

1057
00:39:41,510 --> 00:39:39,200
for very low mass stars which account

1058
00:39:42,630 --> 00:39:41,520
for about 75 percent of all stars in our

1059
00:39:43,990 --> 00:39:42,640
galaxy

1060
00:39:46,230 --> 00:39:44,000
how do uh

1061
00:39:49,990 --> 00:39:46,240
processes like tidal heating affect the

1062
00:39:52,230 --> 00:39:50,000
interiors uh can they even uh develop a

1063
00:39:54,470 --> 00:39:52,240

dynamo if they are locked in synchronous

1064
00:39:56,630 --> 00:39:54,480
rotation which is a scenario that has

1065
00:39:59,430 --> 00:39:56,640
been painted for the habitable zone

1066
00:40:01,430 --> 00:39:59,440
around these low-mass stars um

1067
00:40:03,270 --> 00:40:01,440
because of their their relatively low

1068
00:40:06,230 --> 00:40:03,280
luminance the habitable zone is thought

1069
00:40:08,470 --> 00:40:06,240
to be very close in to the star itself

1070
00:40:11,750 --> 00:40:08,480
which would be perhaps to

1071
00:40:14,069 --> 00:40:11,760
synchronous locking uh of the body uh

1072
00:40:17,030 --> 00:40:14,079
here again this same issue comes up

1073
00:40:19,510 --> 00:40:17,040
again with radiogenic heating

1074
00:40:21,510 --> 00:40:19,520
and can we actually classify planets

1075
00:40:23,589 --> 00:40:21,520
really based on their setting that is

1076
00:40:26,069 --> 00:40:23,599
what their properties

1077
00:40:28,550 --> 00:40:26,079
are in the context of their planetary

1078
00:40:30,870 --> 00:40:28,560
system itself

1079
00:40:32,790 --> 00:40:30,880
hysteresis is important and and we have

1080
00:40:34,790 --> 00:40:32,800
captured that in this one item how

1081
00:40:37,670 --> 00:40:34,800
important is the history for the current

1082
00:40:40,630 --> 00:40:37,680
properties how much system memory

1083
00:40:43,589 --> 00:40:40,640
actually exists in any one of these

1084
00:40:47,510 --> 00:40:43,599
planets and does that matter or

1085
00:40:49,910 --> 00:40:47,520
are initial conditions um perhaps

1086
00:40:51,430 --> 00:40:49,920
really more important than

1087
00:40:53,589 --> 00:40:51,440
what actually goes on in the history of

1088
00:40:56,309 --> 00:40:53,599

that planet we really don't have much of

1089
00:40:58,390 --> 00:40:56,319
a clue and in fact we this is a an arena

1090
00:40:59,349 --> 00:40:58,400
of debate within our own world here on

1091
00:41:00,150 --> 00:40:59,359
earth

1092
00:41:02,550 --> 00:41:00,160
um

1093
00:41:05,510 --> 00:41:02,560
does the stellar composition the degree

1094
00:41:06,630 --> 00:41:05,520
of metallicity that it that it may have

1095
00:41:08,870 --> 00:41:06,640
really

1096
00:41:12,150 --> 00:41:08,880
indicate what kind of planets

1097
00:41:14,870 --> 00:41:12,160
were being created in that system and

1098
00:41:16,550 --> 00:41:14,880
can we look at stellar composition even

1099
00:41:17,990 --> 00:41:16,560
in the case perhaps where we have not

1100
00:41:20,390 --> 00:41:18,000
yet detected

1101
00:41:23,109 --> 00:41:20,400
other planetary bodies and can we

1102
00:41:25,109 --> 00:41:23,119
infer something about the likely

1103
00:41:27,589 --> 00:41:25,119
distribution of materials within those

1104
00:41:28,950 --> 00:41:27,599
planets um

1105
00:41:30,950 --> 00:41:28,960
how do

1106
00:41:32,390 --> 00:41:30,960
these so-called water worlds which tend

1107
00:41:33,510 --> 00:41:32,400
to be

1108
00:41:36,470 --> 00:41:33,520
things like

1109
00:41:39,109 --> 00:41:36,480
neptune or sub-neptune-class planets

1110
00:41:41,750 --> 00:41:39,119
that are relatively close in uh to their

1111
00:41:44,230 --> 00:41:41,760
primary star and where

1112
00:41:46,790 --> 00:41:44,240
we are inferring that they have a huge

1113
00:41:48,870 --> 00:41:46,800

volatile endowment liquid water perhaps

1114
00:41:51,109 --> 00:41:48,880
is the only surface material how do

1115
00:41:53,750 --> 00:41:51,119
their interiors operate how big are

1116
00:41:56,390 --> 00:41:53,760
those interiors we know nothing

1117
00:41:59,190 --> 00:41:56,400
and then our last little point is how do

1118
00:42:01,670 --> 00:41:59,200
very dry but still habitable planet

1119
00:42:03,910 --> 00:42:01,680
interiors operate

1120
00:42:04,870 --> 00:42:03,920
there has been discussion of course of

1121
00:42:10,470 --> 00:42:04,880
the

1122
00:42:13,270 --> 00:42:10,480
perhaps being one factor uh as well as

1123
00:42:15,349 --> 00:42:13,280
its size that may have limited its

1124
00:42:18,069 --> 00:42:15,359
future as a tectonic

1125
00:42:20,390 --> 00:42:18,079
planet and perhaps contributed to

1126
00:42:23,349 --> 00:42:20,400
shutting down of tectonics early on its

1127
00:42:25,109 --> 00:42:23,359
history precluding them all together so

1128
00:42:26,550 --> 00:42:25,119
this is another important area of

1129
00:42:28,870 --> 00:42:26,560
research

1130
00:42:30,870 --> 00:42:28,880
to which little attention is being given

1131
00:42:33,829 --> 00:42:30,880
so uh with that i

1132
00:42:37,190 --> 00:42:33,839
uh conclude the formal slides that we

1133
00:42:40,069 --> 00:42:37,200
have um produced for this and throw this

1134
00:42:42,870 --> 00:42:40,079
open to any questions or comments and

1135
00:42:44,950 --> 00:42:42,880
would like to reemphasize again that

1136
00:42:46,950 --> 00:42:44,960
we're very open to additions from people

1137
00:42:49,829 --> 00:42:46,960
who know more than we do about a lot of

1138
00:42:52,150 --> 00:42:49,839

these uh these arenas and roy did you uh

1139
00:42:53,829 --> 00:42:52,160
want to make any last comments here

1140
00:42:55,349 --> 00:42:53,839
no i don't think so but i do i guess

1141
00:42:56,870 --> 00:42:55,359
other than just reiterate what you just

1142
00:42:59,829 --> 00:42:56,880
said you know penny and i are not

1143
00:43:01,510 --> 00:42:59,839
geophysicists and i think that i would

1144
00:43:03,430 --> 00:43:01,520
encourage everybody if you know a

1145
00:43:05,670 --> 00:43:03,440
geophysicist talk to them try to

1146
00:43:07,750 --> 00:43:05,680
convince them that this is is worthwhile

1147
00:43:09,990 --> 00:43:07,760
i mean there's a lot of astronomers like

1148
00:43:12,309 --> 00:43:10,000
myself who are very interested in these

1149
00:43:14,069 --> 00:43:12,319
kinds of topics and you know most of the

1150
00:43:15,510 --> 00:43:14,079
earth scientists that i know are very

1151
00:43:16,950 --> 00:43:15,520
interested in the earth because as we've

1152
00:43:18,230 --> 00:43:16,960
outlined here today

1153
00:43:20,390 --> 00:43:18,240
we don't really understand the earth

1154
00:43:21,589 --> 00:43:20,400
very well and i think that there's a

1155
00:43:22,870 --> 00:43:21,599
double-edged sword there and that that

1156
00:43:24,870 --> 00:43:22,880
means there's a lot of fascinating

1157
00:43:26,630 --> 00:43:24,880
processes to work on but it also means

1158
00:43:28,710 --> 00:43:26,640
that they don't really want to uh

1159
00:43:30,309 --> 00:43:28,720
try and tackle on these exoplanets that

1160
00:43:31,510 --> 00:43:30,319
we know absolutely nothing about when we

1161
00:43:32,950 --> 00:43:31,520
have all this great data for the earth

1162
00:43:34,870 --> 00:43:32,960
and we still don't know what's what's

1163
00:43:36,230 --> 00:43:34,880

going on here but i sort of see this as

1164
00:43:38,390 --> 00:43:36,240
a journey of a thousand steps as

1165
00:43:40,309 --> 00:43:38,400
beginning here and we need to really

1166
00:43:42,150 --> 00:43:40,319
start finding a way to bring our

1167
00:43:44,470 --> 00:43:42,160
geophysical colleagues into this problem

1168
00:43:45,829 --> 00:43:44,480
because it's really crucial life lives

1169
00:43:48,470 --> 00:43:45,839
on planets and we need to know what's

1170
00:43:52,230 --> 00:43:48,480
going on in your interiors

1171
00:43:53,510 --> 00:43:52,240
so it's be kind to geophysicist day

1172
00:43:57,430 --> 00:43:53,520
um

1173
00:44:01,190 --> 00:43:57,440
so now i i know that paulie often has uh

1174
00:44:03,349 --> 00:44:01,200
the connectivity difficulties so he may

1175
00:44:05,430 --> 00:44:03,359
choose to type things in the text box

1176
00:44:07,990 --> 00:44:05,440
but at this point the phone lines are

1177
00:44:10,150 --> 00:44:08,000
open they're all tied together so if

1178
00:44:12,470 --> 00:44:10,160
there are questions that people would

1179
00:44:15,670 --> 00:44:12,480
like to raise or comments

1180
00:44:18,309 --> 00:44:15,680
now is a great time to do it

1181
00:44:20,870 --> 00:44:18,319
and while you would

1182
00:44:23,190 --> 00:44:20,880
while you were thinking about that

1183
00:44:26,230 --> 00:44:23,200
let me just emphasize that the document

1184
00:44:28,550 --> 00:44:26,240
is open for commenting now

1185
00:44:30,870 --> 00:44:28,560
uh and just in case you're not familiar

1186
00:44:33,589 --> 00:44:30,880
with it uh you can get the document

1187
00:44:36,710 --> 00:44:33,599
right from the front of the astrobiology

1188
00:44:38,069 --> 00:44:36,720

future website it's the top link on that

1189
00:44:39,349 --> 00:44:38,079
and just click on that and that will

1190
00:44:41,589 --> 00:44:39,359
take you through

1191
00:44:43,910 --> 00:44:41,599
to the google doc itself

1192
00:44:46,230 --> 00:44:43,920
if you have a google account we do ask

1193
00:44:48,950 --> 00:44:46,240
you to log in first

1194
00:44:50,870 --> 00:44:48,960
because that allows us to see your name

1195
00:44:52,710 --> 00:44:50,880
attached to your comments if you don't

1196
00:44:54,630 --> 00:44:52,720
have a google account then if you're

1197
00:44:56,309 --> 00:44:54,640
adding comments could you just

1198
00:44:59,109 --> 00:44:56,319
add your name as well so that the

1199
00:45:01,589 --> 00:44:59,119
authors can follow up with you if that's

1200
00:45:02,470 --> 00:45:01,599
a useful thing for them to do

1201
00:45:28,790 --> 00:45:02,480
so

1202
00:45:33,270 --> 00:45:30,829
get

1203
00:45:35,670 --> 00:45:33,280
one yeah um

1204
00:45:37,589 --> 00:45:35,680
this is brad foley i'm a new postdoc at

1205
00:45:40,390 --> 00:45:37,599
dtm i'm sitting here with alicia

1206
00:45:43,109 --> 00:45:40,400
weinberger and i'm one of the

1207
00:45:49,430 --> 00:45:43,119
geophysicists that you're begging people

1208
00:45:53,270 --> 00:45:51,109
see also

1209
00:45:55,190 --> 00:45:53,280
in my i also know peter driscoll very

1210
00:45:56,390 --> 00:45:55,200
well because we overlapped i was a phd

1211
00:45:57,670 --> 00:45:56,400
student at yale while he was doing his

1212
00:45:59,750 --> 00:45:57,680
postdoc there

1213
00:46:01,750 --> 00:45:59,760

but um you know i've been interested in

1214
00:46:03,349 --> 00:46:01,760
things like in plate tectonics and how

1215
00:46:05,990 --> 00:46:03,359
plant tectonics forms from mental

1216
00:46:07,990 --> 00:46:06,000
convection and you know we do actually

1217
00:46:10,470 --> 00:46:08,000
you know a few a number of people in the

1218
00:46:12,150 --> 00:46:10,480
geodynamics community have looked at

1219
00:46:14,470 --> 00:46:12,160
um super earths and whether they have

1220
00:46:17,030 --> 00:46:14,480
plate tectonics and it

1221
00:46:18,630 --> 00:46:17,040
it there's no one answer because there's

1222
00:46:19,430 --> 00:46:18,640
so much we don't know but you know i

1223
00:46:21,270 --> 00:46:19,440
just

1224
00:46:22,870 --> 00:46:21,280
can let you guys know that people like

1225
00:46:23,910 --> 00:46:22,880
us have looked at that

1226
00:46:25,589 --> 00:46:23,920
and uh

1227
00:46:27,990 --> 00:46:25,599
you know we're

1228
00:46:29,829 --> 00:46:28,000
i'm certainly interested in working on

1229
00:46:31,510 --> 00:46:29,839
this more with you guys talking more

1230
00:46:33,990 --> 00:46:31,520
about you guys

1231
00:46:36,630 --> 00:46:34,000
well that would be great um

1232
00:46:38,710 --> 00:46:36,640
brad if you um are interested in

1233
00:46:40,870 --> 00:46:38,720
contributing to the document we would

1234
00:46:43,670 --> 00:46:40,880
welcome input

1235
00:46:46,150 --> 00:46:43,680
because you also um are probably much

1236
00:46:47,190 --> 00:46:46,160
more familiar with some of the relevant

1237
00:46:49,829 --> 00:46:47,200
literature

1238
00:46:51,829 --> 00:46:49,839

than we are we can add some references

1239
00:46:53,589 --> 00:46:51,839
and so forth but um

1240
00:46:55,910 --> 00:46:53,599
one of the things that that i would

1241
00:46:57,270 --> 00:46:55,920
really encourage is you know those of

1242
00:46:58,710 --> 00:46:57,280
your colleagues and you who are

1243
00:47:00,950 --> 00:46:58,720
interested in doing this work and

1244
00:47:03,910 --> 00:47:00,960
perhaps doing this work it is not

1245
00:47:06,390 --> 00:47:03,920
penetrating the astrobiology community

1246
00:47:09,270 --> 00:47:06,400
and this is you know a whole additional

1247
00:47:12,069 --> 00:47:09,280
constituency for your work that

1248
00:47:14,470 --> 00:47:12,079
is out here and is anxious to hear

1249
00:47:15,349 --> 00:47:14,480
uh what you guys are thinking about this

1250
00:47:16,309 --> 00:47:15,359
so

1251
00:47:17,990 --> 00:47:16,319
if you

1252
00:47:21,109 --> 00:47:18,000
would like to contribute

1253
00:47:23,510 --> 00:47:21,119
uh hopefully not a whole lot of uh work

1254
00:47:25,990 --> 00:47:23,520
on your part but we would welcome you as

1255
00:47:28,309 --> 00:47:26,000
an additional author uh on the formal

1256
00:47:29,670 --> 00:47:28,319
white paper

1257
00:47:34,390 --> 00:47:29,680
sure yeah i can definitely help with

1258
00:47:39,750 --> 00:47:37,670
other any other questions or comments

1259
00:47:53,670 --> 00:47:39,760
that people want to raise

1260
00:47:59,270 --> 00:47:57,190
okay uh in that case uh let me thank our

1261
00:48:01,990 --> 00:47:59,280
presenters very much

1262
00:48:03,910 --> 00:48:02,000
uh and penny particularly for struggling

1263
00:48:05,510 --> 00:48:03,920

with the technical difficulties we

1264
00:48:07,190 --> 00:48:05,520
appreciate the fact you made it through

1265
00:48:08,230 --> 00:48:07,200
on this

1266
00:48:11,430 --> 00:48:08,240
and

1267
00:48:13,430 --> 00:48:11,440
this video will be up on the website in

1268
00:48:16,230 --> 00:48:13,440
the next day or so

1269
00:48:18,710 --> 00:48:16,240
so if you think you have colleagues who

1270
00:48:20,550 --> 00:48:18,720
should see the presentation or you want

1271
00:48:22,630 --> 00:48:20,560
to just review anything that was said

1272
00:48:25,670 --> 00:48:22,640
prior to adding your comments to the

1273
00:48:29,270 --> 00:48:25,680
document uh it will be linked directly

1274
00:48:30,710 --> 00:48:29,280
from the event link on the front uh page

1275
00:48:33,430 --> 00:48:30,720
on the website

1276
00:48:36,069 --> 00:48:33,440
and apart from that thank you very much