
AbSciCon
2017
MESA, ARIZONA

1
00:00:06,160 --> 00:00:12,250
you

2
00:00:18,130 --> 00:00:15,310
[Music]

3
00:00:19,960 --> 00:00:18,140
this is update on a project that I'm

4
00:00:22,900 --> 00:00:19,970
doing in sorrow seekers like with the

5
00:00:25,810 --> 00:00:22,910
amateurs and the audience looking at a

6
00:00:28,870 --> 00:00:25,820
systematic database of gases that could

7
00:00:31,390 --> 00:00:28,880
be biosignatures on the world the logic

8
00:00:33,250 --> 00:00:31,400
is this we don't know what gases other

9
00:00:36,070 --> 00:00:33,260
types of biochemistry might produce and

10
00:00:38,020 --> 00:00:36,080
so we take a list of all possible gases

11
00:00:39,790 --> 00:00:38,030
and filter them through different

12
00:00:41,799 --> 00:00:39,800
selections to come up with ones that

13
00:00:43,330 --> 00:00:41,809

could be atmospheric signatures down the

14
00:00:45,729 --> 00:00:43,340
bottom here and I'm going to be talking

15
00:00:48,450 --> 00:00:45,739
about the geochemical fourth positives

16
00:00:51,040 --> 00:00:48,460
things that might be produced by

17
00:00:53,830 --> 00:00:51,050
geochemistry Janish talked at last AB

18
00:00:55,510 --> 00:00:53,840
saikhan about the list so I'm not going

19
00:00:59,229 --> 00:00:55,520
to talk about this it's a long list or

20
00:01:02,049 --> 00:00:59,239
writes 14,000 molecules some of which

21
00:01:03,670 --> 00:01:02,059
are quite weird from a biochemical point

22
00:01:05,830 --> 00:01:03,680
of view I have talked about the ones

23
00:01:07,690 --> 00:01:05,840
that might be readily produced by

24
00:01:09,820 --> 00:01:07,700
geochemical processes because those are

25
00:01:11,800 --> 00:01:09,830
poor biosignatures we see them on an

26
00:01:15,310 --> 00:01:11,810
exoplanet we don't know whether they are

27
00:01:18,190 --> 00:01:15,320
produced by life or by geochemical

28
00:01:20,530 --> 00:01:18,200
processes and so the question I want to

29
00:01:24,250 --> 00:01:20,540
ask is which of that 14k are likely to

30
00:01:25,870 --> 00:01:24,260
produce by geological processes and the

31
00:01:27,640 --> 00:01:25,880
initial step we're doing this in the

32
00:01:30,609 --> 00:01:27,650
thermodynamic one say are they

33
00:01:32,410 --> 00:01:30,619
thermodynamically likely to be made we

34
00:01:33,910 --> 00:01:32,420
want a general solution not the sort of

35
00:01:35,770 --> 00:01:33,920
this is what are still solution but

36
00:01:38,130 --> 00:01:35,780
obviously I'm going to use as a testbed

37
00:01:42,670 --> 00:01:38,140
to see what the methods work at all

38
00:01:47,679 --> 00:01:42,680

that's an amazingly bright light okay

39
00:01:48,490 --> 00:01:47,689
so this is the approach we want the if

40
00:01:49,870 --> 00:01:48,500
we're going to look at the

41
00:01:51,340 --> 00:01:49,880
thermodynamics of whether something is

42
00:01:53,920 --> 00:01:51,350
produced we want to know what the free

43
00:01:55,749 --> 00:01:53,930
energy of formation is you can get that

44
00:02:00,160 --> 00:01:55,759
from a database for this web book

45
00:02:02,440 --> 00:02:00,170
database thank you or if it's not known

46
00:02:04,630 --> 00:02:02,450
then you can calculate it from semi

47
00:02:08,289 --> 00:02:04,640
empirical quantum mechanical methods we

48
00:02:10,840 --> 00:02:08,299
use the game's software to do that over

49
00:02:12,670 --> 00:02:10,850
96% of the molecules in our database

50
00:02:15,120 --> 00:02:12,680
don't have reported free energies of

51
00:02:18,550 --> 00:02:15,130
formation so we had to calculate

52
00:02:20,640 --> 00:02:18,560
enthalpy entropy and specific heat

53
00:02:23,020 --> 00:02:20,650
capacity to work out the energy of

54
00:02:25,390 --> 00:02:23,030
synthesis the other question is since

55
00:02:26,410 --> 00:02:25,400
this from what so volcanoes put out a

56
00:02:27,610 --> 00:02:26,420
lot of gases

57
00:02:30,190 --> 00:02:27,620
and you can assemble them in different

58
00:02:32,140 --> 00:02:30,200
ways to make a molecule so for example

59
00:02:34,990 --> 00:02:32,150
this is glycine and you could make live

60
00:02:36,640 --> 00:02:35,000
seed by this reaction here in theory

61
00:02:38,380 --> 00:02:36,650
okay I'm not saying how it happens or

62
00:02:40,240 --> 00:02:38,390
from this one here these are different

63
00:02:43,150 --> 00:02:40,250

gases and heads will have a different

64
00:02:44,860 --> 00:02:43,160
free energy of formation and how do you

65
00:02:47,770 --> 00:02:44,870
compensate for that well you don't you

66
00:02:50,620 --> 00:02:47,780
look at all of them all combinations of

67
00:02:54,729 --> 00:02:50,630
the different volcanic gases co2 methane

68
00:02:57,370 --> 00:02:54,739
nitrogen ammonia and so on and say what

69
00:02:59,290 --> 00:02:57,380
is the maximum free energy and that's

70
00:03:01,479 --> 00:02:59,300
that the sort of ultimate limit of the

71
00:03:04,660 --> 00:03:01,489
minimum which suggests that this might

72
00:03:07,930 --> 00:03:04,670
happen in a volcanic system so this is

73
00:03:10,750 --> 00:03:07,940
the sort of data we get out this is the

74
00:03:12,729 --> 00:03:10,760
number of molecules produced out of our

75
00:03:15,490 --> 00:03:12,739
database and this is the free energy of

76
00:03:17,520 --> 00:03:15,500
formation from elements in their

77
00:03:19,690 --> 00:03:17,530
standard state there's quite a spread

78
00:03:21,430 --> 00:03:19,700
but it's not terribly interesting

79
00:03:23,740 --> 00:03:21,440
because the elements are not in their

80
00:03:26,170 --> 00:03:23,750
standard state in volcanic gas

81
00:03:28,930 --> 00:03:26,180
this is synthesis from volcanic gases

82
00:03:30,699 --> 00:03:28,940
over here again number of gases and free

83
00:03:34,120 --> 00:03:30,709
energy of formation anything lower than

84
00:03:36,009 --> 00:03:34,130
zero means that's a negative free energy

85
00:03:38,110 --> 00:03:36,019
of formation that means that the

86
00:03:41,319 --> 00:03:38,120
reaction as modeled here is

87
00:03:42,819 --> 00:03:41,329
thermodynamically favored quite a big

88
00:03:44,740 --> 00:03:42,829

spread and some obvious to the bulges

89
00:03:46,000 --> 00:03:44,750
and humps and the curve these guys over

90
00:03:48,819 --> 00:03:46,010
here are mostly compounds with

91
00:03:50,410 --> 00:03:48,829
phosphorous atoms in these guys over

92
00:03:53,440 --> 00:03:50,420
here mostly compounds with nitrogen

93
00:03:54,940 --> 00:03:53,450
atoms in which is interesting and we

94
00:03:58,780 --> 00:03:54,950
haven't followed up on that yet I said

95
00:04:00,759 --> 00:03:58,790
working progress okay and you could do

96
00:04:02,590 --> 00:04:00,769
that for all temperatures so that was

97
00:04:04,170 --> 00:04:02,600
just one temperature one pressure you

98
00:04:07,449 --> 00:04:04,180
can do that for all temperatures and

99
00:04:09,970 --> 00:04:07,459
variety of pressures so here we have

100
00:04:12,430 --> 00:04:09,980
temperature and here we have free energy

101
00:04:15,250 --> 00:04:12,440
of formation and the color scale here is

102
00:04:17,409 --> 00:04:15,260
the number of molecules falling into

103
00:04:19,870 --> 00:04:17,419
that free energy range for that

104
00:04:22,779 --> 00:04:19,880
particular temperature and those look

105
00:04:24,760 --> 00:04:22,789
very pretty and they tell you that as

106
00:04:27,190 --> 00:04:24,770
you increase pressure from one bar here

107
00:04:28,980 --> 00:04:27,200
to 217 this is arbitrary by the way this

108
00:04:31,810 --> 00:04:28,990
is just the critical pressure of water

109
00:04:33,610 --> 00:04:31,820
you get more molecules that are likely

110
00:04:36,720 --> 00:04:33,620
to be formed thermodynamically in other

111
00:04:39,330 --> 00:04:36,730
words it's lower down the scale

112
00:04:41,100 --> 00:04:39,340
the maximum value is higher than the

113
00:04:43,830 --> 00:04:41,110

minimum value always nice to have that

114
00:04:45,510 --> 00:04:43,840
sort of check in your software as you

115
00:04:47,340 --> 00:04:45,520
increase the temperature the number of

116
00:04:49,440 --> 00:04:47,350
sable molecules goes down and all this

117
00:04:52,110 --> 00:04:49,450
is totally expected what isn't expected

118
00:04:53,190 --> 00:04:52,120
is that is this sort of kink here in the

119
00:04:55,980 --> 00:04:53,200
curve and that's where it becomes

120
00:04:59,160 --> 00:04:55,990
thermodynamically favored on the right

121
00:05:01,020 --> 00:04:59,170
to make the molecules from methane and

122
00:05:04,920 --> 00:05:01,030
on the left to make them from carbon

123
00:05:06,360 --> 00:05:04,930
dioxide and hydrogen this can be done

124
00:05:09,060 --> 00:05:06,370
for everything and then what we ask is

125
00:05:10,770 --> 00:05:09,070
how many molecules for below Delta G

126
00:05:12,480 --> 00:05:10,780
equals zero here in other words our

127
00:05:13,110 --> 00:05:12,490
thermodynamically favored under these

128
00:05:18,180 --> 00:05:13,120
conditions

129
00:05:20,670 --> 00:05:18,190
are sort of average volcanic gas if you

130
00:05:22,680 --> 00:05:20,680
look up in apps for a chemistry book

131
00:05:24,210 --> 00:05:22,690
what gases the volcanoes put into the

132
00:05:26,250 --> 00:05:24,220
atmosphere and they come up with a

133
00:05:29,640 --> 00:05:26,260
number that is an average earth is not

134
00:05:32,010 --> 00:05:29,650
an average so to try to get a little bit

135
00:05:35,550 --> 00:05:32,020
nearer to what they're actually does we

136
00:05:37,260 --> 00:05:35,560
looked at actual volcanic locales 53

137
00:05:40,020 --> 00:05:37,270
locales around 60 different papers

138
00:05:41,730 --> 00:05:40,030

recording nearly 600 measurements of the

139
00:05:44,610 --> 00:05:41,740
actual gases coming out of the earth and

140
00:05:46,140 --> 00:05:44,620
did the modeling with that with the

141
00:05:48,810 --> 00:05:46,150
partial pressure of gases at these

142
00:05:50,280 --> 00:05:48,820
locations the temperature at them we

143
00:05:52,110 --> 00:05:50,290
discarded the ones below a hundred

144
00:06:00,110 --> 00:05:52,120
degrees because this is the gas phase

145
00:06:03,660 --> 00:06:02,250
the issues with that is of course that

146
00:06:06,930 --> 00:06:03,670
not all gases are measured at all

147
00:06:08,520 --> 00:06:06,940
locations so we had to fill in the ones

148
00:06:10,140 --> 00:06:08,530
that weren't measured and there are two

149
00:06:11,900 --> 00:06:10,150
ways to doing that you could run a

150
00:06:13,770 --> 00:06:11,910
dynamic model of that gas or

151
00:06:15,630 --> 00:06:13,780
thermodynamic model of the whole system

152
00:06:17,760 --> 00:06:15,640
and that gives slightly different

153
00:06:21,180 --> 00:06:17,770
results which we're still working on so

154
00:06:24,060 --> 00:06:21,190
this is the sort of result you get this

155
00:06:28,830 --> 00:06:24,070
is the number of volcanic sources out of

156
00:06:32,810 --> 00:06:28,840
that collection of 53 low castle or 487

157
00:06:35,730 --> 00:06:32,820
measurements at which a gas is

158
00:06:36,780 --> 00:06:35,740
thermodynamically favored to be produced

159
00:06:39,150 --> 00:06:36,790
under those Delta G of formation

160
00:06:41,640 --> 00:06:39,160
synthesis from those gases less than

161
00:06:44,370 --> 00:06:41,650
zero and this is the number of gases for

162
00:06:47,040 --> 00:06:44,380
which that number is is right so over

163
00:06:48,660 --> 00:06:47,050

here this is one bar that's 30 bars

164
00:06:50,020 --> 00:06:48,670
because I was going to do one and thirty

165
00:06:51,460 --> 00:06:50,030
and a thousand other files

166
00:06:56,080 --> 00:06:51,470
turns out to be on the slide over there

167
00:06:57,430 --> 00:06:56,090
so you know and the large majority of

168
00:06:59,740 --> 00:06:57,440
the gases are not produced in any

169
00:07:02,470 --> 00:06:59,750
volcano good they are not likely be

170
00:07:05,620 --> 00:07:02,480
false positives as you increase the

171
00:07:07,210 --> 00:07:05,630
pressure that number goes down there's a

172
00:07:08,710 --> 00:07:07,220
small number that's produced virtually

173
00:07:11,170 --> 00:07:08,720
everywhere and that includes things like

174
00:07:13,450 --> 00:07:11,180
sulfur dioxide carbon dioxide hydrogen

175
00:07:18,670 --> 00:07:13,460
sulfide which we know volcanoes produce

176
00:07:22,150 --> 00:07:18,680
so again that that's nice okay so for

177
00:07:24,070 --> 00:07:22,160
that one this is the same data plus at a

178
00:07:26,590 --> 00:07:24,080
slightly different way this again this

179
00:07:29,500 --> 00:07:26,600
this time is temperature along here each

180
00:07:32,050 --> 00:07:29,510
of these dot is one volcano and this is

181
00:07:34,930 --> 00:07:32,060
the number of gases produced by that

182
00:07:36,820 --> 00:07:34,940
volcano and it drops off with

183
00:07:38,620 --> 00:07:36,830
temperature as you'd expect that's

184
00:07:40,270 --> 00:07:38,630
really weird outliers up here though and

185
00:07:42,580 --> 00:07:40,280
if you plot the data a slightly

186
00:07:44,740 --> 00:07:42,590
different way so this is temperature

187
00:07:47,290 --> 00:07:44,750
again along here but fraction of water

188
00:07:49,480 --> 00:07:47,300

in the gases the arrived original

189
00:07:51,820 --> 00:07:49,490
fumarole or volcanic vent produces

190
00:07:53,830 --> 00:07:51,830
nineteen ninety-five percent of water as

191
00:07:56,410 --> 00:07:53,840
the gas some of the produce much less

192
00:07:59,200 --> 00:07:56,420
and these large circle fear size of the

193
00:08:01,660 --> 00:07:59,210
circle is proportional to the number of

194
00:08:04,060 --> 00:08:01,670
molecules being produced under this

195
00:08:06,190 --> 00:08:04,070
thermodynamic modeling in the system the

196
00:08:12,160 --> 00:08:06,200
dry gas is down here seem to produce a

197
00:08:13,960 --> 00:08:12,170
lot more potential gases okay but the

198
00:08:16,660 --> 00:08:13,970
important point to remember these are

199
00:08:19,030 --> 00:08:16,670
not the same gases in each volcano so

200
00:08:21,820 --> 00:08:19,040
I've looked at these four examples here

201
00:08:24,130 --> 00:08:21,830
and a sort of average one up here and

202
00:08:26,410 --> 00:08:24,140
this is the number of gases produced by

203
00:08:30,880 --> 00:08:26,420
those modern to be produced by those I

204
00:08:36,010 --> 00:08:30,890
should say and and how many a shared

205
00:08:37,690 --> 00:08:36,020
between them so system a here the 628

206
00:08:39,850 --> 00:08:37,700
molecules we predict as having a

207
00:08:42,600 --> 00:08:39,860
negative free energy of formation that

208
00:08:44,710 --> 00:08:42,610
are not formed than any other system and

209
00:08:46,570 --> 00:08:44,720
there's a there's a tweak to this

210
00:08:48,580 --> 00:08:46,580
because actually a B C and D are all the

211
00:08:52,420 --> 00:08:48,590
same volcano they're all the Lascar

212
00:08:54,010 --> 00:08:52,430
volcano in Chile at different times so

213
00:08:55,420 --> 00:08:54,020

different places different times

214
00:08:57,250 --> 00:08:55,430
different volcanoes all produce

215
00:08:59,050 --> 00:08:57,260
different materials and we're going to

216
00:09:02,330 --> 00:08:59,060
have to capture this if we want to model

217
00:09:05,480 --> 00:09:02,340
this on an exoplanet

218
00:09:08,000 --> 00:09:05,490
okay so interim conclusions are as you'd

219
00:09:10,070 --> 00:09:08,010
expect above a thousand Kelvin you

220
00:09:11,810 --> 00:09:10,080
produce very little complex molecules

221
00:09:13,930 --> 00:09:11,820
they're all the obvious volcanic gases I

222
00:09:16,640 --> 00:09:13,940
was going to put something fairly rude

223
00:09:20,329 --> 00:09:16,650
up here to say well gosh isn't that

224
00:09:22,040 --> 00:09:20,339
surprising but I didn't phosphorous

225
00:09:23,570 --> 00:09:22,050
compounds very few bullet arts if you

226
00:09:27,440 --> 00:09:23,580
see a bullet are phosphorous compound in

227
00:09:29,750 --> 00:09:27,450
our exoplanets atmosphere say wow lots

228
00:09:32,180 --> 00:09:29,760
of molecules likely produce dry sites

229
00:09:35,870 --> 00:09:32,190
produce more what we don't know yet is

230
00:09:38,990 --> 00:09:35,880
where they accumulate biases and the

231
00:09:40,220 --> 00:09:39,000
data phosphorous is a problem and many

232
00:09:42,140 --> 00:09:40,230
we've also asked how I deal with

233
00:09:44,300 --> 00:09:42,150
phosphorous I will tell you either in

234
00:09:46,130 --> 00:09:44,310
questions or afterwards but the big

235
00:09:49,610 --> 00:09:46,140
problem is that these are a very biased

236
00:09:51,800 --> 00:09:49,620
set of volcanic gas samples and their

237
00:09:54,829 --> 00:09:51,810
bias for a very simple reason if you

238
00:09:56,960 --> 00:09:54,839

want to sample this fumarole here it's a

239
00:09:58,880 --> 00:09:56,970
bit hazardous but reasonably safe give

240
00:10:01,190 --> 00:09:58,890
on a sample this active volcanic crater

241
00:10:03,260 --> 00:10:01,200
here it's a really dangerous but

242
00:10:06,710 --> 00:10:03,270
possible and if you want to sample this

243
00:10:08,270 --> 00:10:06,720
well frankly you just don't so but these

244
00:10:09,890 --> 00:10:08,280
sort of things put about third to a half

245
00:10:14,180 --> 00:10:09,900
of all the volcanic gases in the

246
00:10:15,410 --> 00:10:14,190
atmosphere so that this is entering the

247
00:10:17,120 --> 00:10:15,420
number of things we want to do next

248
00:10:19,670 --> 00:10:17,130
which I'd be really key to talk to

249
00:10:22,430 --> 00:10:19,680
people about particularly other worlds

250
00:10:27,400 --> 00:10:22,440
what other volcanic gas models might be

251
00:10:30,170 --> 00:10:27,410
put into those worlds and that's it are

252
00:10:33,020 --> 00:10:30,180
huge thank the yeah no she's down I

253
00:10:35,360 --> 00:10:33,030
can't see you and they were and Sarah of

254
00:10:37,220 --> 00:10:35,370
course who's been my sponsor and doing

255
00:10:42,640 --> 00:10:37,230
this for many years and thank you for

256
00:10:54,340 --> 00:10:44,470
thank you we have time for a couple

257
00:10:56,680 --> 00:10:54,350
questions excellent that's what I like

258
00:10:59,290 --> 00:10:56,690
to see so MLS I'll ask a question if

259
00:11:00,880 --> 00:10:59,300
there are none so you mentioned right

260
00:11:02,470 --> 00:11:00,890
there at the end other models for

261
00:11:04,390 --> 00:11:02,480
different types of planets I mean do you

262
00:11:07,570 --> 00:11:04,400
have any thoughts of where you're going

263
00:11:11,440 --> 00:11:07,580

to start there I really like to start on

264
00:11:14,620 --> 00:11:11,450
Io ok I think iOS just fantastic part

265
00:11:16,720 --> 00:11:14,630
and looking brilliant color but it is a

266
00:11:18,430 --> 00:11:16,730
it's a known body for which you know is

267
00:11:22,480 --> 00:11:18,440
very active it has a lot of volcanic

268
00:11:24,490 --> 00:11:22,490
activity beyond that a Sol maneuvers who

269
00:11:26,710 --> 00:11:24,500
told me that the volcanoes and Venus

270
00:11:28,060 --> 00:11:26,720
have being detective of active but how

271
00:11:28,990 --> 00:11:28,070
do you measure the gases of them it

272
00:11:31,240 --> 00:11:29,000
needs something where you can actually

273
00:11:32,620 --> 00:11:31,250
say what is the gas coming out of this

274
00:11:36,460 --> 00:11:32,630
and then plug that into these sort of

275
00:11:38,250 --> 00:11:36,470
calculations so I will be number one and

276
00:11:40,300 --> 00:11:38,260
then after that you know the fields open

277
00:11:42,850 --> 00:11:40,310
thank you very much

278
00:11:43,930 --> 00:11:42,860
any any other questions you have to go

279
00:11:45,640 --> 00:11:43,940
up to the microphone unfortunately

280
00:11:49,990 --> 00:11:45,650
there's no one who's coming around with

281
00:11:52,750 --> 00:11:50,000
them all right so my question is very

282
00:11:54,970 --> 00:11:52,760
similar to that which is we can find

283
00:11:57,160 --> 00:11:54,980
these volcanoes around other bodies and

284
00:11:59,680 --> 00:11:57,170
measure the gases but what kind of lab

285
00:12:02,530 --> 00:11:59,690
work could be done to actually measure

286
00:12:07,540 --> 00:12:02,540
the gases and they're free energies is

287
00:12:09,400 --> 00:12:07,550
that a viable Avenue as well on to so

288
00:12:11,550 --> 00:12:09,410

this that there's work to measure more

289
00:12:14,860 --> 00:12:11,560
gases and to fill in all those gaps

290
00:12:18,030 --> 00:12:14,870
there's a lot of this is based on

291
00:12:20,920 --> 00:12:18,040
calculated thermodynamic parameters and

292
00:12:22,930 --> 00:12:20,930
some of the calculations are quite badly

293
00:12:24,610 --> 00:12:22,940
off because if you compare them to

294
00:12:26,380 --> 00:12:24,620
what's actually measured you know I mean

295
00:12:28,360 --> 00:12:26,390
they're off by tens of kilojoules per

296
00:12:32,110 --> 00:12:28,370
mole and so there's a first

297
00:12:33,940 --> 00:12:32,120
approximation this is okay but measuring

298
00:12:36,280 --> 00:12:33,950
those thermodynamic parameters would be

299
00:12:38,920 --> 00:12:36,290
really useful but difficulty with this

300
00:12:41,830 --> 00:12:38,930
and we talked about this at the Nexus 7

301
00:12:43,480 --> 00:12:41,840
our summer the doing those measurements

302
00:12:45,400 --> 00:12:43,490
and doing reaction rate to measurements

303
00:12:47,050 --> 00:12:45,410
which is also important for this it's

304
00:12:49,630 --> 00:12:47,060
really difficult really time consuming

305
00:12:51,640 --> 00:12:49,640
and then once you've spent in our six

306
00:12:53,560 --> 00:12:51,650
months doing it for one set of chemicals

307
00:12:55,560 --> 00:12:53,570
you get one data point in one database

308
00:12:58,769 --> 00:12:55,570
and no kudos at all

309
00:13:01,350 --> 00:12:58,779
so those are sort of risk reward time

310
00:13:02,310 --> 00:13:01,360
reward imbalance that don't know how to

311
00:13:04,170 --> 00:13:02,320
get around that but if there's a