
AbSciCon
2017
MESA, ARIZONA

1
00:00:20,580 --> 00:00:06,150
you

2
00:00:23,470 --> 00:00:20,590
here from astrophysics to geophysics

3
00:00:25,150 --> 00:00:23,480
I'll be talking about basically whether

4
00:00:27,160 --> 00:00:25,160
or not you expect planets to look like

5
00:00:29,349 --> 00:00:27,170
earth with some amount of continents and

6
00:00:31,000 --> 00:00:29,359
some amount of ocean or what I define

7
00:00:32,380 --> 00:00:31,010
here is a water world that is a planet

8
00:00:34,150 --> 00:00:32,390
that has the surface completely covered

9
00:00:35,979 --> 00:00:34,160
in water and so there's no exposed

10
00:00:37,540 --> 00:00:35,989
continent and so this kind of ties into

11
00:00:39,189 --> 00:00:37,550
the talks earlier today about volatile

12
00:00:41,380 --> 00:00:39,199
delivered-to planets where here I'm

13
00:00:43,180 --> 00:00:41,390

basically just going to take a wide

14
00:00:44,709 --> 00:00:43,190
variety of initial water contents or

15
00:00:46,660 --> 00:00:44,719
planets and then calculate whether or

16
00:00:49,750 --> 00:00:46,670
not they should be water worlds that is

17
00:00:52,479 --> 00:00:49,760
water covered and so before I talk about

18
00:00:53,979 --> 00:00:52,489
the water cycle this advances I'll talk

19
00:00:55,240 --> 00:00:53,989
about the carbon cycle because it's kind

20
00:00:56,650 --> 00:00:55,250
of an analogue to the water cycle when

21
00:00:58,090 --> 00:00:56,660
it motivates why this is an important

22
00:01:01,959 --> 00:00:58,100
problem to understand

23
00:01:04,389 --> 00:01:01,969
so just to briefly review right the main

24
00:01:06,639 --> 00:01:04,399
sources of carbon from the interior of

25
00:01:08,260 --> 00:01:06,649
Earth or any terrestrial planet with

26
00:01:09,880 --> 00:01:08,270
plate tectonics to the atmosphere ocean

27
00:01:13,180 --> 00:01:09,890
system is basically through volcanism

28
00:01:16,539 --> 00:01:13,190
either at arc arc focus on like the

29
00:01:18,490 --> 00:01:16,549
Cascade Range in Northwest USA or at

30
00:01:20,890 --> 00:01:18,500
mid-ocean ridges and the main return

31
00:01:22,840 --> 00:01:20,900
mechanisms are seafloor weathering

32
00:01:24,280 --> 00:01:22,850
basically hydrothermal alteration at the

33
00:01:26,020 --> 00:01:24,290
seafloor which then gets abducted and

34
00:01:28,420 --> 00:01:26,030
returns carbon in the mantle and then

35
00:01:30,429 --> 00:01:28,430
most importantly silicate weathering and

36
00:01:32,800 --> 00:01:30,439
so the silicate weathering occurs when

37
00:01:35,350 --> 00:01:32,810
you have basically right rain falling it

38
00:01:37,840 --> 00:01:35,360

mixes with co2 to make carbonic acid

39
00:01:39,550 --> 00:01:37,850
which then dissolves silicates on the

40
00:01:41,770 --> 00:01:39,560
continents and then this creates like

41
00:01:44,530 --> 00:01:41,780
bicarbonate which then flow into the

42
00:01:46,270 --> 00:01:44,540
ocean and then eventually lissa phi on

43
00:01:48,249 --> 00:01:46,280
the seafloor and then our subducting in

44
00:01:49,649 --> 00:01:48,259
return to the mantle and so importantly

45
00:01:51,910 --> 00:01:49,659
the silicate weathering

46
00:01:53,740 --> 00:01:51,920
process occurs as a negative feedback

47
00:01:54,969 --> 00:01:53,750
which stabilizes the climate of

48
00:01:57,340 --> 00:01:54,979
terrestrial planets this is because

49
00:01:59,109 --> 00:01:57,350
chemical reactions on the surface of a

50
00:02:01,210 --> 00:01:59,119
planet will run faster if the climate of

51
00:02:02,350 --> 00:02:01,220
the planet is hotter right and so the

52
00:02:03,520 --> 00:02:02,360
silicate weathering feedback will

53
00:02:05,260 --> 00:02:03,530
stabilize your Cartman if you put more

54
00:02:07,389 --> 00:02:05,270
co2 in the atmosphere so look at weather

55
00:02:08,979 --> 00:02:07,399
weather and will run faster remove co2

56
00:02:10,449 --> 00:02:08,989
from the atmosphere into the interior of

57
00:02:12,130 --> 00:02:10,459
the planet and reduce the surface

58
00:02:13,990 --> 00:02:12,140
temperature of the planet and notably

59
00:02:15,640 --> 00:02:14,000
it's not known whether or not seafloor

60
00:02:18,039 --> 00:02:15,650
weathering depends on the climate of the

61
00:02:19,449 --> 00:02:18,049
planet and so if it does not and then

62
00:02:21,309 --> 00:02:19,459
you have a water world where you no

63
00:02:24,100 --> 00:02:21,319

longer has silicate weathering it would

64
00:02:25,930 --> 00:02:24,110
expect then the climate of the planet to

65
00:02:27,490 --> 00:02:25,940
not be stable you would easily runaway

66
00:02:29,530 --> 00:02:27,500
greenhouse unless you very finely tuned

67
00:02:31,060 --> 00:02:29,540
the climate of the planet and so just

68
00:02:32,290 --> 00:02:31,070
look at a little schematic here you can

69
00:02:33,820 --> 00:02:32,300
envision this just by looking at the

70
00:02:35,980 --> 00:02:33,830
habitable zone for water world versus

71
00:02:38,590 --> 00:02:35,990
planets with silicate weathering here

72
00:02:41,080 --> 00:02:38,600
the red area of these of these of these

73
00:02:43,420 --> 00:02:41,090
of these cartoons is where oceans boil

74
00:02:44,980 --> 00:02:43,430
where you enter a runaway greenhouse the

75
00:02:46,330 --> 00:02:44,990
blue the blue region is where greenhouse

76
00:02:48,340 --> 00:02:46,340
gases freeze this is the co2

77
00:02:49,990 --> 00:02:48,350
condensation limit for the habitable

78
00:02:51,670 --> 00:02:50,000
zone and then the green area that is the

79
00:02:53,170 --> 00:02:51,680
habitable zone basically the habitable

80
00:02:55,090 --> 00:02:53,180
zone for Waterworld should be much much

81
00:02:56,110 --> 00:02:55,100
smaller than for planets with silicate

82
00:02:58,720 --> 00:02:56,120
weathering with and with plate tectonics

83
00:03:00,400 --> 00:02:58,730
and so if we want to understand then

84
00:03:02,020 --> 00:03:00,410
whether water world's our Comment we

85
00:03:03,370 --> 00:03:02,030
need to understand how water is

86
00:03:04,900 --> 00:03:03,380
partitioned between the service and the

87
00:03:07,360 --> 00:03:04,910
interior of the planet that is the deep

88
00:03:08,950 --> 00:03:07,370

water cycle and we can look at the deep

89
00:03:10,990 --> 00:03:08,960
water cycle basically it's almost the

90
00:03:12,250 --> 00:03:11,000
same as the carbon cycle but the intake

91
00:03:14,080 --> 00:03:12,260
process into the mantle is slightly

92
00:03:16,390 --> 00:03:14,090
different and so here's just using the

93
00:03:18,040 --> 00:03:16,400
same stacks Kemetic but replacing the

94
00:03:20,170 --> 00:03:18,050
subduction process for water right water

95
00:03:21,820 --> 00:03:20,180
is produced from the interior to the

96
00:03:23,290 --> 00:03:21,830
atmosphere through volcanism just like

97
00:03:26,050 --> 00:03:23,300
carbonates but it's returned in a

98
00:03:28,060 --> 00:03:26,060
different way basically water hydrates

99
00:03:29,350 --> 00:03:28,070
basalt through serpentinization and then

100
00:03:31,510 --> 00:03:29,360
the tighter your basalt is then

101
00:03:33,220 --> 00:03:31,520
subducted in the mantle but it's an open

102
00:03:35,590 --> 00:03:33,230
question so far in literature exactly

103
00:03:37,449 --> 00:03:35,600
what regulates water cycling on fresh

104
00:03:39,670 --> 00:03:37,459
locks of planets and earth itself there

105
00:03:41,620 --> 00:03:39,680
are basically two leading ideas one

106
00:03:43,420 --> 00:03:41,630
leading idea is that mantle convection

107
00:03:44,949 --> 00:03:43,430
regulates water cycling that is if you

108
00:03:46,479 --> 00:03:44,959
have a hundred mantle you'll more fuel

109
00:03:48,610 --> 00:03:46,489
more volcanism and if you have a hotter

110
00:03:51,220 --> 00:03:48,620
mantle you'll have reduced return of

111
00:03:52,420 --> 00:03:51,230
water into the mantle because the amount

112
00:03:54,130 --> 00:03:52,430
of water you can store in the crust is

113
00:03:55,720 --> 00:03:54,140

lessened and then the other idea is the

114
00:03:57,400 --> 00:03:55,730
surface water budget and so the second

115
00:03:59,920 --> 00:03:57,410
idea is relatively new and I'll walk you

116
00:04:02,199 --> 00:03:59,930
through it quickly and also just to just

117
00:04:03,900 --> 00:04:02,209
to run everybody I'm assuming plate

118
00:04:06,430 --> 00:04:03,910
tectonics here and it's not necessarily

119
00:04:08,050 --> 00:04:06,440
expected that all terrestrial exoplanets

120
00:04:10,120 --> 00:04:08,060
have plate tectonics there may be other

121
00:04:12,010 --> 00:04:10,130
tectonic modes like say stagnant laid

122
00:04:13,810 --> 00:04:12,020
tectonics or vertical heat pipe like

123
00:04:15,490 --> 00:04:13,820
tectonics and water cycling would work

124
00:04:16,900 --> 00:04:15,500
completely different on planets with

125
00:04:21,280 --> 00:04:16,910
with these other tectonic regimes so

126
00:04:23,290 --> 00:04:21,290
just keep that caveat in mind and so to

127
00:04:24,940 --> 00:04:23,300
envision how the amount of surface water

128
00:04:26,860 --> 00:04:24,950
affects water cycling let's just look at

129
00:04:29,080 --> 00:04:26,870
go back to the schematic and say we have

130
00:04:30,790 --> 00:04:29,090
some amount of outgassing written by W

131
00:04:32,860 --> 00:04:30,800
up here and some amount of in gassing

132
00:04:34,750 --> 00:04:32,870
written by W down here and if and we

133
00:04:36,730 --> 00:04:34,760
have some ocean depth if we increase the

134
00:04:38,890 --> 00:04:36,740
ocean depth we would expect that the in

135
00:04:40,540 --> 00:04:38,900
gassing increases just because we have

136
00:04:42,820 --> 00:04:40,550
more around the surface available too

137
00:04:44,770 --> 00:04:42,830
and gas and also the outgassing will

138
00:04:46,600 --> 00:04:44,780

decrease because you have a greater load

139
00:04:48,070 --> 00:04:46,610
pressure on mid-ocean ridges and so this

140
00:04:51,790 --> 00:04:48,080
reduces the amount of volcanism at

141
00:04:53,140 --> 00:04:51,800
mid-ocean ridges and so recently Nick

142
00:04:55,150 --> 00:04:53,150
Cowen and Doreen Abbott have looked at

143
00:04:56,890 --> 00:04:55,160
this using a simple steady-state model

144
00:04:58,480 --> 00:04:56,900
so they assume that water second one was

145
00:05:00,430 --> 00:04:58,490
in steady state and wrote down very

146
00:05:01,950 --> 00:05:00,440
simple power laws this is much simpler

147
00:05:04,570 --> 00:05:01,960
physics and the last talk

148
00:05:06,010 --> 00:05:04,580
saying that the the degassing are--

149
00:05:07,480 --> 00:05:06,020
gassing rates are just power laws and

150
00:05:09,490 --> 00:05:07,490
the seafloor pressure that is basically

151
00:05:11,620 --> 00:05:09,500
just the ocean depth and so if you have

152
00:05:13,210 --> 00:05:11,630
more water on the surface that is a

153
00:05:14,890 --> 00:05:13,220
greater seafloor pressure you'll have

154
00:05:16,480 --> 00:05:14,900
less outgassing and if you have more

155
00:05:18,490 --> 00:05:16,490
water on the surface you'll have more in

156
00:05:20,530 --> 00:05:18,500
gassing and so using this you can

157
00:05:22,060 --> 00:05:20,540
basically just predict how much water

158
00:05:23,620 --> 00:05:22,070
you need for the surface of the water to

159
00:05:26,230 --> 00:05:23,630
be serviced with the plan to be covered

160
00:05:28,150 --> 00:05:26,240
to be covered in water as a function of

161
00:05:31,030 --> 00:05:28,160
planetary parameters if I can get it to

162
00:05:32,830 --> 00:05:31,040
move okay so here on the y axis this is

163
00:05:34,390 --> 00:05:32,840

how much water you have on the planet as

164
00:05:35,800 --> 00:05:34,400
a function of its total mass that is the

165
00:05:37,750 --> 00:05:35,810
water mass fraction the planet here

166
00:05:39,400 --> 00:05:37,760
normalized earth where as was mentioned

167
00:05:42,940 --> 00:05:39,410
earlier Earth's water mass fraction is

168
00:05:44,230 --> 00:05:42,950
about 0.1% and then only on the x axis

169
00:05:46,210 --> 00:05:44,240
of the planet mass normalized to earth

170
00:05:47,560 --> 00:05:46,220
and each of these lines shows different

171
00:05:50,050 --> 00:05:47,570
combinations of these parameter values

172
00:05:51,700 --> 00:05:50,060
and if you're above each individual line

173
00:05:53,320 --> 00:05:51,710
your water world that is the plane of

174
00:05:54,910 --> 00:05:53,330
the surface of the planet is totally

175
00:05:56,440 --> 00:05:54,920
covered in water and if you're below the

176
00:05:57,580 --> 00:05:56,450
line there's partial line coverage and

177
00:05:59,470 --> 00:05:57,590
you have the silica weathering feedback

178
00:06:01,060 --> 00:05:59,480
and the climate should be stable and so

179
00:06:02,350 --> 00:06:01,070
you can see that whether or not the plan

180
00:06:03,760 --> 00:06:02,360
is the Waterworld depending on planet

181
00:06:05,860 --> 00:06:03,770
mass and water mass fraction is

182
00:06:08,110 --> 00:06:05,870
extremely dependent on the assumed

183
00:06:10,240 --> 00:06:08,120
seafloor pressure feedbacks in the model

184
00:06:11,520 --> 00:06:10,250
and so this is a natural problem we

185
00:06:14,020 --> 00:06:11,530
don't we don't know whether or not

186
00:06:15,670 --> 00:06:14,030
seafloor seafloor pressure alone

187
00:06:18,270 --> 00:06:15,680
regulates water cycling but also we

188
00:06:20,560 --> 00:06:18,280

don't understand in detail how

189
00:06:22,540 --> 00:06:20,570
what what these power law dependencies

190
00:06:24,220 --> 00:06:22,550
should be for seafloor pressure and then

191
00:06:25,690 --> 00:06:24,230
this is just one paradigm for water

192
00:06:27,100 --> 00:06:25,700
cycling what about the other paradigm

193
00:06:29,080 --> 00:06:27,110
temperature dependent water cycling and

194
00:06:30,850 --> 00:06:29,090
so in this case I mentioned earlier the

195
00:06:31,870 --> 00:06:30,860
degassing right rate is set by the

196
00:06:33,520 --> 00:06:31,880
mental temperature through the melt

197
00:06:35,320 --> 00:06:33,530
fraction if you have more melt field

198
00:06:37,210 --> 00:06:35,330
more volcanism and therefore you'll have

199
00:06:38,500 --> 00:06:37,220
more out casting and the Riu gassing

200
00:06:40,600 --> 00:06:38,510
rate is set by the depth at which rocks

201
00:06:41,890 --> 00:06:40,610
becomes hydrated because subsidization

202
00:06:43,690 --> 00:06:41,900
can only occur below a critical

203
00:06:45,970 --> 00:06:43,700
temperature and so this was looked at

204
00:06:48,520 --> 00:06:45,980
recently in detail for exoplanets by

205
00:06:50,330 --> 00:06:48,530
Schafer and SAS love and they found here

206
00:06:51,740 --> 00:06:50,340
the results from them further from their

207
00:06:53,390 --> 00:06:51,750
numerical model for two different

208
00:06:55,100 --> 00:06:53,400
assumptions for the viscosity ones the

209
00:06:56,480 --> 00:06:55,110
high viscosity of the mantle which is

210
00:06:58,730 --> 00:06:56,490
relevant for the deeper mantle of Earth

211
00:06:59,930 --> 00:06:58,740
and one for the low viscosity mantle and

212
00:07:01,610 --> 00:06:59,940
here are the results for the fraction of

213
00:07:02,960 --> 00:07:01,620

the surface covered by water where one

214
00:07:05,060 --> 00:07:02,970
would be a water world and zero will be

215
00:07:06,770 --> 00:07:05,070
a planet without any surface water as a

216
00:07:08,390 --> 00:07:06,780
function of time and you can see that

217
00:07:09,710 --> 00:07:08,400
for the high viscosity case none of

218
00:07:11,870 --> 00:07:09,720
their models these lines adjust for

219
00:07:14,780 --> 00:07:11,880
different planet masses reaches the

220
00:07:16,820 --> 00:07:14,790
steady-state over ten billion years but

221
00:07:18,440 --> 00:07:16,830
if one assumes the low viscosity

222
00:07:20,210 --> 00:07:18,450
relevant for the shallow mantle you can

223
00:07:22,550 --> 00:07:20,220
see this phase of initial outgassing and

224
00:07:24,200 --> 00:07:22,560
then really fast recasting and then you

225
00:07:26,470 --> 00:07:24,210
end with essentially no service water

226
00:07:28,910 --> 00:07:26,480
available which is in

227
00:07:31,880 --> 00:07:28,920
itself a problem for habitability right

228
00:07:33,290 --> 00:07:31,890
and so we have these two different

229
00:07:35,720 --> 00:07:33,300
paradigms which predict extremely

230
00:07:37,400 --> 00:07:35,730
different rates at which planet should

231
00:07:38,990 --> 00:07:37,410
become water worlds and so I looked at

232
00:07:40,850 --> 00:07:39,000
this with Doreen Abbott in a simple

233
00:07:42,230 --> 00:07:40,860
non-dimensional framework so we

234
00:07:43,490 --> 00:07:42,240
considered three different possibilities

235
00:07:44,540 --> 00:07:43,500
for water cycling we considered this

236
00:07:45,770 --> 00:07:44,550
pressure dependent framework that I

237
00:07:47,480 --> 00:07:45,780
talked about from Cowen Abbott a

238
00:07:49,340 --> 00:07:47,490

temperature dependent model and then we

239
00:07:51,080 --> 00:07:49,350
also looked at a hybrid model basically

240
00:07:52,490 --> 00:07:51,090
combining the two where the recasting

241
00:07:54,140 --> 00:07:52,500
rate is depends on temperature the

242
00:07:55,730 --> 00:07:54,150
reason why is because it has not been

243
00:07:56,990 --> 00:07:55,740
shown experimentally that recasting

244
00:07:58,610 --> 00:07:57,000
should be dependent on how much water is

245
00:07:59,900 --> 00:07:58,620
available on the surface and so we

246
00:08:02,570 --> 00:07:59,910
basically just ignored that possibility

247
00:08:03,860 --> 00:08:02,580
and then the the degassing rate is

248
00:08:05,840 --> 00:08:03,870
dependent on pressure and the reason why

249
00:08:07,220 --> 00:08:05,850
is because at late times pressure Japan

250
00:08:08,750 --> 00:08:07,230
you guessing should have a greater

251
00:08:09,740 --> 00:08:08,760
influence on the you guessing rate than

252
00:08:12,830 --> 00:08:09,750
the mantle temperature because the

253
00:08:14,090 --> 00:08:12,840
mantle is so cold and so we use a simple

254
00:08:15,470 --> 00:08:14,100
non-dimensional framework because then

255
00:08:16,730 --> 00:08:15,480
we can understand the effects of various

256
00:08:17,870 --> 00:08:16,740
unknowns because as you can see there

257
00:08:20,120 --> 00:08:17,880
are lots of unknowns in this problem

258
00:08:21,650 --> 00:08:20,130
that affect the solution on water

259
00:08:22,910 --> 00:08:21,660
cycling and nicely we actually found

260
00:08:25,550 --> 00:08:22,920
that there's only one unknown that

261
00:08:26,930 --> 00:08:25,560
really matters and that is how much how

262
00:08:28,400 --> 00:08:26,940
much water you can stuff from the mantle

263
00:08:31,010 --> 00:08:28,410

all the other unknowns are only about a

264
00:08:33,710 --> 00:08:31,020
factor of two make about a factor of two

265
00:08:35,300 --> 00:08:33,720
difference and how and how common water

266
00:08:36,590 --> 00:08:35,310
worlds are and given that we won't be

267
00:08:38,330 --> 00:08:36,600
able to observe too many water worlds

268
00:08:39,520 --> 00:08:38,340
for about twenty years it's not such a

269
00:08:42,050 --> 00:08:39,530
big deal

270
00:08:43,550 --> 00:08:42,060
so okay so what happens if we just

271
00:08:45,380 --> 00:08:43,560
evolve our model looking at these three

272
00:08:46,790 --> 00:08:45,390
different paradigms for water cycling so

273
00:08:48,230 --> 00:08:46,800
here I'm just showing the ocean depths

274
00:08:50,090 --> 00:08:48,240
that are predicted from the model as a

275
00:08:52,250 --> 00:08:50,100
function of time here in billions of

276
00:08:55,550 --> 00:08:52,260
years and so the earth-like ocean depth

277
00:08:56,780 --> 00:08:55,560
is shown by the dashed line and each of

278
00:08:58,490 --> 00:08:56,790
these different lines is for the

279
00:08:59,540 --> 00:08:58,500
different models so you can see that for

280
00:09:02,269 --> 00:08:59,550
the pressure dependent model there's

281
00:09:04,790 --> 00:09:02,279
essentially just a simple

282
00:09:06,500 --> 00:09:04,800
a relaxation to a given ocean depth and

283
00:09:07,790 --> 00:09:06,510
then for the temperature pennant in the

284
00:09:09,650 --> 00:09:07,800
hybrid model because the mantle

285
00:09:11,000 --> 00:09:09,660
temperature is hot as hot at the start

286
00:09:12,949 --> 00:09:11,010
and cools off with time you have initial

287
00:09:14,930 --> 00:09:12,959
really fast outgassing and then really

288
00:09:16,819 --> 00:09:14,940

fast in gassing and the hybrid model you

289
00:09:17,870 --> 00:09:16,829
you end up with something similar to the

290
00:09:19,759 --> 00:09:17,880
pressure dependent model in terms of how

291
00:09:21,019 --> 00:09:19,769
much service water is on the surface but

292
00:09:22,449 --> 00:09:21,029
for the temperature credit model you end

293
00:09:25,310 --> 00:09:22,459
up with very little water on the surface

294
00:09:27,530 --> 00:09:25,320
and so you can see that at the ends of

295
00:09:31,069 --> 00:09:27,540
these integrations I'm running these out

296
00:09:32,569 --> 00:09:31,079
to well past the edge of the universe

297
00:09:34,340 --> 00:09:32,579
each of these lines seems a flattened

298
00:09:36,379 --> 00:09:34,350
out so it looks like a steady-state but

299
00:09:37,819 --> 00:09:36,389
if one looks at this in more detail one

300
00:09:39,500 --> 00:09:37,829
can see that actually the temperature

301
00:09:41,000 --> 00:09:39,510
dependent model is not in a steady state

302
00:09:43,100 --> 00:09:41,010
so here I'm plotting the recasting idea

303
00:09:44,870 --> 00:09:43,110
in via gassing fluxes from the model so

304
00:09:46,400 --> 00:09:44,880
the solid line is the reacting flux and

305
00:09:47,900 --> 00:09:46,410
the dashed lines of the degassing fluxes

306
00:09:49,670 --> 00:09:47,910
from the models of the same colors and

307
00:09:50,750 --> 00:09:49,680
you can see that the hybrid model in the

308
00:09:52,639 --> 00:09:50,760
pressure dependent model do reach a

309
00:09:53,780 --> 00:09:52,649
steady state where the lines balance out

310
00:09:55,970 --> 00:09:53,790
for the two and the temperature

311
00:09:57,740 --> 00:09:55,980
dependent muddle the rege assing at late

312
00:09:59,720 --> 00:09:57,750
times dominates over the degassing and

313
00:10:01,579 --> 00:09:59,730

notably this is actually currently what

314
00:10:02,960 --> 00:10:01,589
what we think is happening on earth and

315
00:10:05,180 --> 00:10:02,970
so this temperature credit model is the

316
00:10:06,800 --> 00:10:05,190
most relevant for Earth but it's

317
00:10:10,519 --> 00:10:06,810
possible at these other paradigms maybe

318
00:10:12,470 --> 00:10:10,529
maybe relevant as well and so now using

319
00:10:13,790 --> 00:10:12,480
these end results these steady States we

320
00:10:16,340 --> 00:10:13,800
can make predictions because their model

321
00:10:17,660 --> 00:10:16,350
is essentially analytic for how much

322
00:10:19,069 --> 00:10:17,670
water you need to become a water roll

323
00:10:21,079 --> 00:10:19,079
just like the count and Abbott and

324
00:10:22,430 --> 00:10:21,089
Abbott model did but now for all these

325
00:10:25,160 --> 00:10:22,440
different paradigms for water cycling

326
00:10:26,449 --> 00:10:25,170
and so doing so here I'm showing this is

327
00:10:27,769 --> 00:10:26,459
the same plot as I showed before if

328
00:10:30,230 --> 00:10:27,779
you're above the line near water world

329
00:10:31,280 --> 00:10:30,240
for a given water mass fraction and if

330
00:10:33,079 --> 00:10:31,290
you're below the line you have partial

331
00:10:34,670 --> 00:10:33,089
Lange coverage and this is again the

332
00:10:36,259 --> 00:10:34,680
x-axis planet master normalized Earth

333
00:10:37,819 --> 00:10:36,269
and I'm showing the earth value of the

334
00:10:40,550 --> 00:10:37,829
water mass fraction which is about 0.05

335
00:10:41,990 --> 00:10:40,560
percent in the dashed line and so I'm

336
00:10:43,069 --> 00:10:42,000
showing these different models so black

337
00:10:44,269 --> 00:10:43,079
line is the temperature dependent model

338
00:10:46,100 --> 00:10:44,279

and you can see that you need quite a

339
00:10:47,540 --> 00:10:46,110
bit of water you need to be about one

340
00:10:49,370 --> 00:10:47,550
percent of water by mass even if you're

341
00:10:50,540 --> 00:10:49,380
a super earth to become a Waterworld at

342
00:10:52,069 --> 00:10:50,550
the temperature dependent paradigm and

343
00:10:54,110 --> 00:10:52,079
the pressure dependent paradigm are

344
00:10:55,730 --> 00:10:54,120
correct I notably this line is

345
00:10:57,860 --> 00:10:55,740
essentially just regulated by how much

346
00:10:59,750 --> 00:10:57,870
water one can fit into the mantle and so

347
00:11:01,519 --> 00:10:59,760
this basically Maxima mental water mass

348
00:11:03,530 --> 00:11:01,529
fraction so slowly determines where this

349
00:11:04,879 --> 00:11:03,540
line is and so if one can stuff more

350
00:11:06,500 --> 00:11:04,889
water into the mantle of the super earth

351
00:11:09,259 --> 00:11:06,510
with a different mineralogy say it has a

352
00:11:10,790 --> 00:11:09,269
post products cat mantle then this line

353
00:11:12,980 --> 00:11:10,800
would move upwards it would be even less

354
00:11:15,199 --> 00:11:12,990
likely that super Earths will be water

355
00:11:15,980 --> 00:11:15,209
world's but you can see that this hybrid

356
00:11:18,080 --> 00:11:15,990
line

357
00:11:19,430 --> 00:11:18,090
is actually very close to a limit where

358
00:11:21,020 --> 00:11:19,440
there's no water cycling at all which is

359
00:11:22,640 --> 00:11:21,030
shown by the dashed out of line this

360
00:11:23,990 --> 00:11:22,650
would basically just be if all the water

361
00:11:25,550 --> 00:11:24,000
available was on the surface and there

362
00:11:27,590 --> 00:11:25,560
were there was no water in the interior

363
00:11:29,240 --> 00:11:27,600

and so if this hybrid model is relevant

364
00:11:30,560 --> 00:11:29,250
one would expect it's about an order of

365
00:11:32,780 --> 00:11:30,570
magnitude easier in terms of how much

366
00:11:34,250 --> 00:11:32,790
water you need as a fraction of the

367
00:11:36,050 --> 00:11:34,260
total planet mass for a plan to become a

368
00:11:38,690 --> 00:11:36,060
water world and so this is a relatively

369
00:11:39,860 --> 00:11:38,700
a large difference and one what one

370
00:11:40,970 --> 00:11:39,870
would expected in the future we might

371
00:11:42,740 --> 00:11:40,980
actually be able to observational e

372
00:11:44,690 --> 00:11:42,750
distinguish this difference with

373
00:11:48,530 --> 00:11:44,700
telescopes issues Lavar making maps of

374
00:11:49,730 --> 00:11:48,540
terrestrial exoplanets and so just hit

375
00:11:51,470 --> 00:11:49,740
the point home that the maximum and

376
00:11:53,450 --> 00:11:51,480
we'll wash water mass fraction is the

377
00:11:55,280 --> 00:11:53,460
key unknown here I'm showing how the

378
00:11:57,230 --> 00:11:55,290
maximum amount of water mass fraction

379
00:11:58,460 --> 00:11:57,240
shown on the x-axis changes the water

380
00:11:59,870 --> 00:11:58,470
mass fraction at which the planet

381
00:12:01,340 --> 00:11:59,880
becomes a water world and we're going to

382
00:12:02,720 --> 00:12:01,350
see that it's essentially just a power

383
00:12:04,940 --> 00:12:02,730
law relationship between the two and so

384
00:12:07,220 --> 00:12:04,950
this is a really key unknown for future

385
00:12:08,420 --> 00:12:07,230
experiments to determine how much water

386
00:12:10,730 --> 00:12:08,430
can you stuff into high pressure

387
00:12:14,870 --> 00:12:10,740
minerals that are not like earth

388
00:12:16,190 --> 00:12:14,880

minerals and so just a parameters only

389
00:12:19,400 --> 00:12:16,200
change the water or boundary by about a

390
00:12:21,680 --> 00:12:19,410
factor of two and so just to summarize

391
00:12:23,180 --> 00:12:21,690
how water cycling depends on properties

392
00:12:24,650 --> 00:12:23,190
of the planet makes a pretty significant

393
00:12:25,910 --> 00:12:24,660
but an order of magnitude difference as

394
00:12:28,130 --> 00:12:25,920
to whether or not water worlds are

395
00:12:29,450 --> 00:12:28,140
common in the universe and potentially

396
00:12:31,400 --> 00:12:29,460
this could be resolved of course just by

397
00:12:32,900 --> 00:12:31,410
understanding better how water cycling

398
00:12:34,190 --> 00:12:32,910
happens on earth right and so we could

399
00:12:36,260 --> 00:12:34,200
have more detailed modeling of Rou

400
00:12:37,579 --> 00:12:36,270
gassing and degassing processes and also

401
00:12:38,900 --> 00:12:37,589
experiments would be nice to show if the

402
00:12:40,430 --> 00:12:38,910
salt hydration does depend on the

403
00:12:41,750 --> 00:12:40,440
overburden pressure and whether or not

404
00:12:44,360 --> 00:12:41,760
this Coward Navarrete prescription is

405
00:12:45,440 --> 00:12:44,370
actually relevant for exoplanets but the

406
00:12:47,690 --> 00:12:45,450
coolest way is because this is an

407
00:12:49,070 --> 00:12:47,700
astrobiology conference is to map

408
00:12:51,110 --> 00:12:49,080
services with pressure electric planets

409
00:12:52,850 --> 00:12:51,120
to reflected light with perhaps leVoir

410
00:12:54,530 --> 00:12:52,860
maybe in twenty years or so and then

411
00:12:56,450 --> 00:12:54,540
actually count how many planets or water

412
00:12:58,730 --> 00:12:56,460
worlds and how many are not and given

413
00:13:00,740 --> 00:12:58,740

some model for the the water delivered

414
00:13:02,810 --> 00:13:00,750
exoplanets like heist I was talking

415
00:13:04,340 --> 00:13:02,820
about earlier then you can basically

416
00:13:05,960 --> 00:13:04,350
figure out which of these models is

417
00:13:08,150 --> 00:13:05,970
correct and so we might be able to and

418
00:13:09,290 --> 00:13:08,160
the very far future use exoplanets to

419
00:13:10,880 --> 00:13:09,300
teach us something about Earth and so I

420
00:13:17,150 --> 00:13:10,890
think that's really neat and thank you

421
00:13:22,170 --> 00:13:20,730
thanks tad we have about a minute or so

422
00:13:23,389 --> 00:13:22,180
for questions and then we'll move into a

423
00:13:25,499 --> 00:13:23,399
discussion

424
00:13:27,389 --> 00:13:25,509
so there's other one of the property

425
00:13:29,519 --> 00:13:27,399
abortions that you didn't speak about

426
00:13:32,160 --> 00:13:29,529
and I'm curious is the salinity of the

427
00:13:34,259 --> 00:13:32,170
water there's adding salt affect the

428
00:13:35,720 --> 00:13:34,269
femini properties enough to change any

429
00:13:38,869 --> 00:13:35,730
of your conclusions

430
00:13:42,350 --> 00:13:38,879
hi I have no idea

431
00:13:44,699 --> 00:13:42,360
yeah I mean I would

432
00:13:46,559 --> 00:13:44,709
it definitely doesn't affect the

433
00:13:48,660 --> 00:13:46,569
outgassing but it may affect in gassing

434
00:13:51,090 --> 00:13:48,670
of water yeah I don't understand some

435
00:13:52,740 --> 00:13:51,100
prepend ization enough but yeah there's

436
00:13:54,569 --> 00:13:52,750
there's that there's been sessions on

437
00:13:56,660 --> 00:13:54,579
that earlier yeah I don't either but

438
00:14:00,090 --> 00:13:56,670

that's great

439
00:14:02,910 --> 00:14:00,100
so my question is about the deep earth

440
00:14:04,650 --> 00:14:02,920
the deep planet minerals which is it's

441
00:14:06,660 --> 00:14:04,660
been shown that bridge night cannot hold

442
00:14:07,769 --> 00:14:06,670
on to water very well at all and even in

443
00:14:10,769 --> 00:14:07,779
a super-earth you would still go through

444
00:14:12,840 --> 00:14:10,779
Bridgman night phase it may be shallow

445
00:14:14,970 --> 00:14:12,850
but you would still have it so if in

446
00:14:17,610 --> 00:14:14,980
this in gassing model if you go through

447
00:14:19,639 --> 00:14:17,620
if your plate or whatever is in gassing

448
00:14:22,490 --> 00:14:19,649
has to go through a region that

449
00:14:25,740 --> 00:14:22,500
nominally can't hold on to water

450
00:14:27,240 --> 00:14:25,750
how does that change the story well that

451
00:14:28,650 --> 00:14:27,250
seems it actually being I mean earth

452
00:14:29,970 --> 00:14:28,660
goes through this the same sort of

453
00:14:31,499 --> 00:14:29,980
transition I didn't talk about this but

454
00:14:32,879 --> 00:14:31,509
most most of Earth's water is stuck at a

455
00:14:34,769 --> 00:14:32,889
region the mental call that transitions

456
00:14:37,050 --> 00:14:34,779
them and so it essentially be the same

457
00:14:38,400 --> 00:14:37,060
story as Earth in terms of these models

458
00:14:40,110 --> 00:14:38,410
all you need to do is just get the water

459
00:14:42,090 --> 00:14:40,120
into the mantle and then how it deep it

460
00:14:43,079 --> 00:14:42,100
goes is not really relevant because it

461
00:14:44,759 --> 00:14:43,089
should just be mixed on the mantle

462
00:14:46,340 --> 00:14:44,769
convection or overturn timescale which

463
00:14:48,269 --> 00:14:46,350

is relatively short

464
00:14:50,850 --> 00:14:48,279
depends on the on the plant on the

465
00:14:52,379 --> 00:14:50,860
planet properties of course but yeah I

466
00:14:54,540 --> 00:14:52,389
would expect not to change the story

467
00:14:56,490 --> 00:14:54,550
that much well I wonder because your the

468
00:14:59,280 --> 00:14:56,500
depth of your transition zone and the

469
00:15:00,870 --> 00:14:59,290
sort of width of your transition zone

470
00:15:02,790 --> 00:15:00,880
should be smaller on super-earths as

471
00:15:06,590 --> 00:15:02,800
well so I'd be I'd be curious to talk to

472
00:15:11,069 --> 00:15:08,790
okay thanks Ted we'll move on to

473
00:15:13,309 --> 00:15:11,079
discussion I certainly have a few

474
00:15:16,650 --> 00:15:13,319
questions but

475
00:15:19,470 --> 00:15:16,660
so we've talked about planet composition

476
00:15:21,139 --> 00:15:19,480
and observe observations and the origins

477
00:15:23,429 --> 00:15:21,149
of water and so

478
00:15:24,710 --> 00:15:23,439
you don't really have a discussion topic

479
00:15:26,610 --> 00:15:24,720
per se but

480
00:15:28,320 --> 00:15:26,620
do we have more questions for the

481
00:15:29,570 --> 00:15:28,330
speaker or do we see a theme popping up

482
00:15:32,130 --> 00:15:29,580
in terms of

483
00:15:38,270 --> 00:15:32,140
the formation of habitable planets and

484
00:15:38,280 --> 00:15:42,530
yeah Elizabeth

485
00:15:46,410 --> 00:15:44,400
questions for last week I may have

486
00:15:49,070 --> 00:15:46,420
missed it but did we talk about topology

487
00:15:50,810 --> 00:15:49,080
and gravity

488
00:15:53,670 --> 00:15:50,820

[Music]

489
00:15:55,500 --> 00:15:53,680
good question so to calculate whether or

490
00:15:58,260 --> 00:15:55,510
not a plant should be a Waterworld we

491
00:16:00,690 --> 00:15:58,270
basically just assume that the maximum

492
00:16:02,370 --> 00:16:00,700
topography of a planet is exactly what

493
00:16:03,960 --> 00:16:02,380
it would be for Earth and so we just say

494
00:16:05,370 --> 00:16:03,970
that the maximum topography is the

495
00:16:06,660 --> 00:16:05,380
Himalayas for an earth-like planet and

496
00:16:08,940 --> 00:16:06,670
then if you increase the mass of the

497
00:16:10,560 --> 00:16:08,950
planet because it has a greater volume

498
00:16:12,600 --> 00:16:10,570
to surface area ratio it should have a

499
00:16:14,760 --> 00:16:12,610
reduced topography and so basically just

500
00:16:16,620 --> 00:16:14,770
have a scaling that says that the

501
00:16:18,690 --> 00:16:16,630
maximum topography is the Himalayas

502
00:16:20,310 --> 00:16:18,700
times gravity to the minus one which

503
00:16:21,570 --> 00:16:20,320
accounts for that and so then we were

504
00:16:22,680 --> 00:16:21,580
when we're tracking whether or not a

505
00:16:25,050 --> 00:16:22,690
planet is the Waterworld you're just

506
00:16:26,370 --> 00:16:25,060
saying if the ocean depth is greater

507
00:16:35,370 --> 00:16:26,380
than what the Himalayas would be on a

508
00:16:39,180 --> 00:16:37,800
can you repeat the question so he asked

509
00:16:40,920 --> 00:16:39,190
about erosion I think I think the

510
00:16:42,690 --> 00:16:40,930
relevant thing is whether or not the

511
00:16:44,670 --> 00:16:42,700
continent would start flowing under its

512
00:16:46,140 --> 00:16:44,680
own weight so it's not a rosin it's it's

513
00:16:48,110 --> 00:16:46,150

a much more serious constraint it's

514
00:16:51,090 --> 00:16:48,120
isostasy yeah I

515
00:16:53,460 --> 00:16:51,100
had a question for Owen which was about

516
00:16:56,510 --> 00:16:53,470
the in regards to what Stephen asked in

517
00:16:59,580 --> 00:16:56,520
terms of magnetic fields is

518
00:17:01,080 --> 00:16:59,590
we know we may not think the earth may

519
00:17:03,120 --> 00:17:01,090
not have had a magnetic field at the

520
00:17:06,030 --> 00:17:03,130
moment it you know had this proto

521
00:17:08,550 --> 00:17:06,040
atmosphere so how quickly would a planet

522
00:17:11,040 --> 00:17:08,560
need to have a magnetic field in order

523
00:17:13,740 --> 00:17:11,050
for that effect even need to be taken to

524
00:17:15,330 --> 00:17:13,750
into account for for an earth-mass

525
00:17:18,000 --> 00:17:15,340
planet you would have to be very quick

526
00:17:20,790 --> 00:17:18,010
it loses its entire proto atmosphere and

527
00:17:21,870 --> 00:17:20,800
maybe ten million years so if you if it

528
00:17:23,970 --> 00:17:21,880
took more than that for a magnetic

529
00:17:25,860 --> 00:17:23,980
fields to form then then I wouldn't even

530
00:17:27,660 --> 00:17:25,870
expect that okay and how about says you

531
00:17:29,970 --> 00:17:27,670
go out to five or six or eight masses

532
00:17:31,860 --> 00:17:29,980
out of that range then you're going past

533
00:17:34,050 --> 00:17:31,870
you know tens of millions of years into

534
00:17:36,390 --> 00:17:34,060
that range so maybe 50 60 million years

535
00:17:38,550 --> 00:17:36,400
for some of the model parameters but is

536
00:17:40,440 --> 00:17:38,560
it ever a billion years or anything like

537
00:17:42,090 --> 00:17:40,450
that by the time you hit seven or eight

538
00:17:43,950 --> 00:17:42,100

earth masses then you're looking at sort

539
00:17:45,600 --> 00:17:43,960
of the billion year time scales but at

540
00:17:47,430 --> 00:17:45,610
that point the XUV flux is dropping off

541
00:17:49,410 --> 00:17:47,440
so you know then the solar wind would

542
00:17:51,870 --> 00:17:49,420
probably be the dominant loss process at

543
00:17:53,070 --> 00:17:51,880
that point instead and then another

544
00:17:56,220 --> 00:17:53,080
question I had was how does that change

545
00:17:57,330 --> 00:17:56,230
with spectral type is like just a

546
00:17:58,950 --> 00:17:57,340
different year for forming planets

547
00:18:00,840 --> 00:17:58,960
around a different star that's not like

548
00:18:02,340 --> 00:18:00,850
so that's actually a great question and

549
00:18:04,470 --> 00:18:02,350
so we were only looking at the sun-like

550
00:18:06,420 --> 00:18:04,480
stars to compare our model to the Rogers

551
00:18:08,640 --> 00:18:06,430
paper which is looking at planets around

552
00:18:10,950 --> 00:18:08,650
sun-like stars since it's difficult to

553
00:18:12,420 --> 00:18:10,960
measure the properties of those those M

554
00:18:15,060 --> 00:18:12,430
dwarf planets because they're so faint

555
00:18:16,830 --> 00:18:15,070
but if you have the that's XE V

556
00:18:19,410 --> 00:18:16,840
saturation time around m dwarf planets

557
00:18:20,670 --> 00:18:19,420
can be much longer than 100 100 million

558
00:18:23,160 --> 00:18:20,680
years that you see for some like stars

559
00:18:25,650 --> 00:18:23,170
in which case I would expect to be able

560
00:18:27,750 --> 00:18:25,660
to erode larger mass planets so you

561
00:18:29,970 --> 00:18:27,760
could maybe get that limiting radii

562
00:18:32,040 --> 00:18:29,980
pushed up a little bit if indeed that

563
00:18:33,510 --> 00:18:32,050

XUV saturation time is lasting for

564
00:18:34,920 --> 00:18:33,520
billions of years in terms closing

565
00:18:36,420 --> 00:18:34,930
planets so that's not something that

566
00:18:38,100 --> 00:18:36,430
I've modeled so I'm not sure if that's

567
00:18:39,560 --> 00:18:38,110
actually how it would turn out

568
00:18:42,210 --> 00:18:39,570
Thanks

569
00:18:46,500 --> 00:18:42,220
any more questions for our speakers sir

570
00:18:48,269 --> 00:18:46,510
yeah excellent yeah Jake go ahead oh and

571
00:18:51,200 --> 00:18:48,279
I have a quick question for you I was

572
00:18:54,000 --> 00:18:51,210
wondering if you know how high up the

573
00:18:56,190 --> 00:18:54,010
the x-ray flux is penetrating so

574
00:18:59,419 --> 00:18:56,200
relative to the surface where the peak

575
00:19:02,039 --> 00:18:59,429
and x-ray absorption is

576
00:19:05,100 --> 00:19:02,049
so the x-ray absorption is typically

577
00:19:06,690 --> 00:19:05,110
within SOTA and a pressure coordinate

578
00:19:09,659 --> 00:19:06,700
would be at about 0.1 so maybe 10

579
00:19:12,840 --> 00:19:09,669
Pascal's from the top of the atmosphere

580
00:19:14,399 --> 00:19:12,850
something to depends how much you how

581
00:19:16,799 --> 00:19:14,409
much atmosphere you have accreted so for

582
00:19:18,320 --> 00:19:16,809
a few weight percent I'm not sure what

583
00:19:21,419 --> 00:19:18,330
the actual

584
00:19:23,340 --> 00:19:21,429
distance and say kilometers would be but

585
00:19:24,720 --> 00:19:23,350
it's so we assumed in our model is that

586
00:19:26,879 --> 00:19:24,730
below that point the atmosphere is in

587
00:19:27,930 --> 00:19:26,889
hydrostatic equilibrium and so you can

588
00:19:30,570 --> 00:19:27,940

just calculate it from the hydrostatic

589
00:19:34,549 --> 00:19:30,580
equation with that that upper pressure

590
00:19:40,610 --> 00:19:38,840
have a question for this

591
00:19:45,779 --> 00:19:40,620
scientist

592
00:19:47,190 --> 00:19:45,789
have you thought about and discussed

593
00:19:49,440 --> 00:19:47,200
with the relevant people the

594
00:19:53,250 --> 00:19:49,450
implications of your discovery that the

595
00:19:56,430 --> 00:19:53,260
Earth's primeval water was a factor of

596
00:20:01,919 --> 00:19:56,440
two or more lower in deuterium than the

597
00:20:05,700 --> 00:20:01,929
ocean because if if the primeval water

598
00:20:07,169 --> 00:20:05,710
is much poorer in in deuterium than for

599
00:20:09,389 --> 00:20:07,179
instance that means that for instance

600
00:20:11,789 --> 00:20:09,399
you got Mars okay it's got six times the

601
00:20:14,250 --> 00:20:11,799
deuterium to hydrogen ratio that Earth

602
00:20:16,919 --> 00:20:14,260
does okay so people been saying well

603
00:20:20,240 --> 00:20:16,929
that means that it once had six times as

604
00:20:24,149 --> 00:20:20,250
much water or more than it does now and

605
00:20:29,100 --> 00:20:24,159
hydrogen went away and the deuterium has

606
00:20:32,940 --> 00:20:29,110
been enriched accordingly but if Mars is

607
00:20:34,549 --> 00:20:32,950
primeval water was only half as rich in

608
00:20:38,129 --> 00:20:34,559
DT reham as

609
00:20:40,169 --> 00:20:38,139
the Earth's ocean and not equal to the

610
00:20:44,240 --> 00:20:40,179
Earth's ocean then it means that Mars

611
00:20:46,649 --> 00:20:44,250
has lost twice as much water than

612
00:20:49,080 --> 00:20:46,659
they think and that means there was a

613
00:20:52,400 --> 00:20:49,090

lot more water on the surface of ancient

614
00:20:55,310 --> 00:20:52,410
Mars than and people currently suppose

615
00:20:57,860 --> 00:20:55,320
and also a lot more water on the ancient

616
00:21:01,430 --> 00:20:57,870
earth for that matter in others that

617
00:21:03,530 --> 00:21:01,440
there's implications this for lots of

618
00:21:14,110 --> 00:21:03,540
things I have you had discussions with

619
00:21:21,980 --> 00:21:18,680
no I haven't I do know that Lydia Callis

620
00:21:24,650 --> 00:21:21,990
has looked at the DTH in some of the

621
00:21:26,750 --> 00:21:24,660
Mars meteorites and has found have found

622
00:21:30,980 --> 00:21:26,760
some that are equivalent to Earth's

623
00:21:34,780 --> 00:21:30,990
oceans so Yoshi I'm not sure that the

624
00:21:37,220 --> 00:21:34,790
data H of Mars has been established yet

625
00:21:39,380 --> 00:21:37,230
certainly this has implications on the

626
00:21:42,020 --> 00:21:39,390
sources of water because if it turns out

627
00:21:44,510 --> 00:21:42,030
we get down as low as the solar nebula

628
00:21:46,670 --> 00:21:44,520
gas then that means we don't need an

629
00:21:48,710 --> 00:21:46,680
exogenous delivery at all it could be

630
00:21:50,930 --> 00:21:48,720
some of the models that just say earth

631
00:21:53,270 --> 00:21:50,940
got its water from the gases out of

632
00:21:55,160 --> 00:21:53,280
which we formed I think this is very

633
00:21:57,500 --> 00:21:55,170
much like a question of what is the

634
00:21:59,960 --> 00:21:57,510
origin of life the farther you dig the

635
00:22:01,820 --> 00:21:59,970
more questions you come up with and I

636
00:22:02,470 --> 00:22:01,830
think we're also seeing that there may

637
00:22:05,090 --> 00:22:02,480
be

638
00:22:06,680 --> 00:22:05,100

processes within the earth that we have

639
00:22:08,170 --> 00:22:06,690
to take account of in terms of

640
00:22:12,290 --> 00:22:08,180
fractionation

641
00:22:16,010 --> 00:22:12,300
mantle and I think that's why Steve is

642
00:22:18,170 --> 00:22:16,020
standing behind me also so I think it's

643
00:22:20,750 --> 00:22:18,180
an interesting story that's now opening

644
00:22:22,490 --> 00:22:20,760
up some new avenues before you come up

645
00:22:24,410 --> 00:22:22,500
to the mic Steve someone was in front of

646
00:22:31,570 --> 00:22:24,420
you in terms of those mic I know we well

647
00:22:35,810 --> 00:22:34,040
hi amber Britt Goddard Space Flight

648
00:22:38,090 --> 00:22:35,820
Center I just had a quick question about

649
00:22:40,250 --> 00:22:38,100
the water worlds talk and being outside

650
00:22:42,350 --> 00:22:40,260
of that particular subject was really

651
00:22:44,990 --> 00:22:42,360
interesting and I wanted to know why

652
00:22:46,400 --> 00:22:45,000
plate tectonics were being assumed for

653
00:22:50,090 --> 00:22:46,410
all these water worlds that a safe

654
00:22:51,680 --> 00:22:50,100
assumption for every water world's

655
00:22:56,270 --> 00:22:51,690
that's terrestrial are we just looking

656
00:22:59,600 --> 00:22:57,920
the inserts because we don't know how

657
00:23:01,300 --> 00:22:59,610
volatile is like we work if it wasn't

658
00:23:04,070 --> 00:23:01,310
plate tectonics

659
00:23:05,540 --> 00:23:04,080
there's work by bread Foley that'll be

660
00:23:06,910 --> 00:23:05,550
coming up soon talking about the

661
00:23:10,850 --> 00:23:06,920
stagnant lid

662
00:23:12,290 --> 00:23:10,860
the dynamics and volatile cycling on

663
00:23:13,720 --> 00:23:12,300

stagnant lead planets so keep an eye out

664
00:23:16,970 --> 00:23:13,730
for that

665
00:23:19,940 --> 00:23:16,980
so I wanted to address Bob's comment

666
00:23:22,250 --> 00:23:19,950
about the Hallett's at all result it is

667
00:23:23,870 --> 00:23:22,260
very hard to lower D to H ratios of

668
00:23:25,250 --> 00:23:23,880
course you can raise d-date ratios by

669
00:23:27,980 --> 00:23:25,260
hydrogen loss but it's hard to lower

670
00:23:30,530 --> 00:23:27,990
them so a low D to H ratio I would argue

671
00:23:33,020 --> 00:23:30,540
does demand and a component of in

672
00:23:36,110 --> 00:23:33,030
gassing of hydrogen gas into the magma

673
00:23:38,690 --> 00:23:36,120
ocean and I present it work we were

674
00:23:42,410 --> 00:23:38,700
doing at ASU at LPS C I presented this a

675
00:23:44,450 --> 00:23:42,420
model that we're soon to publish showing

676
00:23:47,000 --> 00:23:44,460
that we think that earth accreted may be

677
00:23:49,700 --> 00:23:47,010
over ten oceans worth of water and then

678
00:23:51,830 --> 00:23:49,710
immediately stored much of it much of

679
00:23:53,450 --> 00:23:51,840
the hydrogen in the core with an

680
00:23:55,490 --> 00:23:53,460
isotopic fractionation that went along

681
00:23:57,830 --> 00:23:55,500
with that and so I think that might

682
00:24:00,170 --> 00:23:57,840
demand a radically different view of how

683
00:24:01,700 --> 00:24:00,180
water is stored and then that would have

684
00:24:03,140 --> 00:24:01,710
implications for Mars as well although I

685
00:24:06,070 --> 00:24:03,150
don't know what they'd be maybe you want

686
00:24:11,300 --> 00:24:09,410
so on the question of Mars data age we

687
00:24:14,870 --> 00:24:11,310
published a paper paper in science in

688
00:24:17,470 --> 00:24:14,880

2015 in which we had mapped both HDO and

689
00:24:19,370 --> 00:24:17,480
h2o on the planet over several seasons

690
00:24:22,490 --> 00:24:19,380
using high-resolution infrared

691
00:24:24,200 --> 00:24:22,500
spectroscopy and we were able to show

692
00:24:27,130 --> 00:24:24,210
that the data weight ratio in the

693
00:24:31,100 --> 00:24:27,140
atmosphere is in fact a very misleading

694
00:24:33,980 --> 00:24:31,110
number in terms of the average if you do

695
00:24:37,370 --> 00:24:33,990
the analysis properly what you find out

696
00:24:39,710 --> 00:24:37,380
is that the near the polar cap you see

697
00:24:43,190 --> 00:24:39,720
d2h enriched by a factor of eight

698
00:24:45,770 --> 00:24:43,200
relative to be small and this means that

699
00:24:48,050 --> 00:24:45,780
the north polar cap is in fact even more

700
00:24:50,630 --> 00:24:48,060
highly enriched in deuterium than the

701
00:24:52,880 --> 00:24:50,640
atmospheric water that you see and so

702
00:24:54,770 --> 00:24:52,890
based on that we compared that with the

703
00:24:58,160 --> 00:24:54,780
measurement of dido H in a very early

704
00:25:01,490 --> 00:24:58,170
meteorite from Mars which was dated some

705
00:25:04,270 --> 00:25:01,500
years ago just recently and it had to be

706
00:25:07,720 --> 00:25:04,280
small without 1.3

707
00:25:12,190 --> 00:25:07,730
Dida wage was 1.3 be small at four point

708
00:25:12,960 --> 00:25:12,200
three years of age very early but in

709
00:25:16,330 --> 00:25:12,970
addition

710
00:25:19,539 --> 00:25:16,340
curiosity showed that in a Hesperian age

711
00:25:21,310 --> 00:25:19,549
Tito aged near Gale Crater in the soil

712
00:25:24,370 --> 00:25:21,320
was actually enriched by a factor of

713
00:25:26,409 --> 00:25:24,380

three so if you look at this over time

714
00:25:28,720 --> 00:25:26,419
you can estimate the amount of water

715
00:25:33,190 --> 00:25:28,730
that Mars actually had to lose in order

716
00:25:35,289 --> 00:25:33,200
to go from 1.3 be smoked to a little

717
00:25:37,539 --> 00:25:35,299
more than eight in the current reservoir

718
00:25:42,600 --> 00:25:37,549
and that turns out to have been an ocean

719
00:25:44,770 --> 00:25:42,610
the size of the Arctic on Mars or if

720
00:25:46,870 --> 00:25:44,780
scaled to the earth would have been the

721
00:25:49,419 --> 00:25:46,880
North and South Atlantic together it's

722
00:25:52,330 --> 00:25:49,429
about 20% of the cover 20% of the

723
00:25:54,730 --> 00:25:52,340
Earth's surface so anyway it was a lot

724
00:25:57,630 --> 00:25:54,740
of water and the number we came up with

725
00:26:00,340 --> 00:25:57,640
was actually consistent with the

726
00:26:03,279 --> 00:26:00,350
amount that was required to form the

727
00:26:06,430 --> 00:26:03,289
valley channels but I think it was Nick

728
00:26:07,600 --> 00:26:06,440
Baker some 20 years ago who or 25 years

729
00:26:09,669 --> 00:26:07,610
ago we've actually worked on that

730
00:26:11,799 --> 00:26:09,679
problem so there is there are two lines

731
00:26:14,080 --> 00:26:11,809
of evidence that suggest that this was

732
00:26:20,730 --> 00:26:14,090
in fact a correct amount for the amount

733
00:26:26,159 --> 00:26:24,390
which companies Mike

734
00:26:30,669 --> 00:26:26,169
what

735
00:26:34,419 --> 00:26:30,679
the Earth's original if you know it's

736
00:26:38,409 --> 00:26:34,429
people comparing Mars is d2h to what we

737
00:26:42,340 --> 00:26:38,419
commonly see on earth and if there if

738
00:26:45,490 --> 00:26:42,350

the original earth had a d2h ratio much

739
00:26:47,620 --> 00:26:45,500
lower than what we commonly see on earth

740
00:26:51,070 --> 00:26:47,630
that moves the baseline on these

741
00:26:52,840 --> 00:26:51,080
calculations so that it could be twice

742
00:26:56,680 --> 00:26:52,850
as much water in other words if you're

743
00:27:00,460 --> 00:26:56,690
comparing Mars is elevated d2h to you

744
00:27:02,169 --> 00:27:00,470
know the water in the ocean here but

745
00:27:04,480 --> 00:27:02,179
really should be comparing it to the

746
00:27:07,659 --> 00:27:04,490
primeval water here then the then the

747
00:27:09,640 --> 00:27:07,669
elevation is twice as much that's true

748
00:27:13,320 --> 00:27:09,650
but we really compare it with the value

749
00:27:17,130 --> 00:27:13,330
at 4.30 years that is

750
00:27:19,260 --> 00:27:17,140
the young moto meteorite and so that is

751
00:27:20,940 --> 00:27:19,270
irrelevant to what earth had it's really

752
00:27:23,420 --> 00:27:20,950
a quantitative measure what was lost

753
00:27:27,000 --> 00:27:23,430
from Mars over the last four point three

754
00:27:28,500 --> 00:27:27,010
billion years and so one can argue about

755
00:27:31,530 --> 00:27:28,510
whether the Earth's number should be

756
00:27:33,780 --> 00:27:31,540
smaller originally or not in be small

757
00:27:35,820 --> 00:27:33,790
that's a very valid argument but what we

758
00:27:39,420 --> 00:27:35,830
can say is that the u.s. ratio in this

759
00:27:42,390 --> 00:27:39,430
early marta meteorite was in fact forget

760
00:27:44,880 --> 00:27:42,400
about v snow it was essentially nine

761
00:27:47,490 --> 00:27:44,890
times the terrestrial excuse me the

762
00:27:49,380 --> 00:27:47,500
nebular value of d2h okay that's a

763
00:27:51,450 --> 00:27:49,390

better metric in my view because we know

764
00:27:53,730 --> 00:27:51,460
earth isn't be snow is enriched by a

765
00:27:57,120 --> 00:27:53,740
factor of seven but with a Buehler

766
00:27:59,280 --> 00:27:57,130
hydrogen so I think you want to take the

767
00:28:02,640 --> 00:27:59,290
earth out of the picture Mars still lost

768
00:28:04,640 --> 00:28:02,650
an ocean in the last 4.3 billion years

769
00:28:07,560 --> 00:28:04,650
it was on the size of the Arctic Ocean

770
00:28:09,270 --> 00:28:07,570
so something that comes up bringing it

771
00:28:12,620 --> 00:28:09,280
back to the more broad topic of water

772
00:28:15,330 --> 00:28:12,630
worlds is

773
00:28:16,800 --> 00:28:15,340
if that amount of water was delivered to

774
00:28:20,010 --> 00:28:16,810
Mars and this amount of water was

775
00:28:21,600 --> 00:28:20,020
delivered to earth are those small

776
00:28:22,860 --> 00:28:21,610
numbers compared to what we expect on

777
00:28:25,410 --> 00:28:22,870
water worlds or is that a large amount

778
00:28:27,560 --> 00:28:25,420
sort of in the in the broader scope of

779
00:28:30,150 --> 00:28:27,570
planetary diversity

780
00:28:31,160 --> 00:28:30,160
do we have a definition for water worlds

781
00:28:34,320 --> 00:28:31,170
and

782
00:28:36,020 --> 00:28:34,330
I think that's a good play a good

783
00:28:38,100 --> 00:28:36,030
question to start with

784
00:28:40,640 --> 00:28:38,110
okay is there any way to keep track of

785
00:28:43,820 --> 00:28:40,650
where it even came from

786
00:28:47,220 --> 00:28:43,830
so I think

787
00:28:48,750 --> 00:28:47,230
we've got about five minutes note one

788
00:28:52,670 --> 00:28:48,760

minute so you can have that conversation

789
00:28:57,480 --> 00:28:55,110
water world something that has no

790
00:29:00,720 --> 00:28:57,490
continent or is it something that has

791
00:29:04,020 --> 00:29:00,730
one or ten percent water by mass I think

792
00:29:05,340 --> 00:29:04,030
we should decide that well I think you

793
00:29:07,290 --> 00:29:05,350
would be hard-pressed to have continents

794
00:29:10,500 --> 00:29:07,300
if you had ten weight percent water well

795
00:29:12,900 --> 00:29:10,510
right right but but but if it's only

796
00:29:16,200 --> 00:29:12,910
like five oceans and you just submerge

797
00:29:18,960 --> 00:29:16,210
the Himalayas is that now what right

798
00:29:22,470 --> 00:29:18,970
yeah so defining a water world in terms

799
00:29:26,400 --> 00:29:22,480
of its behavior not necessarily

800
00:29:28,770 --> 00:29:26,410
yeah so GCMs that use like full surface

801
00:29:30,720 --> 00:29:28,780
oceans often call them aqua planets so

802
00:29:32,760 --> 00:29:30,730
maybe we could call water world's the

803
00:29:34,200 --> 00:29:32,770
things that are mostly water by mass and

804
00:29:37,620 --> 00:29:34,210
call the things that are covered in

805
00:29:40,490 --> 00:29:37,630
water aqua planets that could work done

806
00:29:43,350 --> 00:29:40,500
thanks Ted I'll stop using the term

807
00:29:46,330 --> 00:29:43,360
alright thank you everyone thank all the