
MODELING VENUS-LIKE WORLDS
THROUGH TIME
MICHAEL WAY

1
00:00:09,190 --> 00:00:06,750
[Music]

2
00:00:10,629 --> 00:00:09,200
thank you again to the organizers as

3
00:00:12,310 --> 00:00:10,639
everyone has said it's absolutely

4
00:00:14,589 --> 00:00:12,320
required to thank them for winning such

5
00:00:16,030 --> 00:00:14,599
a great show here and especially to Rhea

6
00:00:19,240 --> 00:00:16,040
and Philippa for dealing with all of my

7
00:00:20,530 --> 00:00:19,250
registration issues in particular my

8
00:00:21,760 --> 00:00:20,540
voice is a bit weak today so I'm sorry

9
00:00:24,460 --> 00:00:21,770
I've had a bad call for a couple weeks

10
00:00:26,010 --> 00:00:24,470
hopefully it'll hold out so this is some

11
00:00:30,580 --> 00:00:26,020
work I've been doing with Toni del Genio

12
00:00:31,839 --> 00:00:30,590
for the last few years and I hope it'll

13
00:00:34,389 --> 00:00:31,849

convince you to think a bit more about

14
00:00:36,190 --> 00:00:34,399
Venus as an exoplanet in a sense because

15
00:00:37,480 --> 00:00:36,200
there might be some stuff that we're

16
00:00:39,220 --> 00:00:37,490
missing out there and I hope I can

17
00:00:43,390 --> 00:00:39,230
convince you that this is a possible

18
00:00:45,250 --> 00:00:43,400
scenario anyway amongst many others so

19
00:00:47,410 --> 00:00:45,260
what is the motivation in some sense for

20
00:00:49,540 --> 00:00:47,420
Venus as an exoplanet and only we should

21
00:00:50,680 --> 00:00:49,550
rely only upon Earth's through time as

22
00:00:52,510 --> 00:00:50,690
our only indicator of habitability

23
00:00:55,450 --> 00:00:52,520
that's what we really basically rely on

24
00:00:56,920 --> 00:00:55,460
today for most of our modeling of course

25
00:00:58,870 --> 00:00:56,930
paleo Mars and Paleo Venus may offer

26
00:01:00,910 --> 00:00:58,880
some useful habitats and hey maybe Venus

27
00:01:02,350 --> 00:01:00,920
is simply interesting I mean this is

28
00:01:04,240 --> 00:01:02,360
probably the first conference I've been

29
00:01:06,249 --> 00:01:04,250
to in a long time that wasn't a Venus

30
00:01:09,219 --> 00:01:06,259
conference where Venus was mentioned

31
00:01:11,349 --> 00:01:09,229
more than Mars so I gave you people a

32
00:01:12,789 --> 00:01:11,359
lot of crude kudos for that that's

33
00:01:18,190 --> 00:01:12,799
because it has interesting stuff in its

34
00:01:19,209 --> 00:01:18,200
atmosphere that okay so thankfully and I

35
00:01:21,129 --> 00:01:19,219
knew this before and that Laura was

36
00:01:24,129 --> 00:01:21,139
gonna talk about mag motion so that

37
00:01:25,719 --> 00:01:24,139
makes my life a lot easier but I think

38
00:01:27,809 --> 00:01:25,729

we have to basically scenarios here for

39
00:01:30,010 --> 00:01:27,819
a Venus could evolve through time

40
00:01:31,840 --> 00:01:30,020
well Earth and Venus probably start out

41
00:01:35,139 --> 00:01:31,850
as Laura was talking about and a magma

42
00:01:36,639 --> 00:01:35,149
ocean phase and after a few million

43
00:01:38,889 --> 00:01:36,649
years earth would have cooled down and

44
00:01:41,800 --> 00:01:38,899
had some sort of atmosphere as we know

45
00:01:43,330 --> 00:01:41,810
co2 dominated and n2 dominated the

46
00:01:44,739 --> 00:01:43,340
question is what could have happened to

47
00:01:46,929 --> 00:01:44,749
Venus could have ended up in a scenario

48
00:01:49,330 --> 00:01:46,939
where it also cooled down fairly rapidly

49
00:01:52,330 --> 00:01:49,340
after the magma ocean phase or has it

50
00:01:54,969 --> 00:01:52,340
always been this very dense co2

51
00:01:57,879 --> 00:01:54,979
dominated into 450 degree centigrade

52
00:02:02,349 --> 00:01:57,889
beast for its entire evolutionary

53
00:02:04,719 --> 00:02:02,359
history as I said that longevity of the

54
00:02:06,999 --> 00:02:04,729
magma ocean is crucial as Laura showed

55
00:02:09,749 --> 00:02:07,009
out there have been some very nice work

56
00:02:12,280 --> 00:02:09,759
by cake over mono that that Laura showed

57
00:02:14,590 --> 00:02:12,290
that basically shows that if the planet

58
00:02:16,960 --> 00:02:14,600
magma ocean stays around a bit too long

59
00:02:18,180 --> 00:02:16,970
say order 100 million years you outcast

60
00:02:20,580 --> 00:02:18,190
all of your bolts

61
00:02:22,380 --> 00:02:20,590
and this planet is bone-dry from a start

62
00:02:24,900 --> 00:02:22,390
and that work has been backed up by

63
00:02:26,460 --> 00:02:24,910

others since then if you look carefully

64
00:02:28,860 --> 00:02:26,470
at that mono paper though Venus it's

65
00:02:30,690 --> 00:02:28,870
right at the margins of where they

66
00:02:32,460 --> 00:02:30,700
believe that it will either go one way

67
00:02:34,320 --> 00:02:32,470
or that they'd be type 1 or type 2 so we

68
00:02:37,110 --> 00:02:34,330
actually don't know and we probably will

69
00:02:40,440 --> 00:02:37,120
never know until you people get us some

70
00:02:43,170 --> 00:02:40,450
exoplanet data on really young Venus's

71
00:02:44,910 --> 00:02:43,180
around g2 our stars right in the right

72
00:02:46,949 --> 00:02:44,920
phase and we can make some observations

73
00:02:48,720 --> 00:02:46,959
find out if we see a Venus that's only

74
00:02:51,059 --> 00:02:48,730
200 million years or say 50 million

75
00:02:52,530 --> 00:02:51,069
years old and has no magma ocean that

76
00:02:54,059 --> 00:02:52,540
that could be very interesting for

77
00:02:56,550 --> 00:02:54,069
understanding the evolution of these

78
00:02:59,400 --> 00:02:56,560
Magma's and in particular our own nearby

79
00:03:02,940 --> 00:02:59,410
neighbor so the question is was all the

80
00:03:05,750 --> 00:03:02,950
water lost and is it possible to get

81
00:03:08,180 --> 00:03:05,760
some water back through the late venire

82
00:03:10,380 --> 00:03:08,190
mm because we know that of course Earth

83
00:03:12,860 --> 00:03:10,390
it's Meg motion didn't stay around too

84
00:03:15,449 --> 00:03:12,870
long and there has been some work by

85
00:03:16,770 --> 00:03:15,459
Greenwood and others from 2018 that

86
00:03:18,809 --> 00:03:16,780
states the late veneer could have added

87
00:03:20,820 --> 00:03:18,819
between 5 and 30 percent of Earth's

88
00:03:22,199 --> 00:03:20,830

entire water budget now they're pushing

89
00:03:24,330 --> 00:03:22,209
the envelope of course on those kind of

90
00:03:26,099 --> 00:03:24,340
numbers but imagine if you could get the

91
00:03:29,099 --> 00:03:26,109
same kind of water delivery into Venus

92
00:03:30,660 --> 00:03:29,109
later on even if it lost its magma and

93
00:03:32,880 --> 00:03:30,670
as long as the surface is relatively

94
00:03:35,069 --> 00:03:32,890
cool in the atmosphere it's not crazy

95
00:03:35,819 --> 00:03:35,079
hot it may get a sick it may get a

96
00:03:39,140 --> 00:03:35,829
second chance

97
00:03:41,580 --> 00:03:39,150
actually at being a kind of a thin

98
00:03:42,930 --> 00:03:41,590
veneer of water and having some kind of

99
00:03:46,830 --> 00:03:42,940
the reasonable evolutionary history

100
00:03:49,110 --> 00:03:46,840
comparable to that of Earth okay so then

101
00:03:51,000 --> 00:03:49,120
the question becomes is there really any

102
00:03:54,660 --> 00:03:51,010
evidence for surface liquid water in

103
00:03:56,759 --> 00:03:54,670
Venus is history and if so then clouds

104
00:03:58,860 --> 00:03:56,769
in concert with rotation rate may have

105
00:04:01,080 --> 00:03:58,870
played a key role in Venus's climate

106
00:04:02,449 --> 00:04:01,090
evolution some of that is work that you

107
00:04:06,020 --> 00:04:02,459
all have seen before

108
00:04:08,220 --> 00:04:06,030
so did Venus have surface liquid water

109
00:04:09,210 --> 00:04:08,230
we believe for most of the planet

110
00:04:10,710 --> 00:04:09,220
formation models that they probably

111
00:04:12,690 --> 00:04:10,720
started out with around the same amount

112
00:04:14,520 --> 00:04:12,700
of water as Earth given their similar

113
00:04:17,120 --> 00:04:14,530

masses and given their proximity and the

114
00:04:19,349 --> 00:04:17,130
original disk of our solar system I

115
00:04:20,750 --> 00:04:19,359
mentioned this life and near business

116
00:04:23,250 --> 00:04:20,760
that would have also added some water

117
00:04:25,320 --> 00:04:23,260
the key measurement that we have for

118
00:04:27,210 --> 00:04:25,330
Venus it's really this high d2h ratio

119
00:04:29,190 --> 00:04:27,220
that's about 150 times time terrestrial

120
00:04:31,770 --> 00:04:29,200
they got from the Pioneer Venus mission

121
00:04:33,450 --> 00:04:31,780
way back in the 1970s

122
00:04:36,150 --> 00:04:33,460
the whole problem is that we don't know

123
00:04:37,680 --> 00:04:36,160
the time scale of this water loss we

124
00:04:39,330 --> 00:04:37,690
don't know if this was the original

125
00:04:41,160 --> 00:04:39,340
water with that original steam

126
00:04:44,910 --> 00:04:41,170
atmosphere from the magma ocean days or

127
00:04:46,890 --> 00:04:44,920
was this water lost very rapidly in the

128
00:04:49,080 --> 00:04:46,900
last hundred million years or was itwas

129
00:04:49,440 --> 00:04:49,090
lost very slowly over several billion

130
00:04:51,570 --> 00:04:49,450
years

131
00:04:54,900 --> 00:04:51,580
that's information we can get but which

132
00:04:56,820 --> 00:04:54,910
we did not have today there have been

133
00:04:59,040 --> 00:04:56,830
some other observations from Galileo

134
00:05:01,920 --> 00:04:59,050
NIMS this is a paper from Hashimoto in

135
00:05:04,110 --> 00:05:01,930
2018 who who came up with Vidya that's a

136
00:05:06,210 --> 00:05:04,120
lot of the highlands appear to be

137
00:05:07,680 --> 00:05:06,220
composed of felsic rocks and that could

138
00:05:09,450 --> 00:05:07,690

give us some indications that there's

139
00:05:11,640 --> 00:05:09,460
some granitic material there if you have

140
00:05:13,950 --> 00:05:11,650
been any material you have water at some

141
00:05:16,740 --> 00:05:13,960
point in its history whether everybody

142
00:05:17,160 --> 00:05:16,750
believes in this or not that's that's up

143
00:05:19,940 --> 00:05:17,170
for debate

144
00:05:22,110 --> 00:05:19,950
mmm but it's an it's an interesting idea

145
00:05:25,530 --> 00:05:22,120
then there's also this very interesting

146
00:05:28,440 --> 00:05:25,540
two papers from 1990 and then the work

147
00:05:31,950 --> 00:05:28,450
was done in 2019 as well by by shell nut

148
00:05:34,830 --> 00:05:31,960
that threw some quite modeling dependent

149
00:05:37,200 --> 00:05:34,840
aspects believe that veneer a probe

150
00:05:39,330 --> 00:05:37,210
might have encountered a fragment of a

151
00:05:40,890 --> 00:05:39,340
crust from the original Venus that

152
00:05:43,500 --> 00:05:40,900
presentable to trust your green stone

153
00:05:45,390 --> 00:05:43,510
Bell again very modeling dependent but

154
00:05:47,219 --> 00:05:45,400
very enticing but that's all we have

155
00:05:49,020 --> 00:05:47,229
basically that's the only evidence that

156
00:05:50,550 --> 00:05:49,030
we have that there might have been water

157
00:05:53,159 --> 00:05:50,560
on the surface of Venus at some point

158
00:05:55,140 --> 00:05:53,169
it's not very much I admit means that

159
00:05:58,680 --> 00:05:55,150
where a data star field is what it's

160
00:06:00,560 --> 00:05:58,690
telling you okay if we assume that we

161
00:06:03,390 --> 00:06:00,570
have some water on the surface

162
00:06:04,890 --> 00:06:03,400
let me go back to some really great work

163
00:06:07,500 --> 00:06:04,900

by joonyoung and some other people

164
00:06:08,880 --> 00:06:07,510
people in this room they show there's

165
00:06:10,230 --> 00:06:08,890
this very strong dependence on the inner

166
00:06:12,690 --> 00:06:10,240
edge of the habitable zone on planetary

167
00:06:14,250 --> 00:06:12,700
rotation rate so these are our two

168
00:06:16,290 --> 00:06:14,260
figures that people are using all the

169
00:06:18,510 --> 00:06:16,300
time now and on the x-axis here on the

170
00:06:20,130 --> 00:06:18,520
left you see the incident stellar flux

171
00:06:21,870 --> 00:06:20,140
on the world you can see an early Venus

172
00:06:23,340 --> 00:06:21,880
from about 40 years ago that's the kind

173
00:06:25,500 --> 00:06:23,350
of flux it would have had and even

174
00:06:27,630 --> 00:06:25,510
modern-day Venus and then each one of

175
00:06:31,080 --> 00:06:27,640
these curves is a rotation rate speed so

176
00:06:33,330 --> 00:06:31,090
one is Earth's rotation rate today 16 is

177
00:06:37,230 --> 00:06:33,340
16 times Earth's sidereal rotation rate

178
00:06:38,580 --> 00:06:37,240
64 128 and 256 and the key result from

179
00:06:40,920 --> 00:06:38,590
this paper of course is that this is

180
00:06:43,140 --> 00:06:40,930
kind of dichotomy between slow rotators

181
00:06:45,320 --> 00:06:43,150
and fast rotators so as you amp up your

182
00:06:48,140 --> 00:06:45,330
solar insolation on these worlds

183
00:06:50,450 --> 00:06:48,150
these fast rotators quickly go into a

184
00:06:52,610 --> 00:06:50,460
moister runaway greenhouse de whereas

185
00:06:55,820 --> 00:06:52,620
those slow rotators they heat up much

186
00:06:57,499 --> 00:06:55,830
much more slowly on the right you see

187
00:06:58,939 --> 00:06:57,509
the very similar figure for the same

188
00:07:00,230 --> 00:06:58,949

colors for the same rotation rates and

189
00:07:02,240 --> 00:07:00,240
what you see here is planetary albedo

190
00:07:05,119 --> 00:07:02,250
and the key thing here is you see the

191
00:07:10,219 --> 00:07:05,129
planet Obito is rocketing up on these

192
00:07:11,360 --> 00:07:10,229
slow rotators as I think most of you may

193
00:07:12,980 --> 00:07:11,370
know who knows something about these

194
00:07:15,200 --> 00:07:12,990
papers that's basically because the

195
00:07:17,149 --> 00:07:15,210
planet is slowing down of course the

196
00:07:19,249 --> 00:07:17,159
Hadley cells are increasing in size and

197
00:07:21,350 --> 00:07:19,259
you're getting a large cloud convective

198
00:07:23,089 --> 00:07:21,360
front at the substellar point a very

199
00:07:25,580 --> 00:07:23,099
massive sort of anvil cloud of the

200
00:07:26,959 --> 00:07:25,590
substellar point and that's shown in

201
00:07:29,300 --> 00:07:26,969
this very nice figure from joon-young on

202
00:07:30,589 --> 00:07:29,310
the Left we have a rapid rotator this is

203
00:07:33,230 --> 00:07:30,599
the percentage of clouds and you can see

204
00:07:34,879 --> 00:07:33,240
the cloud is a very banded structure and

205
00:07:37,339 --> 00:07:34,889
on the right you can see for the same

206
00:07:39,559 --> 00:07:37,349
solar insolation a slow rotator hundred

207
00:07:42,350 --> 00:07:39,569
twenty eight sidereal day we have this a

208
00:07:43,700 --> 00:07:42,360
massive cloud clean convective cloud at

209
00:07:45,950 --> 00:07:43,710
the subsolar point and this is what

210
00:07:47,659 --> 00:07:45,960
drives that very high planetary video

211
00:07:49,969 --> 00:07:47,669
and that's what keeps the surface warm

212
00:07:51,230 --> 00:07:49,979
and that's what allows the slow rotators

213
00:07:58,399 --> 00:07:51,240

to move the inner edge of the habitable

214
00:08:00,529 --> 00:07:58,409
zone in quite far okay now I need to ask

215
00:08:01,909 --> 00:08:00,539
you like what do we know about Venus's

216
00:08:04,909 --> 00:08:01,919
rotation and obliquity because I've just

217
00:08:07,100 --> 00:08:04,919
explained to you that if Venus has has

218
00:08:09,110 --> 00:08:07,110
had water it has to have the right

219
00:08:11,570 --> 00:08:09,120
rotation rate for it to have the climate

220
00:08:12,920 --> 00:08:11,580
that is that's possible for having some

221
00:08:15,200 --> 00:08:12,930
kind of habitable conditions so the

222
00:08:16,939 --> 00:08:15,210
question is as the rotation rate evolved

223
00:08:21,019 --> 00:08:16,949
through time and what are the prevailing

224
00:08:22,730 --> 00:08:21,029
theories today so there's a long history

225
00:08:25,219 --> 00:08:22,740
of looking at this stuff I think the

226
00:08:26,779 --> 00:08:25,229
most popular hypothesis is a paper that

227
00:08:28,490 --> 00:08:26,789
actually isn't even a paper it's just a

228
00:08:31,040 --> 00:08:28,500
conference abstract but everybody cites

229
00:08:33,529 --> 00:08:31,050
it like it's it's it's it's the greatest

230
00:08:36,889 --> 00:08:33,539
thing and you read you read popular

231
00:08:39,050 --> 00:08:36,899
science articles or you read even quite

232
00:08:40,819 --> 00:08:39,060
reasonable publications who say Venus's

233
00:08:42,740 --> 00:08:40,829
has the rotation rate and obliquity it

234
00:08:45,050 --> 00:08:42,750
has today because of a of a massive

235
00:08:46,939 --> 00:08:45,060
impactor but nobody's actually done the

236
00:08:48,410 --> 00:08:46,949
dirty work on this we can believe it no

237
00:08:50,000 --> 00:08:48,420
one's done a simulation anything like

238
00:08:52,639 --> 00:08:50,010

the work that random robin canook has

239
00:08:55,400 --> 00:08:52,649
done for our own planet moon it's never

240
00:08:56,960 --> 00:08:55,410
been done nobody's interested so it's

241
00:08:59,250 --> 00:08:56,970
low-hanging fruit for some ambitious

242
00:09:03,640 --> 00:08:59,260
graduate student in this world okay

243
00:09:07,660 --> 00:09:03,650
so we don't know then some earlier work

244
00:09:09,070 --> 00:09:07,670
from the 60 of 60s and 70s looking at

245
00:09:11,800 --> 00:09:09,080
core mental friction and atmosphere

246
00:09:13,420 --> 00:09:11,810
titled torques shown I've shown that

247
00:09:15,340 --> 00:09:13,430
it's possible for the Venus to evolve in

248
00:09:17,350 --> 00:09:15,350
time and also they involves some flips

249
00:09:19,540 --> 00:09:17,360
of the obliquity access basically to

250
00:09:20,800 --> 00:09:19,550
drive it into the state it has and

251
00:09:22,680 --> 00:09:20,810
that's really goes back to this like I

252
00:09:26,050 --> 00:09:22,690
said these papers from Goldman sodor

253
00:09:27,460 --> 00:09:26,060
gold Reich and Pele dobrovolsky and

254
00:09:28,690 --> 00:09:27,470
Ingersoll did the really first heavy

255
00:09:31,360 --> 00:09:28,700
lifting and then Lasker and Correa

256
00:09:34,330 --> 00:09:31,370
basically have done this too in finite

257
00:09:37,330 --> 00:09:34,340
detail since the Senate since 2001 and

258
00:09:39,310 --> 00:09:37,340
Ford one thing that I found really

259
00:09:40,650 --> 00:09:39,320
useful and interesting was this great

260
00:09:43,140 --> 00:09:40,660
paper by Jeremy Lacombe and

261
00:09:45,850 --> 00:09:43,150
collaborators from 2015 that show that

262
00:09:48,340 --> 00:09:45,860
all of these works here assuming that

263
00:09:50,140 --> 00:09:48,350

you have this 90 bar atmosphere and that

264
00:09:51,670 --> 00:09:50,150
is causing the title torque that keeps

265
00:09:55,180 --> 00:09:51,680
it in the retrograde rotation state

266
00:09:56,830 --> 00:09:55,190
basically the idea before was that you

267
00:09:58,420 --> 00:09:56,840
didn't have this super thick atmosphere

268
00:10:00,850 --> 00:09:58,430
the planet would eventually end up in a

269
00:10:02,080 --> 00:10:00,860
tightly lock state but Jeremy showed

270
00:10:04,570 --> 00:10:02,090
through some very nice simulations that

271
00:10:05,620 --> 00:10:04,580
even with a 1 bar atmosphere you can

272
00:10:08,580 --> 00:10:05,630
still end up in a retrograde rotation

273
00:10:11,380 --> 00:10:08,590
state which is really interesting for us

274
00:10:13,570 --> 00:10:11,390
ok so in the meantime we've done it a

275
00:10:15,790 --> 00:10:13,580
couple more simulations looking at solid

276
00:10:17,260 --> 00:10:15,800
body tidal dissipation and possible

277
00:10:18,900 --> 00:10:17,270
ocean cuddle dissipation which I think

278
00:10:21,190 --> 00:10:18,910
you might find interesting

279
00:10:23,110 --> 00:10:21,200
so these are some calculations that I've

280
00:10:25,120 --> 00:10:23,120
done using an equilibrium tide model

281
00:10:27,790 --> 00:10:25,130
developed by Rory Barnes at University

282
00:10:29,080 --> 00:10:27,800
of Washington on the left is a constant

283
00:10:30,460 --> 00:10:29,090
phase lag version of that model and

284
00:10:31,660 --> 00:10:30,470
constant time lag version I'm gonna

285
00:10:33,040 --> 00:10:31,670
constantly I'm gonna focus on the

286
00:10:35,350 --> 00:10:33,050
constant phase lag because it gives me

287
00:10:36,790 --> 00:10:35,360
the answers I want we don't know which

288
00:10:41,980 --> 00:10:36,800

one of these models is correct to be

289
00:10:44,170 --> 00:10:41,990
honest I use a keep win and a love

290
00:10:47,260 --> 00:10:44,180
number two that are values similar to

291
00:10:49,660 --> 00:10:47,270
earth or lack of having any reasonable Q

292
00:10:50,980 --> 00:10:49,670
values for ancient Venus and we have not

293
00:10:52,840 --> 00:10:50,990
really great constraints on either he's

294
00:10:55,480 --> 00:10:52,850
numbers for modern Venus either we just

295
00:10:56,500 --> 00:10:55,490
don't were just a data star field but

296
00:10:59,080 --> 00:10:56,510
the key on the left here is this

297
00:11:00,610 --> 00:10:59,090
constant phase lag model is that if

298
00:11:02,560 --> 00:11:00,620
Venus starts out with a three-day

299
00:11:04,750 --> 00:11:02,570
rotation period in this model and ends

300
00:11:08,350 --> 00:11:04,760
up synchronous 3 Earth Day rotation ends

301
00:11:10,450 --> 00:11:08,360
up synchronous in 684 million years if

302
00:11:12,030 --> 00:11:10,460
it starts out with a 15-day rotation

303
00:11:14,670 --> 00:11:12,040
period it go

304
00:11:17,040 --> 00:11:14,680
synchronous in 132 million years so the

305
00:11:19,650 --> 00:11:17,050
solid-body tides on Venus will slow this

306
00:11:22,530 --> 00:11:19,660
planet down fairly rapidly depending on

307
00:11:24,629 --> 00:11:22,540
what its initial rotation rate was this

308
00:11:26,490 --> 00:11:24,639
is context this is nice paper from Rory

309
00:11:29,819 --> 00:11:26,500
Barnes in 2018 where he uses the same

310
00:11:31,499 --> 00:11:29,829
model he assumes that if earth had not

311
00:11:33,720 --> 00:11:31,509
been hit by the moon and had started out

312
00:11:37,290 --> 00:11:33,730
with a three-day rotation period it

313
00:11:39,090 --> 00:11:37,300

would have gone synchronous about now so

314
00:11:40,710 --> 00:11:39,100
if we had had the moon impact earth

315
00:11:42,269 --> 00:11:40,720
would be approaching a title lock state

316
00:11:44,040 --> 00:11:42,279
as we speak which would be kind of

317
00:11:45,809 --> 00:11:44,050
interesting because we always have this

318
00:11:47,610 --> 00:11:45,819
idea when we do our modeling of

319
00:11:50,220 --> 00:11:47,620
exoplanets that all these planets have

320
00:11:51,780 --> 00:11:50,230
the same spin state as Earth right when

321
00:11:56,939 --> 00:11:51,790
they're out at Earth's orbit that may

322
00:11:58,769 --> 00:11:56,949
not be a very good assumption okay this

323
00:12:01,290 --> 00:11:58,779
is another paper that I've been working

324
00:12:04,620 --> 00:12:01,300
on with Matthias green at the school of

325
00:12:05,160 --> 00:12:04,630
ocean sciences in Bangor Wales and Rory

326
00:12:08,100 --> 00:12:05,170
Barnes

327
00:12:09,809 --> 00:12:08,110
mm-hmm a bit more speculative but the

328
00:12:11,430 --> 00:12:09,819
idea here is to use a numerical ocean

329
00:12:14,220 --> 00:12:11,440
type model that is very commonly used in

330
00:12:17,040 --> 00:12:14,230
the ocean sciences community we took a

331
00:12:19,500 --> 00:12:17,050
modern venous topography with a with two

332
00:12:21,120 --> 00:12:19,510
different kinds of depth ocean we did a

333
00:12:22,860 --> 00:12:21,130
whole suite of simulation using

334
00:12:26,790 --> 00:12:22,870
rotational periods from what Venus is

335
00:12:29,670 --> 00:12:26,800
today - 23 - pro-grade plus 64 sidereal

336
00:12:32,579 --> 00:12:29,680
day and the title dissipation just from

337
00:12:34,019 --> 00:12:32,589
the ocean varies by five orders of

338
00:12:35,519 --> 00:12:34,029

magnitude depending on where you are in

339
00:12:38,430 --> 00:12:35,529
this parameter space and the maximum

340
00:12:41,660 --> 00:12:38,440
slowdown for this model is that it will

341
00:12:43,980 --> 00:12:41,670
slow down by 72 days per million years

342
00:12:46,829 --> 00:12:43,990
so total dissipation from a shallow

343
00:12:48,120 --> 00:12:46,839
ocean on Venus is extremely efficient at

344
00:12:49,410 --> 00:12:48,130
slowing down the rotation rate of this

345
00:12:50,879 --> 00:12:49,420
world another thing we should be

346
00:12:54,059 --> 00:12:50,889
thinking about when we think about

347
00:12:55,530 --> 00:12:54,069
rotation rates of exoplanets should this

348
00:12:57,689 --> 00:12:55,540
be surprising I don't I'm not so sure

349
00:12:59,670 --> 00:12:57,699
because on earth we already know that

350
00:13:01,379 --> 00:12:59,680
the total love for the subtle earth is

351
00:13:03,360 --> 00:13:01,389
much lower than the total love for the

352
00:13:04,439 --> 00:13:03,370
ocean so we already know that the oceans

353
00:13:06,000 --> 00:13:04,449
are dissipating are much more

354
00:13:08,939 --> 00:13:06,010
dissipative on earth and the solid-body

355
00:13:10,110 --> 00:13:08,949
torques are so that shouldn't be so

356
00:13:12,210 --> 00:13:10,120
surprising although some of my friends

357
00:13:15,470 --> 00:13:12,220
who work in dynamics were surprised by

358
00:13:19,160 --> 00:13:17,750
okay so now that I've giving you all

359
00:13:20,510 --> 00:13:19,170
that and I'm gonna make these

360
00:13:22,430 --> 00:13:20,520
assumptions that the planet has been

361
00:13:26,450 --> 00:13:22,440
slit has been spinning slowly for most

362
00:13:28,550 --> 00:13:26,460
of its history and it had some kind of

363
00:13:31,340 --> 00:13:28,560

atmosphere early on and it's gonna show

364
00:13:34,400 --> 00:13:31,350
you some some fairly simple simulation

365
00:13:37,160 --> 00:13:34,410
so this is using our rocky 3d general

366
00:13:38,240 --> 00:13:37,170
circulation model and I'm just going to

367
00:13:39,800 --> 00:13:38,250
talk quickly about a couple different

368
00:13:42,230 --> 00:13:39,810
atmospheres of tried so we went back to

369
00:13:44,410 --> 00:13:42,240
4.2 giga years ago when the insulation

370
00:13:47,330 --> 00:13:44,420
that Venus was receiving was about 40%

371
00:13:50,660 --> 00:13:47,340
what earth receives today and I gave it

372
00:13:52,520 --> 00:13:50,670
a hundred percent co2 atmosphere because

373
00:13:53,960 --> 00:13:52,530
there are some models that show that

374
00:13:55,400 --> 00:13:53,970
early Earth's atmosphere could have been

375
00:13:57,350 --> 00:13:55,410
very I mean very early Earth's

376
00:13:59,420 --> 00:13:57,360
atmosphere could have been a pure co2

377
00:14:01,850 --> 00:13:59,430
atmosphere before the nitrogen started

378
00:14:03,050 --> 00:14:01,860
getting out mixing things up then we

379
00:14:04,310 --> 00:14:03,060
have another simulation a set of

380
00:14:06,590 --> 00:14:04,320
simulations at point seventy eighty

381
00:14:09,350 --> 00:14:06,600
years ago where we're receiving about

382
00:14:11,000 --> 00:14:09,360
70% more rated incidents flux than the

383
00:14:13,520 --> 00:14:11,010
nurse receiving we use a very modern

384
00:14:14,720 --> 00:14:13,530
earth composition in that sense assuming

385
00:14:15,980 --> 00:14:14,730
that some kind of carbon and silicate

386
00:14:17,510 --> 00:14:15,990
cycle would have taken place in the

387
00:14:19,400 --> 00:14:17,520
planet carbon would have been drawn down

388
00:14:22,550 --> 00:14:19,410

nitrogen would have gone up and other

389
00:14:24,590 --> 00:14:22,560
species would have been produced and

390
00:14:27,050 --> 00:14:24,600
then given the fact that Venus is

391
00:14:28,580 --> 00:14:27,060
topography from four billion years ago

392
00:14:30,770 --> 00:14:28,590
or 1 billion years ago it's completely

393
00:14:33,530 --> 00:14:30,780
unknown because the surface of Venus is

394
00:14:34,640 --> 00:14:33,540
is is one of the youngest surfaces in

395
00:14:36,350 --> 00:14:34,650
the solar system it's less than a

396
00:14:38,120 --> 00:14:36,360
billion years old we know that from

397
00:14:39,800 --> 00:14:38,130
crater counts I tried a whole slew of

398
00:14:41,480 --> 00:14:39,810
different we try to whole slew of

399
00:14:43,880 --> 00:14:41,490
different topography so the first one we

400
00:14:46,250 --> 00:14:43,890
did using the first we are using modern

401
00:14:47,240 --> 00:14:46,260
Venus topography in lieu of using

402
00:14:49,730 --> 00:14:47,250
anything else because there's sort of

403
00:14:51,530 --> 00:14:49,740
the least worst choice that we have the

404
00:14:53,870 --> 00:14:51,540
first one is an Ave type dune world

405
00:14:55,940 --> 00:14:53,880
where we only put twenty centimeters of

406
00:14:58,960 --> 00:14:55,950
water in the soil so that limits the

407
00:15:01,280 --> 00:14:58,970
amount of h2o into the atmosphere and

408
00:15:02,990 --> 00:15:01,290
basically eight h2o is an efficient

409
00:15:05,180 --> 00:15:03,000
greenhouse gases as Lara showed us with

410
00:15:06,470 --> 00:15:05,190
some of her stuff earlier then we have

411
00:15:08,930 --> 00:15:06,480
another simulation we put ten meter

412
00:15:10,400 --> 00:15:08,940
water equivalent layer and lakes in the

413
00:15:12,320 --> 00:15:10,410

lowest lying regions of the planet we

414
00:15:14,390 --> 00:15:12,330
let the planet evolve in time and we as

415
00:15:16,640 --> 00:15:14,400
a model decide where the water should

416
00:15:18,410 --> 00:15:16,650
actually go so it will do a calculation

417
00:15:20,630 --> 00:15:18,420
based on evaporation versus

418
00:15:21,980 --> 00:15:20,640
precipitation versus runoff and it

419
00:15:23,120 --> 00:15:21,990
distributes the model model quite

420
00:15:25,850 --> 00:15:23,130
differently than what you would expect

421
00:15:27,230 --> 00:15:25,860
from your initial conditions and the

422
00:15:29,360 --> 00:15:27,240
third one was a three ten meter deep

423
00:15:31,340 --> 00:15:29,370
ocean basically we use in our

424
00:15:33,410 --> 00:15:31,350
sixteen paper again using modern Venus

425
00:15:35,360 --> 00:15:33,420
topography and then because everyone

426
00:15:37,070 --> 00:15:35,370
uses modern modern earth topography we

427
00:15:39,110 --> 00:15:37,080
also did that for fun of course it never

428
00:15:40,519 --> 00:15:39,120
had modern orthography but we just use

429
00:15:42,890 --> 00:15:40,529
it for a different kind of topography

430
00:15:46,610 --> 00:15:42,900
with a three ten meter deep bathtub

431
00:15:48,560 --> 00:15:46,620
ocean we use these kind of depths of the

432
00:15:50,450 --> 00:15:48,570
ocean because the DTH ratio estimate

433
00:15:52,940 --> 00:15:50,460
does give us a very broad window the

434
00:15:54,800 --> 00:15:52,950
driver trucks through from the donahue

435
00:15:56,030 --> 00:15:54,810
and russell papers from the 80s they

436
00:15:59,750 --> 00:15:56,040
basically said that venus could have had

437
00:16:01,550 --> 00:15:59,760
anywhere between five and 550 meters of

438
00:16:03,230 --> 00:16:01,560

water water equivalent across the

439
00:16:05,660 --> 00:16:03,240
surface so that's why we have a lot of

440
00:16:06,800 --> 00:16:05,670
room to play with here and because aqua

441
00:16:08,840 --> 00:16:06,810
planets are very popular in this

442
00:16:12,410 --> 00:16:08,850
community we also did an aqua ponic just

443
00:16:14,000 --> 00:16:12,420
for fun so instead of showing you lots

444
00:16:16,460 --> 00:16:14,010
of plots with lots of lines and lots of

445
00:16:19,850 --> 00:16:16,470
points i've been inspired by calling

446
00:16:21,290 --> 00:16:19,860
Goldblatt's talk back in CC t p3 so you

447
00:16:23,300 --> 00:16:21,300
can crucify him if you don't like my

448
00:16:25,130 --> 00:16:23,310
cartoon drawing of what i'm about to

449
00:16:28,010 --> 00:16:25,140
show you so this is all of the

450
00:16:30,320 --> 00:16:28,020
simulations and a really fancy cartoon i

451
00:16:34,100 --> 00:16:30,330
would call it in a sense so what you see

452
00:16:35,510 --> 00:16:34,110
on the left here is the temperature of

453
00:16:38,240 --> 00:16:35,520
the world and then on the bottom axis

454
00:16:40,730 --> 00:16:38,250
you see a timeline from 4 Giga years ago

455
00:16:42,920 --> 00:16:40,740
where the insulation was 40% more than

456
00:16:45,829 --> 00:16:42,930
present-day earth 70 % and even i did

457
00:16:48,530 --> 00:16:45,839
some simulations today what happens here

458
00:16:50,920 --> 00:16:48,540
is still completely unknown and can stun

459
00:16:53,570 --> 00:16:50,930
constrained as Laura said we don't know

460
00:16:55,160 --> 00:16:53,580
how fast this planet cooled down we

461
00:16:56,630 --> 00:16:55,170
don't know the timescale we don't know

462
00:16:59,480 --> 00:16:56,640
what the atmosphere was even made of but

463
00:17:01,040 --> 00:16:59,490

I'm gonna assume because of the ideas of

464
00:17:02,930 --> 00:17:01,050
using compared to climatology they

465
00:17:04,910 --> 00:17:02,940
probably had a co2 down eight atmosphere

466
00:17:07,549 --> 00:17:04,920
if you take all those topographies I

467
00:17:09,470 --> 00:17:07,559
used for co2 dominated atmospheres the

468
00:17:11,960 --> 00:17:09,480
temperature ranges for any of those

469
00:17:13,520 --> 00:17:11,970
topographies even at a co2 dominated

470
00:17:15,679 --> 00:17:13,530
atmosphere because of the slow rotation

471
00:17:18,740 --> 00:17:15,689
of the world and the effects the clouds

472
00:17:20,090 --> 00:17:18,750
have on their planetary albedo I get a

473
00:17:24,679 --> 00:17:20,100
range of temperatures from somewhere

474
00:17:27,110 --> 00:17:24,689
around 30 to 50 degrees centigrade so

475
00:17:29,900 --> 00:17:27,120
it's not it's not a it's not a crazy

476
00:17:31,669 --> 00:17:29,910
world the stratosphere and some of these

477
00:17:33,710 --> 00:17:31,679
models does have a lot of water vapour

478
00:17:35,600 --> 00:17:33,720
in it which means the plan is going to

479
00:17:38,300 --> 00:17:35,610
lose what ocean it has over some time

480
00:17:39,440 --> 00:17:38,310
scale which we haven't calculated and

481
00:17:40,610 --> 00:17:39,450
then the idea again as I said is that

482
00:17:42,110 --> 00:17:40,620
there would be some kind of carbon in

483
00:17:43,280 --> 00:17:42,120
silicates cycle of course it won't be

484
00:17:44,720 --> 00:17:43,290
linear like this

485
00:17:46,460 --> 00:17:44,730
it'll go up and down and all kinds of

486
00:17:48,110 --> 00:17:46,470
things will happen but the last

487
00:17:51,140 --> 00:17:48,120
simulation or one of the last emulation

488
00:17:54,230 --> 00:17:51,150

she did was at 0.7 0.0 0.7 giggy years

489
00:17:56,870 --> 00:17:54,240
ago again with that into co2 dominate

490
00:17:57,800 --> 00:17:56,880
atmosphere and you get temperatures that

491
00:18:01,070 --> 00:17:57,810
are quite a bit lower

492
00:18:02,450 --> 00:18:01,080
they're basically between 15 and 30

493
00:18:05,390 --> 00:18:02,460
degrees centigrade no matter what your

494
00:18:07,040 --> 00:18:05,400
topography is now why did I kind of stop

495
00:18:08,630 --> 00:18:07,050
there because the surface is completely

496
00:18:10,700 --> 00:18:08,640
new to us we don't know what happened

497
00:18:13,520 --> 00:18:10,710
but the idea in this model would be that

498
00:18:15,200 --> 00:18:13,530
the planet evolved in time and that what

499
00:18:16,910 --> 00:18:15,210
drove the planet into its present-day

500
00:18:19,280 --> 00:18:16,920
state was some kind of major overturning

501
00:18:21,020 --> 00:18:19,290
event the results of which we see on the

502
00:18:23,240 --> 00:18:21,030
surface today that very new surface we

503
00:18:25,070 --> 00:18:23,250
see on Venus and that's what drove the

504
00:18:27,410 --> 00:18:25,080
planet into its present state where the

505
00:18:29,240 --> 00:18:27,420
co2 was released from the carbonate that

506
00:18:31,790 --> 00:18:29,250
were locked up on the surface into the

507
00:18:33,890 --> 00:18:31,800
atmosphere over a fairly short timescale

508
00:18:35,720 --> 00:18:33,900
say hundreds of millions of years it

509
00:18:36,830 --> 00:18:35,730
will not be a catastrophic resurfacing I

510
00:18:38,750 --> 00:18:36,840
think that's pretty much agreed in the

511
00:18:39,920 --> 00:18:38,760
Venus community now it's not like it's

512
00:18:41,660 --> 00:18:39,930
overturn event and the resurfacing

513
00:18:43,430 --> 00:18:41,670

happened like in the blink of an eye

514
00:18:44,540 --> 00:18:43,440
geologically which is 50 hundred million

515
00:18:47,000 --> 00:18:44,550
years we're talking about hundreds of

516
00:18:48,650 --> 00:18:47,010
millions of years but that would drive

517
00:18:51,650 --> 00:18:48,660
to pun it into the into the current

518
00:18:53,180 --> 00:18:51,660
runaway greenhouse date but we did do

519
00:18:54,860 --> 00:18:53,190
one more simulate a set of simulations

520
00:18:57,080 --> 00:18:54,870
again where we kept this set of modern

521
00:19:02,300 --> 00:18:57,090
day earth and to dominate atmosphere and

522
00:19:03,530 --> 00:19:02,310
even today at one point 999 time one

523
00:19:05,450 --> 00:19:03,540
point nine times what earth receives

524
00:19:07,190 --> 00:19:05,460
today in terms of solar insolation the

525
00:19:08,240 --> 00:19:07,200
temperature the atmosphere for any of

526
00:19:10,220 --> 00:19:08,250
these simulations didn't change very

527
00:19:11,600 --> 00:19:10,230
much and that corresponds actually to a

528
00:19:13,880 --> 00:19:11,610
couple of simulations that joonyoung

529
00:19:18,890 --> 00:19:13,890
actually did in this 2014 paper that

530
00:19:21,050 --> 00:19:18,900
don't get a lot of press so I think this

531
00:19:23,720 --> 00:19:21,060
fits kind of nicely in with an old paper

532
00:19:26,420 --> 00:19:23,730
that I really like from John Valle from

533
00:19:27,490 --> 00:19:26,430
2002 the papers titled a cool early

534
00:19:30,050 --> 00:19:27,500
Earth

535
00:19:33,380 --> 00:19:30,060
now John plots has access the other way

536
00:19:35,570 --> 00:19:33,390
so again I I took Liberty and redrew his

537
00:19:37,730 --> 00:19:35,580
plot for you so on the Left axis you see

538
00:19:39,830 --> 00:19:37,740

impact rate there's some kind of

539
00:19:42,470 --> 00:19:39,840
planetary accretion here and the planets

540
00:19:44,180 --> 00:19:42,480
he does a very nice job of looking at

541
00:19:47,030 --> 00:19:44,190
zircon ages he's gone all the way back

542
00:19:49,250 --> 00:19:47,040
to 4.3 Giga years ago now in his 2014

543
00:19:51,800 --> 00:19:49,260
paper to show that Earth probably had

544
00:19:54,920 --> 00:19:51,810
this cool period very early on in its

545
00:19:56,420 --> 00:19:54,930
history back then there were a lot more

546
00:19:57,200 --> 00:19:56,430
proponents I would say in the community

547
00:19:59,570 --> 00:19:57,210
for the LH

548
00:20:01,909 --> 00:19:59,580
but I think that a lot of that that

549
00:20:06,080 --> 00:20:01,919
enthusiasm has gone by the wayside in

550
00:20:08,029 --> 00:20:06,090
recent years but if this is true

551
00:20:09,919 --> 00:20:08,039
these zircon measurements by Valley and

552
00:20:11,870 --> 00:20:09,929
many others we probably certainly had

553
00:20:13,909 --> 00:20:11,880
most surface temperatures we had liquid

554
00:20:15,680 --> 00:20:13,919
water we have continental crust that's

555
00:20:17,000 --> 00:20:15,690
that's work that's also been supported

556
00:20:20,180 --> 00:20:17,010
by a couple of really nice papers by

557
00:20:24,019 --> 00:20:20,190
Corey Naga and collaborators and just

558
00:20:26,630 --> 00:20:24,029
yesterday I saw this paper by Moses and

559
00:20:28,789 --> 00:20:26,640
brass er who were at Colorado and lcn

560
00:20:29,960 --> 00:20:28,799
collaborators that say that show

561
00:20:31,760 --> 00:20:29,970
basically the same thing they have some

562
00:20:33,289 --> 00:20:31,770
very beautiful plots in there and their

563
00:20:35,659 --> 00:20:33,299

paper that show almost the same thing as

564
00:20:36,980 --> 00:20:35,669
valley has here but without the LHB

565
00:20:39,220 --> 00:20:36,990
because they are not good performance to

566
00:20:41,539 --> 00:20:39,230
the LHB the let you have a bombardment

567
00:20:42,889 --> 00:20:41,549
so this kind of fits nicely into that

568
00:20:45,260 --> 00:20:42,899
picture I showed you for Venus if the

569
00:20:47,180 --> 00:20:45,270
planet can cool down early then you end

570
00:20:49,730 --> 00:20:47,190
up in this very cool early phase pretty

571
00:20:53,480 --> 00:20:49,740
easily again depending on rotation rate

572
00:20:55,430 --> 00:20:53,490
for Venus and and that it has surface

573
00:20:56,870 --> 00:20:55,440
liquid water for Earth we don't have

574
00:20:58,100 --> 00:20:56,880
that problem but in the interest of

575
00:21:01,720 --> 00:20:58,110
compared to comet ology I thought this

576
00:21:05,570 --> 00:21:01,730
was a really interesting picture to see

577
00:21:07,190 --> 00:21:05,580
okay so I would also like to talk about

578
00:21:09,169 --> 00:21:07,200
this in the tents of the the Kane zone

579
00:21:11,299 --> 00:21:09,179
I'm sorry I meant that the Venus zone

580
00:21:13,330 --> 00:21:11,309
that's a reminder for you guys to all go

581
00:21:15,950 --> 00:21:13,340
look at Steven Kane's poster tomorrow on

582
00:21:19,639 --> 00:21:15,960
Venus as an exoplanet or ex planetary

583
00:21:20,810 --> 00:21:19,649
laboratory so idea here is that we have

584
00:21:22,159 --> 00:21:20,820
that this Venus own which people

585
00:21:24,649 --> 00:21:22,169
basically have been ignoring for years

586
00:21:25,970 --> 00:21:24,659
and in terms of the habitable zone and I

587
00:21:28,610 --> 00:21:25,980
once it I want to promote the idea of

588
00:21:30,409 --> 00:21:28,620

what I call the optimistic Venus zone we

589
00:21:32,060 --> 00:21:30,419
always think these ridiculous labels for

590
00:21:33,470 --> 00:21:32,070
things optimistic habitable zone you

591
00:21:35,659 --> 00:21:33,480
know pessimistic habitable zone

592
00:21:36,440 --> 00:21:35,669
conservative habitable zone pretty thing

593
00:21:38,570 --> 00:21:36,450
we're gonna have like the Trump

594
00:21:41,120 --> 00:21:38,580
habitable zone but I want to stick with

595
00:21:42,200 --> 00:21:41,130
the optimistic Venus zone it's what I

596
00:21:43,940 --> 00:21:42,210
want to promote to you and that we

597
00:21:46,220 --> 00:21:43,950
shouldn't discount all of these these

598
00:21:48,039 --> 00:21:46,230
worlds sitting in here we have to know

599
00:21:50,299 --> 00:21:48,049
the rotation rates of these planets

600
00:21:52,190 --> 00:21:50,309
before we really go looking at them and

601
00:21:53,720 --> 00:21:52,200
maybe more ten to twenty years away from

602
00:21:56,899 --> 00:21:53,730
from doing that depends on who you talk

603
00:21:58,070 --> 00:21:56,909
to and what they think our next

604
00:21:59,990 --> 00:21:58,080
generation of telescopes going to be

605
00:22:01,850 --> 00:22:00,000
capable of but we shouldn't discard all

606
00:22:03,500 --> 00:22:01,860
these just like we shouldn't discard our

607
00:22:05,360 --> 00:22:03,510
nearest neighbor which is completely

608
00:22:07,010 --> 00:22:05,370
neglected by the planetary science

609
00:22:09,019 --> 00:22:07,020
community for the most part I mean Mars

610
00:22:10,960 --> 00:22:09,029
gets a mission every 18 months or or

611
00:22:13,060 --> 00:22:10,970
more and Venus gets in

612
00:22:14,860 --> 00:22:13,070
maybe every 10 years if it's lucky we

613
00:22:18,250 --> 00:22:14,870

haven't had an institution mission to

614
00:22:19,240 --> 00:22:18,260
Venus since the 1980s basically that's

615
00:22:21,549 --> 00:22:19,250
why we don't know anything about this

616
00:22:22,810 --> 00:22:21,559
appointment and one other thing I want

617
00:22:24,700 --> 00:22:22,820
to show you very quickly that our model

618
00:22:25,990 --> 00:22:24,710
outputs at the very end is some direct

619
00:22:28,330 --> 00:22:26,000
imaging spectrum now there's no noise

620
00:22:29,830 --> 00:22:28,340
model in this or anything but on the

621
00:22:32,020 --> 00:22:29,840
left you can see that co2 dominate

622
00:22:34,029 --> 00:22:32,030
atmosphere is very easy to detect you

623
00:22:35,770 --> 00:22:34,039
have these very large bands co2 bands

624
00:22:37,930 --> 00:22:35,780
that were very easy to detect compared

625
00:22:39,700 --> 00:22:37,940
to the in to dominate atmosphere in

626
00:22:41,380 --> 00:22:39,710
terms of the thermal light that you can

627
00:22:44,049 --> 00:22:41,390
rip detection ones this is from 4 to 20

628
00:22:45,730 --> 00:22:44,059
microns so this kind of thing would be

629
00:22:47,440 --> 00:22:45,740
observable in a fairly even in a fairly

630
00:22:49,750 --> 00:22:47,450
young Venus even a few hundred million

631
00:22:53,500 --> 00:22:49,760
years old if it had this kind of surface

632
00:22:55,169 --> 00:22:53,510
habitable water conditions okay

633
00:22:57,730 --> 00:22:55,179
so I want to try to keep my talk short

634
00:22:59,200 --> 00:22:57,740
so my point is that if a cool early

635
00:23:00,700 --> 00:22:59,210
Venus had surface like what it's not

636
00:23:02,140 --> 00:23:00,710
clear that solar luminosity is the

637
00:23:04,930 --> 00:23:02,150
defining factor in its climate evolution

638
00:23:06,520 --> 00:23:04,940

why do I say that because I read things

639
00:23:08,560 --> 00:23:06,530
in the popular press about this all the

640
00:23:10,899 --> 00:23:08,570
time Venus had liquid oceans and if the

641
00:23:12,399 --> 00:23:10,909
Sun got warmer and warmer the oceans

642
00:23:14,680 --> 00:23:12,409
boiled off and then it was the end of

643
00:23:17,470 --> 00:23:14,690
the world our models do not ship it in

644
00:23:18,880 --> 00:23:17,480
any any way at all and and this guy is

645
00:23:20,260 --> 00:23:18,890
one of the guys to blame for it Paul

646
00:23:21,399 --> 00:23:20,270
Sutter at Ohio State here it is but as

647
00:23:22,990 --> 00:23:21,409
the Sun age that half of those own

648
00:23:24,010 --> 00:23:23,000
steadily moved outward and as Venus

649
00:23:26,500 --> 00:23:24,020
approached the inner edge of the zone

650
00:23:28,000 --> 00:23:26,510
things started to go haywire doesn't

651
00:23:33,669 --> 00:23:28,010
work in school okay

652
00:23:35,230 --> 00:23:33,679
anyway optimistic Venus zone exoplanet

653
00:23:36,490 --> 00:23:35,240
habitability essence require rotation

654
00:23:38,680 --> 00:23:36,500
rate knowledge I think I think it's do

655
00:23:40,930 --> 00:23:38,690
we need Venus in situ observations to

656
00:23:42,880 --> 00:23:40,940
Khmers geologic and volatile history

657
00:23:45,340 --> 00:23:42,890
that means all these beautiful noble

658
00:23:47,440 --> 00:23:45,350
gases and all of their isotopes it's the

659
00:23:49,779 --> 00:23:47,450
only way we're gonna know if this planet

660
00:23:51,490 --> 00:23:49,789
ever had liquid water in its surface and

661
00:23:54,159 --> 00:23:51,500
when it lost that water and how it lost

662
00:23:55,659 --> 00:23:54,169
that water no mapping mission nothing

663
00:23:57,399 --> 00:23:55,669

from orbits ever gonna tell us any of

664
00:23:58,690 --> 00:23:57,409
that so dude ever tells you I want to do

665
00:23:59,919 --> 00:23:58,700
an orbital mission for Venus it's gonna

666
00:24:03,220 --> 00:23:59,929
be so great we're gonna get all this you

667
00:24:05,500 --> 00:24:03,230
can tell them no we need noble gas

668
00:24:07,080 --> 00:24:05,510
abundances and so for this for this

669
00:24:09,640 --> 00:24:07,090
reason I give the Russians great credit

670
00:24:12,060 --> 00:24:09,650
they're really trying hard to redo the

671
00:24:15,460 --> 00:24:12,070
the Vega missions but kind of amped up

672
00:24:17,830 --> 00:24:15,470
once more to do one more mission to the

673
00:24:20,020 --> 00:24:17,840
surface some of us are going to Moscow

674
00:24:23,409 --> 00:24:20,030
next month to do some landing site

675
00:24:24,490 --> 00:24:23,419
selection and hope the NASA will pony up

676
00:24:25,840 --> 00:24:24,500
some money it is to put

677
00:24:27,790 --> 00:24:25,850
balloon instrument on this mission and

678
00:24:29,920 --> 00:24:27,800
get us these noble gas instruments

679
00:24:33,010 --> 00:24:29,930
Institute on the surface from that

680
00:24:34,660 --> 00:24:33,020
Russian spacecraft the question is will

681
00:24:36,730 --> 00:24:34,670
Venus is history constrained possible

682
00:24:37,900 --> 00:24:36,740
exoplanetary climates don't know it

683
00:24:39,520 --> 00:24:37,910
depends if we go back to the surface of

684
00:24:40,900 --> 00:24:39,530
Venus and otherwise if you're gonna tell

685
00:24:42,190 --> 00:24:40,910
us everything about Venus cuz we ain't

686
00:24:43,900 --> 00:24:42,200
gonna know our nearest neighbor is

687
00:24:45,850 --> 00:24:43,910
gonna be sittin there waiting for us to

688
00:24:56,770 --> 00:24:45,860

make some it anyway thank you very much

689
00:24:57,970 --> 00:24:56,780
I'm so glad my voice fell down we have

690
00:25:04,840 --> 00:24:57,980
time for questions

691
00:25:09,700 --> 00:25:07,450
Edwin kite University of Chicago what's

692
00:25:12,820 --> 00:25:09,710
observation either from liberal gases or

693
00:25:15,310 --> 00:25:12,830
other sources were disproved the early

694
00:25:17,500 --> 00:25:15,320
habitable fetus hypothesis what would

695
00:25:18,700 --> 00:25:17,510
disprove it well if we did find out that

696
00:25:21,820 --> 00:25:18,710
it lost all of its water in the first

697
00:25:24,010 --> 00:25:21,830
hundred million years that the noble

698
00:25:24,340 --> 00:25:24,020
gases will tell us that that's all we

699
00:25:31,000 --> 00:25:24,350
need

700
00:25:34,060 --> 00:25:31,010
I hate that was a excellent talk thank

701
00:25:36,040 --> 00:25:34,070
you a lot of the work that shows the

702
00:25:37,480 --> 00:25:36,050
dependence of the state of the

703
00:25:38,860 --> 00:25:37,490
sensitivity of the climate of the

704
00:25:41,110 --> 00:25:38,870
rotation rate will depend on cloud

705
00:25:43,360 --> 00:25:41,120
feedback parameters so as any of the

706
00:25:46,060 --> 00:25:43,370
uncertainty of that or maybe convection

707
00:25:48,220 --> 00:25:46,070
scale modeling being looked at not in

708
00:25:51,100 --> 00:25:48,230
not in detail no but it has been seen in

709
00:25:52,660 --> 00:25:51,110
three different GCMs that have coated up

710
00:25:54,760 --> 00:25:52,670
their cloud convection schemes in

711
00:25:59,280 --> 00:25:54,770
completely different ways so that's all

712
00:26:02,500 --> 00:25:59,290
I can say on that I was encouraged by

713
00:26:04,600 --> 00:26:02,510

awareness II was his talk I was anyway I

714
00:26:06,070 --> 00:26:04,610
was too conversed by this by this by by

715
00:26:08,050 --> 00:26:06,080
Dennis's talk sorry by Dennis's talk

716
00:26:10,150 --> 00:26:08,060
yesterday that showed this very detailed

717
00:26:12,760 --> 00:26:10,160
of cloud resolving model in its

718
00:26:14,080 --> 00:26:12,770
comparison to the GCM if I don't think

719
00:26:15,370 --> 00:26:14,090
he did it on purpose it was kind of

720
00:26:17,380 --> 00:26:15,380
portrayed like a GCM doesn't do a very

721
00:26:18,490 --> 00:26:17,390
good job but I actually think the GCM

722
00:26:20,350 --> 00:26:18,500
did a very good job if you look at his

723
00:26:22,450 --> 00:26:20,360
figures very carefully it mimics very

724
00:26:24,250 --> 00:26:22,460
nicely with the cloud resolving model

725
00:26:26,680 --> 00:26:24,260
legs are actually doing so I think the

726
00:26:28,600 --> 00:26:26,690
GCMs are doing a quiet good job we have

727
00:26:30,370 --> 00:26:28,610
also completely rewritten our claude

728
00:26:32,500 --> 00:26:30,380
convection scheme for our next version

729
00:26:33,940 --> 00:26:32,510
of the model but the earth climate model

730
00:26:35,680 --> 00:26:33,950
it's going to come out next year and

731
00:26:37,270 --> 00:26:35,690
we're going to release the planetary

732
00:26:38,289 --> 00:26:37,280
version of that it's one of the first

733
00:26:43,799 --> 00:26:38,299
things we're gonna chest out

734
00:26:54,430 --> 00:26:52,599
you methods obey from a Geneva

735
00:26:56,259 --> 00:26:54,440
Observatory I would like to know if you

736
00:26:58,509 --> 00:26:56,269
explore whether this crowd feedback

737
00:27:01,419 --> 00:26:58,519
could also work if the background

738
00:27:03,129 --> 00:27:01,429

pressure was ire and if they were like a

739
00:27:04,959 --> 00:27:03,139
freak suit atmosphere is it something

740
00:27:08,589 --> 00:27:04,969
that could be robust to thicker

741
00:27:11,049 --> 00:27:08,599
atmosphere I think it is I've only done

742
00:27:12,190 --> 00:27:11,059
a couple bars Co to my goal is to do up

743
00:27:14,469 --> 00:27:12,200
to ten bars because we have the

744
00:27:15,819 --> 00:27:14,479
radiation tables for that and I just

745
00:27:17,259 --> 00:27:15,829
haven't gotten around to it but I think

746
00:27:20,049 --> 00:27:17,269
it's a really great idea I mean I

747
00:27:22,149 --> 00:27:20,059
actually I put a proposal and recently

748
00:27:23,889 --> 00:27:22,159
to one of the Roses programs to work

749
00:27:26,379 --> 00:27:23,899
with Roxanna lucu who some of whose data

750
00:27:28,060 --> 00:27:26,389
Lara showed and Mark Marley and Kevin's

751
00:27:30,729 --> 00:27:28,070
on Lee and Stephen canes in that

752
00:27:32,859 --> 00:27:30,739
proposal to to really redo some of those

753
00:27:34,810 --> 00:27:32,869
tamaño models and loop whose models

754
00:27:36,879 --> 00:27:34,820
early on but put clouds and actually

755
00:27:38,279 --> 00:27:36,889
didn't have clouds in those models so we

756
00:27:41,799 --> 00:27:38,289
are going to put clouds in and then

757
00:27:44,289 --> 00:27:41,809
bring those models down from say you

758
00:27:46,269 --> 00:27:44,299
know thousand bar atmospheres whatever

759
00:27:48,549 --> 00:27:46,279
you want very high temperatures and then

760
00:27:50,769 --> 00:27:48,559
down to where my model can meet them say

761
00:27:52,749 --> 00:27:50,779
at ten thirty forty bars because their

762
00:27:54,519 --> 00:27:52,759
models are all you know much lower

763
00:27:56,019 --> 00:27:54,529

dimensionally models obviously and then

764
00:27:58,119 --> 00:27:56,029
see what we can see if we can if we can

765
00:28:00,399 --> 00:27:58,129
tie up assuming that their models are

766
00:28:01,930 --> 00:28:00,409
giving answers that are useful to our

767
00:28:09,149 --> 00:28:01,940
models inputs basically down the road

768
00:28:16,139 --> 00:28:13,629
you know so I'm going back to one of

769
00:28:19,569 --> 00:28:16,149
castings early papers he remarked that

770
00:28:22,930 --> 00:28:19,579
clouds could would tend to inhibit the

771
00:28:26,739 --> 00:28:22,940
the true runaway greenhouse of in for

772
00:28:28,690 --> 00:28:26,749
early Venus but but he argued that that

773
00:28:31,389 --> 00:28:28,700
the the moist green house effect or what

774
00:28:33,999 --> 00:28:31,399
I call the wet runaway would lose the

775
00:28:36,369 --> 00:28:34,009
water just fine anyway and so you

776
00:28:38,319 --> 00:28:36,379
mentioned that that your stratosphere is

777
00:28:41,919 --> 00:28:38,329
get moist in a lot of these cases and so

778
00:28:45,669 --> 00:28:41,929
I just knew wonder whether that just

779
00:28:48,039 --> 00:28:45,679
negates this whole added ability

780
00:28:50,709 --> 00:28:48,049
range yeah it's a good point right it

781
00:28:52,120 --> 00:28:50,719
depends on which simulation it is and

782
00:28:54,130 --> 00:28:52,130
the strategies are not all

783
00:28:56,320 --> 00:28:54,140
weighs the same witness and I haven't

784
00:28:57,850 --> 00:28:56,330
done any actual calculations to know you

785
00:29:01,090 --> 00:28:57,860
know what the longevity of those oceans

786
00:29:02,890 --> 00:29:01,100
are I mean in castings paper he loses a

787
00:29:05,320 --> 00:29:02,900
whole Earth's ocean but over four

788
00:29:07,630 --> 00:29:05,330

billion years so it's not like if the

789
00:29:08,890 --> 00:29:07,640
stratosphere is as wet as he says it is

790
00:29:10,570 --> 00:29:08,900
it's gonna lose it in the billionaires

791
00:29:12,700 --> 00:29:10,580
for 500 million years it depends on what

792
00:29:14,260 --> 00:29:12,710
the how much water vapor is up there and

793
00:29:16,090 --> 00:29:14,270
what is the incident flux on the

794
00:29:17,620 --> 00:29:16,100
atmosphere so it depends but you might

795
00:29:21,280 --> 00:29:17,630
like to know that Jim Pollock also wrote

796
00:29:23,590 --> 00:29:21,290
a paper in like this in 1977 I think

797
00:29:25,750 --> 00:29:23,600
where he does the same thing he uses a

798
00:29:28,270 --> 00:29:25,760
1d model he uses a hundred percent cloud

799
00:29:29,410 --> 00:29:28,280
cover for Venus and he gets 300 K for

800
00:29:31,660 --> 00:29:29,420
the surface temperature he's the first

801
00:29:32,980 --> 00:29:31,670
person to ever do that actually funny

802
00:29:35,500 --> 00:29:32,990
enough he didn't know why to use why

803
00:29:36,850 --> 00:29:35,510
he's 100 percent cloud cover but it

804
00:29:41,950 --> 00:29:36,860
turned out it was a good choice for

805
00:29:48,250 --> 00:29:41,960
reasons he didn't understand give you

806
00:29:50,350 --> 00:29:48,260
one more question so I'm gonna make it

807
00:29:51,430 --> 00:29:50,360
two but the first one is quick do you

808
00:29:54,850 --> 00:29:51,440
think we should go back to the surface

809
00:29:56,590 --> 00:29:54,860
of Venus no no okay okay the other is

810
00:29:59,860 --> 00:29:56,600
actually I got a little fixated on a

811
00:30:01,960 --> 00:29:59,870
small point you made about how it

812
00:30:02,860 --> 00:30:01,970
weren't through the impact that forms

813
00:30:04,720 --> 00:30:02,870

the moon the earth

814
00:30:07,090 --> 00:30:04,730
might be tightly synchronized by now

815
00:30:09,340 --> 00:30:07,100
yeah and so there's nice that set our

816
00:30:11,140 --> 00:30:09,350
expectations for exoplanets yes but then

817
00:30:13,390 --> 00:30:11,150
I'm also remembering that during Laura's

818
00:30:16,150 --> 00:30:13,400
talk you referenced some paper that

819
00:30:19,030 --> 00:30:16,160
predicted the planets should in general

820
00:30:20,530 --> 00:30:19,040
have a few impacts during the plant

821
00:30:21,940 --> 00:30:20,540
information process and then I'm

822
00:30:24,220 --> 00:30:21,950
wondering where 3 was what her model

823
00:30:25,720 --> 00:30:24,230
showed I think right and so if we think

824
00:30:28,060 --> 00:30:25,730
that most planets should have some

825
00:30:30,160 --> 00:30:28,070
impact how does that plus this

826
00:30:33,340 --> 00:30:30,170
information set our expectation for

827
00:30:36,970 --> 00:30:33,350
rotation rates terrestrial planet good

828
00:30:39,160 --> 00:30:36,980
question anyone like I said I would like

829
00:30:41,800 --> 00:30:39,170
someone to do the the moon impact for

830
00:30:43,090 --> 00:30:41,810
Venus and tell me can you get retrograde

831
00:30:44,890 --> 00:30:43,100
rotation rate out of that impact

832
00:30:47,080 --> 00:30:44,900
depending on what the rotation rate of

833
00:30:50,940 --> 00:30:47,090
the world was to start it's those are

834
00:30:52,830 --> 00:30:50,950
really good questions yeah we don't know