
AbSciCon
2019

1
00:00:00,790 --> 00:00:07,320
[Music]

2
00:00:11,650 --> 00:00:08,680
[Applause]

3
00:00:14,560 --> 00:00:11,660
I like the Sierra's tournament she

4
00:00:18,220 --> 00:00:14,570
brought up earlier about talking about

5
00:00:19,240 --> 00:00:18,230
weird life and I feel like we maybe we

6
00:00:20,710 --> 00:00:19,250
should have kept it maybe we lost

7
00:00:24,339 --> 00:00:20,720
something when we convened the topic

8
00:00:26,710 --> 00:00:24,349
because what I'm obsessed with what

9
00:00:28,179 --> 00:00:26,720
Vladimir's obsessed with and Kobayashi

10
00:00:30,849 --> 00:00:28,189
sensei is obsessed with his weird

11
00:00:33,070 --> 00:00:30,859
chemistry we are so far beyond

12
00:00:35,710 --> 00:00:33,080
equilibrium it's not even funny

13
00:00:38,439 --> 00:00:35,720

right so what happens when we are really

14
00:00:40,360 --> 00:00:38,449
really far away from conditions that are

15
00:00:42,490 --> 00:00:40,370
near and dear and Clement to us as

16
00:00:46,540 --> 00:00:42,500
organisms what does the chemistry look

17
00:00:49,180 --> 00:00:46,550
like and I'm basically obsessed with

18
00:00:52,209 --> 00:00:49,190
this question and it's tied to getting

19
00:00:54,880 --> 00:00:52,219
really far from equilibrium about at

20
00:00:56,770 --> 00:00:54,890
what point in the prebiotic history did

21
00:00:58,660 --> 00:00:56,780
life's organizational attributes arise

22
00:01:00,189 --> 00:00:58,670
I'm not the first one and this is not

23
00:01:03,880 --> 00:01:00,199
even my main thing but I'm obsessed with

24
00:01:06,070 --> 00:01:03,890
this question and there are a couple of

25
00:01:08,109 --> 00:01:06,080
ways that we can approach this or think

26
00:01:09,850 --> 00:01:08,119
about how it could have happened one is

27
00:01:11,950 --> 00:01:09,860
to just say well it showed up as an

28
00:01:13,900 --> 00:01:11,960
emergent property and maybe it's nearer

29
00:01:18,669 --> 00:01:13,910
to the emergence of a cell than it was

30
00:01:20,020 --> 00:01:18,679
the chemistry or perhaps it was if you

31
00:01:21,880 --> 00:01:20,030
strip away everything you know about a

32
00:01:24,040 --> 00:01:21,890
cell everything you know about chemistry

33
00:01:27,040 --> 00:01:24,050
and molecules and you only talk about

34
00:01:28,449 --> 00:01:27,050
the relationships among objects to me

35
00:01:30,249 --> 00:01:28,459
it's really intriguing if those

36
00:01:32,230 --> 00:01:30,259
organizational attributes go all the way

37
00:01:34,570 --> 00:01:32,240
back all the way back to the very

38
00:01:36,370 --> 00:01:34,580

beginning of the process itself and in

39
00:01:38,469 --> 00:01:36,380
fact maybe could have only life could

40
00:01:42,389 --> 00:01:38,479
have only arisen in those circumstances

41
00:01:45,070 --> 00:01:42,399
and localities where the environment is

42
00:01:46,839 --> 00:01:45,080
driving organizational attributes to

43
00:01:48,309 --> 00:01:46,849
arise among objects from the very

44
00:01:53,830 --> 00:01:48,319
beginning and that's what this talk is

45
00:01:55,419 --> 00:01:53,840
about today so when we talk about making

46
00:01:57,339 --> 00:01:55,429
this transition we have to go from

47
00:01:59,290 --> 00:01:57,349
prebiotic chemistry which is just a

48
00:02:00,580 --> 00:01:59,300
bunch of of reactions that are occurring

49
00:02:03,240 --> 00:02:00,590
and products that are coming out and

50
00:02:05,949 --> 00:02:03,250
coming up with some integrated holistic

51
00:02:07,779 --> 00:02:05,959
entity something that's reacting with

52
00:02:10,630 --> 00:02:07,789
itself and its environment in a very

53
00:02:13,150 --> 00:02:10,640
complex way and when we think about this

54
00:02:14,140 --> 00:02:13,160
transition we can think about it and

55
00:02:16,660 --> 00:02:14,150
looking at it from a network perspective

56
00:02:19,030 --> 00:02:16,670
I know Sarah Walker's been working on

57
00:02:21,940 --> 00:02:19,040
things like this for a long time but

58
00:02:23,800 --> 00:02:21,950
something about the network the network

59
00:02:25,270 --> 00:02:23,810
active gives us this information when we

60
00:02:26,920 --> 00:02:25,280
look at it so you're looking at a

61
00:02:29,380 --> 00:02:26,930
protein interaction map for an e coli

62
00:02:31,290 --> 00:02:29,390
cell and it might not make a lot of

63
00:02:33,729 --> 00:02:31,300

sense to you when you first see it but

64
00:02:35,110 --> 00:02:33,739
to people who study these things there

65
00:02:36,490 --> 00:02:35,120
are a couple of attributes that jump out

66
00:02:38,830 --> 00:02:36,500
with a network like this that are very

67
00:02:41,259 --> 00:02:38,840
striking they're very unusual very

68
00:02:43,630 --> 00:02:41,269
unlikely and one of those things is that

69
00:02:47,410 --> 00:02:43,640
the arrangement of objects is is very

70
00:02:49,330 --> 00:02:47,420
heterogeneous there's a cluster of very

71
00:02:51,250 --> 00:02:49,340
highly connected things in the center

72
00:02:52,570 --> 00:02:51,260
and there's a relatively small number of

73
00:02:55,120 --> 00:02:52,580
the total number of things in the

74
00:02:57,699 --> 00:02:55,130
network around it are a moderate number

75
00:03:00,309 --> 00:02:57,709
of moderately well connected objects and

76
00:03:01,539 --> 00:03:00,319
all around the periphery are a really

77
00:03:04,600 --> 00:03:01,549
high number of things that are only

78
00:03:05,920 --> 00:03:04,610
connected once or twice all right this

79
00:03:08,770 --> 00:03:05,930
is what's known as a heavy tailed

80
00:03:10,720 --> 00:03:08,780
distribution okay and we're gonna talk

81
00:03:12,910 --> 00:03:10,730
about I'm gonna kind of use this as an

82
00:03:14,589 --> 00:03:12,920
example to compare these two types of

83
00:03:15,819 --> 00:03:14,599
network arrangements and talk about why

84
00:03:18,550 --> 00:03:15,829
they're fundamentally different from one

85
00:03:20,020 --> 00:03:18,560
another so if you imagine a network with

86
00:03:22,120 --> 00:03:20,030
this you know these are two networks

87
00:03:24,160 --> 00:03:22,130
with the same number of components but

88
00:03:27,280 --> 00:03:24,170

one of them has an average distribution

89
00:03:29,020 --> 00:03:27,290
of connections per object in the network

90
00:03:30,309 --> 00:03:29,030
there's going to be this kind of bell

91
00:03:32,680 --> 00:03:30,319
curve it's a called a Poisson

92
00:03:33,970 --> 00:03:32,690
distribution and most nodes have an

93
00:03:36,009 --> 00:03:33,980
average number of links there might be a

94
00:03:37,420 --> 00:03:36,019
couple to have one more two more it

95
00:03:39,610 --> 00:03:37,430
might be a couple that have a little bit

96
00:03:41,590 --> 00:03:39,620
less but basically it's statistically

97
00:03:43,390 --> 00:03:41,600
impossible for highly linked nodes to

98
00:03:46,420 --> 00:03:43,400
occur even with a high number of objects

99
00:03:47,410 --> 00:03:46,430
in this system but this is fundamentally

100
00:03:49,390 --> 00:03:47,420
different from a heavy tailed

101
00:03:52,000 --> 00:03:49,400
distribution because there's basically

102
00:03:54,400 --> 00:03:52,010
no average there's no average property

103
00:03:56,559 --> 00:03:54,410
when that you can extrapolate the kind

104
00:03:58,240 --> 00:03:56,569
of network behavior properties based on

105
00:04:00,670 --> 00:03:58,250
analyzing each of these individual

106
00:04:02,080 --> 00:04:00,680
things and we see hubs that are really

107
00:04:04,330 --> 00:04:02,090
highly connected but there's a

108
00:04:05,530 --> 00:04:04,340
relatively few of them we see a moderate

109
00:04:07,150 --> 00:04:05,540
number of things that are moderately

110
00:04:09,849 --> 00:04:07,160
well-connected and in a bunch of stuff

111
00:04:12,580 --> 00:04:09,859
at the edge that is only connected once

112
00:04:14,740 --> 00:04:12,590
or twice all right so the kind of

113
00:04:17,020 --> 00:04:14,750

analogies I use this is you know 20

114
00:04:20,110 --> 00:04:17,030
people waiting in line at the DMV this

115
00:04:22,839 --> 00:04:20,120
is 20 people at a Flaming Lips concert

116
00:04:25,330 --> 00:04:22,849
all right this is 300 people on a plane

117
00:04:27,550 --> 00:04:25,340
from Chicago to Seattle last Sunday this

118
00:04:29,469 --> 00:04:27,560
is AB saikhan all right in one of these

119
00:04:31,540 --> 00:04:29,479
situations not a lots going to happen

120
00:04:33,610 --> 00:04:31,550
the random people they're interacting in

121
00:04:34,490 --> 00:04:33,620
very limited ways nothing surprising is

122
00:04:36,140 --> 00:04:34,500
gonna happen

123
00:04:39,470 --> 00:04:36,150
but when you connect things like this

124
00:04:41,510 --> 00:04:39,480
you get nonlinear behaviors unexpected

125
00:04:43,310 --> 00:04:41,520
things all right you can force the

126
00:04:43,850 --> 00:04:43,320
system you can perturb it maybe nothing

127
00:04:45,380 --> 00:04:43,860
happens

128
00:04:46,880 --> 00:04:45,390
maybe then all of a sudden a step

129
00:04:50,000 --> 00:04:46,890
function happens in things change very

130
00:04:51,620 --> 00:04:50,010
quickly and it all comes down to the

131
00:04:54,650 --> 00:04:51,630
existence of these links that are

132
00:04:56,660 --> 00:04:54,660
concentrated in relatively few objects

133
00:04:58,880 --> 00:04:56,670
so to understand how the system is going

134
00:05:00,710 --> 00:04:58,890
to unfold you really have to understand

135
00:05:02,870 --> 00:05:00,720
these really highly linked objects and

136
00:05:04,820 --> 00:05:02,880
when we think about the chemistry we

137
00:05:08,960 --> 00:05:04,830
want to maybe look for systems that look

138
00:05:11,390 --> 00:05:08,970

like this from the very beginning why do

139
00:05:13,040 --> 00:05:11,400
we think this because we see it repeated

140
00:05:15,080 --> 00:05:13,050
as a pattern across all of life's

141
00:05:15,650 --> 00:05:15,090
organizational hierarchy all the way to

142
00:05:17,540 --> 00:05:15,660
the top

143
00:05:20,680 --> 00:05:17,550
it's a planetary level to biosphere in

144
00:05:23,270 --> 00:05:20,690
the middle with groups of ecosystems

145
00:05:26,270 --> 00:05:23,280
populations of cells and even at the sub

146
00:05:28,159 --> 00:05:26,280
cellular level with gene transcription

147
00:05:29,900 --> 00:05:28,169
rates and protein protein interaction

148
00:05:32,690 --> 00:05:29,910
networks it's everywhere on this

149
00:05:34,310 --> 00:05:32,700
hierarchy so how far about how far down

150
00:05:37,460 --> 00:05:34,320
does it go and does it proceed all the

151
00:05:39,050 --> 00:05:37,470
way back to the origins of life itself a

152
00:05:40,880 --> 00:05:39,060
lot of work has been done kind of

153
00:05:44,060 --> 00:05:40,890
describing this it was a hot topic about

154
00:05:45,440 --> 00:05:44,070
15 20 years ago and recent work has been

155
00:05:47,690 --> 00:05:45,450
published kind of explaining and

156
00:05:49,280 --> 00:05:47,700
describing why this is interesting what

157
00:05:51,590 --> 00:05:49,290
the unique properties of such systems

158
00:05:56,780 --> 00:05:51,600
might be as they pertain to prebiotic

159
00:06:00,050 --> 00:05:56,790
chemistry and so I got started on this

160
00:06:02,030 --> 00:06:00,060
basically because networks at that have

161
00:06:03,170 --> 00:06:02,040
been reported recently in the literature

162
00:06:05,450 --> 00:06:03,180
this is kind of where things are

163
00:06:07,790 --> 00:06:05,460

progressing we're not as much interested

164
00:06:09,830 --> 00:06:07,800
in whether we find amino acids or

165
00:06:12,260 --> 00:06:09,840
whether we find nucleotides or whether

166
00:06:13,909 --> 00:06:12,270
they join together we want to know how

167
00:06:15,710 --> 00:06:13,919
they relate to one another and if they

168
00:06:17,360 --> 00:06:15,720
interact with one another because if

169
00:06:18,980 --> 00:06:17,370
they don't interact with one another you

170
00:06:20,409 --> 00:06:18,990
have all the amino acids you want on all

171
00:06:23,180 --> 00:06:20,419
the planets in the solar system

172
00:06:25,490 --> 00:06:23,190
nothing's going to happen but the

173
00:06:26,840 --> 00:06:25,500
network's we do have are relatively

174
00:06:29,390 --> 00:06:26,850
limited it is almost like a micro

175
00:06:32,150 --> 00:06:29,400
network and you start with in this case

176
00:06:34,250 --> 00:06:32,160
you're trying to assemble a nucleotide

177
00:06:35,750 --> 00:06:34,260
that will lead you into RNA world and

178
00:06:38,030 --> 00:06:35,760
you're trying to assemble it with the

179
00:06:40,790 --> 00:06:38,040
fewest steps possible and you rely on

180
00:06:42,800 --> 00:06:40,800
these really reactive relatively

181
00:06:45,290 --> 00:06:42,810
unlikely compounds to be present in high

182
00:06:47,779 --> 00:06:45,300
abundance things like cyano acetylene

183
00:06:48,230 --> 00:06:47,789
cyanamide and your sugar precursors

184
00:06:50,540 --> 00:06:48,240
closer

185
00:06:53,300 --> 00:06:50,550
aldehyde and glycol aldehyde so my work

186
00:06:55,850 --> 00:06:53,310
involved trying to generate these

187
00:06:57,409 --> 00:06:55,860
compounds from scratch you know don't

188
00:06:59,480 --> 00:06:57,419

take them as a given in the environment

189
00:07:03,589 --> 00:06:59,490
where do they come from nitrogen carbon

190
00:07:05,749 --> 00:07:03,599
dioxide etc and we focused on one of the

191
00:07:07,520 --> 00:07:05,759
ways of getting to this step and the

192
00:07:09,860 --> 00:07:07,530
shortest way possible would be to use

193
00:07:11,510 --> 00:07:09,870
free radical chemistry chemistry really

194
00:07:14,689 --> 00:07:11,520
far from equilibrium so what are free

195
00:07:16,939 --> 00:07:14,699
radicals free radicals are I don't know

196
00:07:19,640 --> 00:07:16,949
the island of misfit molecules all right

197
00:07:21,559 --> 00:07:19,650
you start with a nice stable

198
00:07:23,659 --> 00:07:21,569
clément molecule it's very happy

199
00:07:26,930 --> 00:07:23,669
relatively unreactive it's not doing

200
00:07:29,350 --> 00:07:26,940
much of anything but if you blink off

201
00:07:32,930 --> 00:07:29,360
one of its electrons and its outer shell

202
00:07:34,879 --> 00:07:32,940
it becomes a free radical and this

203
00:07:36,290 --> 00:07:34,889
radical is very highly reactive and very

204
00:07:38,360 --> 00:07:36,300
promiscuous it doesn't really care

205
00:07:39,770 --> 00:07:38,370
what's around it it's going to react

206
00:07:42,200 --> 00:07:39,780
with something eventually it's going to

207
00:07:44,629 --> 00:07:42,210
do it very very quickly so all of a

208
00:07:46,219 --> 00:07:44,639
sudden you've turned your molecules

209
00:07:47,899 --> 00:07:46,229
which are otherwise kind of spectators

210
00:07:49,760 --> 00:07:47,909
in the chemistry around it and in the

211
00:07:54,230 --> 00:07:49,770
environment around it things like water

212
00:07:55,550 --> 00:07:54,240
or nitrogen or carbon dioxide all of a

213
00:07:58,070 --> 00:07:55,560

sudden they've become highly reactive

214
00:07:59,600 --> 00:07:58,080
and they can interact the the number of

215
00:08:01,879 --> 00:07:59,610
interactions that are possible increased

216
00:08:03,290 --> 00:08:01,889
dramatically we haven't added any

217
00:08:05,270 --> 00:08:03,300
reactive compounds we don't need to

218
00:08:07,459 --> 00:08:05,280
remove any waste products we're just

219
00:08:09,860 --> 00:08:07,469
adding energy to the system and we're

220
00:08:11,540 --> 00:08:09,870
asking where does this take us so we

221
00:08:13,430 --> 00:08:11,550
started investigating the radio lytic

222
00:08:14,870 --> 00:08:13,440
chemistry of these ribonucleotide

223
00:08:17,510 --> 00:08:14,880
precursors and we found some really

224
00:08:19,430 --> 00:08:17,520
interesting things over the last three

225
00:08:21,350 --> 00:08:19,440
years we've kind of distilled these kind

226
00:08:23,240 --> 00:08:21,360
of high-level rules that might point to

227
00:08:24,980 --> 00:08:23,250
where what a network would look like if

228
00:08:27,499 --> 00:08:24,990
we were to build one or actually realize

229
00:08:29,540 --> 00:08:27,509
the system and the first is that you

230
00:08:30,980 --> 00:08:29,550
think if you've got energy that's so far

231
00:08:33,769 --> 00:08:30,990
from equilibrium that you're going to

232
00:08:35,360 --> 00:08:33,779
degrade compounds in equal measure as

233
00:08:38,240 --> 00:08:35,370
you produce them but that's just not the

234
00:08:41,389 --> 00:08:38,250
case in these systems what you're seeing

235
00:08:43,130 --> 00:08:41,399
here is a sequential kind of increase in

236
00:08:45,199 --> 00:08:43,140
dose as you go up on this chromatogram

237
00:08:47,060 --> 00:08:45,209
and what you see is that the relative

238
00:08:49,819 --> 00:08:47,070

concentrations of some compounds

239
00:08:51,199 --> 00:08:49,829
increase with total dose so your

240
00:08:54,139 --> 00:08:51,209
irradiating the hell out of this system

241
00:08:56,720 --> 00:08:54,149
some compounds are responding to that in

242
00:08:58,400 --> 00:08:56,730
in terms of growing over time and the

243
00:08:59,780 --> 00:08:58,410
more you radiate it the more compounds

244
00:09:03,079 --> 00:08:59,790
are going to come out they don't get

245
00:09:06,229 --> 00:09:03,089
degraded so that's interesting

246
00:09:08,299 --> 00:09:06,239
it scales with energy and but the next

247
00:09:11,119 --> 00:09:08,309
rule we discerned is that we could see

248
00:09:12,949 --> 00:09:11,129
repeated actions of the usual suspects

249
00:09:15,139 --> 00:09:12,959
the same radical showing up over and

250
00:09:17,720 --> 00:09:15,149
over and over and over again to kind of

251
00:09:20,530 --> 00:09:17,730
impart order on this system so we didn't

252
00:09:22,879 --> 00:09:20,540
get some kind of complicated Malou of

253
00:09:24,499 --> 00:09:22,889
sugars reacting with other sugars and

254
00:09:26,809 --> 00:09:24,509
spitting out this kind of shotgun blast

255
00:09:29,329 --> 00:09:26,819
of compounds the reason we only see some

256
00:09:32,749 --> 00:09:29,339
counts compounds produced in excess over

257
00:09:35,150 --> 00:09:32,759
others is because these same radicals

258
00:09:37,579 --> 00:09:35,160
interact with the secondary products the

259
00:09:39,319 --> 00:09:37,589
tertiary products and end up directing

260
00:09:41,119 --> 00:09:39,329
the chemistry in a very specific way and

261
00:09:42,829 --> 00:09:41,129
this was a finding that we just reported

262
00:09:45,439 --> 00:09:42,839
over this last year I think it's really

263
00:09:47,979 --> 00:09:45,449

really profound to think that we can

264
00:09:50,989 --> 00:09:47,989
generate our sugar precursors from

265
00:09:53,299 --> 00:09:50,999
basically water hydrogen cyanide a

266
00:09:54,799 --> 00:09:53,309
little bit of energy and we end up with

267
00:09:56,539 --> 00:09:54,809
exactly the sugars that we need for

268
00:09:59,059 --> 00:09:56,549
ribonucleotide assembly without creating

269
00:10:00,379 --> 00:09:59,069
the the excess mixture of sugars that

270
00:10:01,879 --> 00:10:00,389
are associated with the for most

271
00:10:05,119 --> 00:10:01,889
reaction this is a very significant

272
00:10:07,039 --> 00:10:05,129
finding but it allows us to kind of

273
00:10:08,780 --> 00:10:07,049
extract this room we saw this repeated

274
00:10:12,799 --> 00:10:08,790
in other areas of the work we were doing

275
00:10:14,269 --> 00:10:12,809
as well and the final rule is that it's

276
00:10:16,549 --> 00:10:14,279
really interesting to think but we can

277
00:10:18,710 --> 00:10:16,559
do reducing and oxidizing reactions in

278
00:10:21,220 --> 00:10:18,720
the exact same volume without a need for

279
00:10:24,169 --> 00:10:21,230
spatial or temporal compartmentalization

280
00:10:25,939 --> 00:10:24,179
these reactions can occur micrometer x'

281
00:10:27,650 --> 00:10:25,949
or maybe even nano nano meters from each

282
00:10:30,049 --> 00:10:27,660
other all right the species are so

283
00:10:32,720 --> 00:10:30,059
energetic and the compounds are moving

284
00:10:34,069 --> 00:10:32,730
so quickly in the system that right next

285
00:10:36,169 --> 00:10:34,079
to you can have a water molecule which

286
00:10:39,169 --> 00:10:36,179
becomes a hydroxyl radical and a

287
00:10:41,090 --> 00:10:39,179
hydrogen radical or you can have a salt

288
00:10:43,999 --> 00:10:41,100

ion that ends up contributing to the

289
00:10:46,009 --> 00:10:44,009
formation of hypochlorite in the same

290
00:10:47,900 --> 00:10:46,019
system they don't just back react with

291
00:10:49,699 --> 00:10:47,910
each other and dissipate the energy they

292
00:10:52,069 --> 00:10:49,709
end up driving very specific pathways

293
00:10:53,840 --> 00:10:52,079
that lead to our nucleotide precursors

294
00:10:56,539 --> 00:10:53,850
that we need our assembly compounds are

295
00:10:59,119 --> 00:10:56,549
condensing agents when you add up all

296
00:11:01,039 --> 00:10:59,129
these three rules together you can start

297
00:11:02,299 --> 00:11:01,049
to ask okay what's the smallest box that

298
00:11:04,939 --> 00:11:02,309
we could put this in and what would

299
00:11:06,650 --> 00:11:04,949
happen what's the smallest number of

300
00:11:08,509 --> 00:11:06,660
reactants that we would need to assemble

301
00:11:10,100 --> 00:11:08,519
a nucleotide what would be the energy

302
00:11:12,409 --> 00:11:10,110
source that you'd use as a proxy for

303
00:11:13,939 --> 00:11:12,419
analyzing the system so we came up with

304
00:11:15,410 --> 00:11:13,949
this kind of idea that we completely

305
00:11:17,810 --> 00:11:15,420
enclose the system

306
00:11:20,050 --> 00:11:17,820
we set it at some average temperature T

307
00:11:23,480 --> 00:11:20,060
and we account for all the schnapps

308
00:11:25,310 --> 00:11:23,490
carbon hydrogen nitrogen sulfur we throw

309
00:11:27,230 --> 00:11:25,320
in some iron sulfide because we know at

310
00:11:30,200 --> 00:11:27,240
some point in life iron sulfur clusters

311
00:11:33,110 --> 00:11:30,210
are important as metabolic cofactors in

312
00:11:34,700 --> 00:11:33,120
enzymes and we throw in uranium oxide as

313
00:11:36,950 --> 00:11:34,710

a proxy for this really high energy

314
00:11:39,830 --> 00:11:36,960
system that we're looking for basically

315
00:11:41,600 --> 00:11:39,840
mega electron volts millions of times

316
00:11:43,910 --> 00:11:41,610
past the bond dissociation energy of

317
00:11:45,350 --> 00:11:43,920
these compounds and even just putting

318
00:11:46,670 --> 00:11:45,360
them in the box we can see okay there's

319
00:11:50,150 --> 00:11:46,680
gonna be some Network what is it going

320
00:11:51,470 --> 00:11:50,160
to look like what are the network

321
00:11:53,240 --> 00:11:51,480
properties that we observe in this

322
00:11:55,520 --> 00:11:53,250
system and do they look like properties

323
00:11:57,320 --> 00:11:55,530
we see in biological systems and if so

324
00:12:00,350 --> 00:11:57,330
would these network properties confer

325
00:12:02,570 --> 00:12:00,360
really unique dynamic robust chemical

326
00:12:04,160 --> 00:12:02,580
capabilities that we would see in life

327
00:12:07,670 --> 00:12:04,170
that we otherwise wouldn't see in these

328
00:12:09,500 --> 00:12:07,680
chemical systems we basically have been

329
00:12:10,910 --> 00:12:09,510
collecting free radical and radiolysis

330
00:12:13,070 --> 00:12:10,920
experiments that have been reported in

331
00:12:14,480 --> 00:12:13,080
the literature of the last 30 years some

332
00:12:16,450 --> 00:12:14,490
of them are the ones that we help piece

333
00:12:19,400 --> 00:12:16,460
together you saw in the previous slides

334
00:12:21,200 --> 00:12:19,410
we've been the photonic spectrum into

335
00:12:23,390 --> 00:12:21,210
these really coarse categories to

336
00:12:25,970 --> 00:12:23,400
account for energy transitions across

337
00:12:27,980 --> 00:12:25,980
these thresholds associated with say the

338
00:12:32,330 --> 00:12:27,990

nuclear force intervene lines electrons

339
00:12:33,860 --> 00:12:32,340
outer valence electrons and rotational

340
00:12:36,350 --> 00:12:33,870
and vibrational modes of the molecules

341
00:12:38,270 --> 00:12:36,360
just to try to keep track of where the

342
00:12:39,560 --> 00:12:38,280
non molecular species in the system of

343
00:12:42,680 --> 00:12:39,570
what they're doing how often they show

344
00:12:46,400 --> 00:12:42,690
up on top of this kind of fundamental

345
00:12:48,500 --> 00:12:46,410
base of free radical reactions we also

346
00:12:50,120 --> 00:12:48,510
added redox equations that would

347
00:12:52,010 --> 00:12:50,130
naturally occur because you have this

348
00:12:54,320 --> 00:12:52,020
abundance of reactive species showing up

349
00:12:56,300 --> 00:12:54,330
and getting produced over time and then

350
00:12:57,620 --> 00:12:56,310
we analyze the network in Jeffie to try

351
00:13:00,170 --> 00:12:57,630
to visualize what the network will look

352
00:13:01,340 --> 00:13:00,180
playing and what does the network look

353
00:13:04,250 --> 00:13:01,350
like it looks like this

354
00:13:05,660 --> 00:13:04,260
it looks something like what we saw in

355
00:13:08,780 --> 00:13:05,670
that first slide about the e coli

356
00:13:10,400 --> 00:13:08,790
protein interaction Network we see what

357
00:13:13,250 --> 00:13:10,410
we have here are all of the molecular

358
00:13:15,230 --> 00:13:13,260
and atomic species in green we have the

359
00:13:18,740 --> 00:13:15,240
equations that connect them in red and

360
00:13:20,510 --> 00:13:18,750
we've scaled the size of the molecular

361
00:13:22,490 --> 00:13:20,520
species by the number of times they're

362
00:13:24,050 --> 00:13:22,500
referenced in the network so if you're a

363
00:13:25,910 --> 00:13:24,060

hub if you're connected to a lot of

364
00:13:27,350 --> 00:13:25,920
other things you're being produced in

365
00:13:28,970 --> 00:13:27,360
excess and you're also producing a bunch

366
00:13:32,660 --> 00:13:28,980
of other things in excess

367
00:13:34,730 --> 00:13:32,670
you are a big hub in this and we see one

368
00:13:36,020 --> 00:13:34,740
or two major hubs a small assortment of

369
00:13:37,550 --> 00:13:36,030
minor hubs and a whole bunch of

370
00:13:40,490 --> 00:13:37,560
peripheral stuff that's only connected

371
00:13:41,900 --> 00:13:40,500
say twice right in the system so let's

372
00:13:44,240 --> 00:13:41,910
break this down let's put some names on

373
00:13:46,010 --> 00:13:44,250
this and see what we're looking at you

374
00:13:48,860 --> 00:13:46,020
can classify these by the types of

375
00:13:50,660 --> 00:13:48,870
reactions that are going on and we have

376
00:13:52,520 --> 00:13:50,670
basically all the high-energy stuff

377
00:13:54,590 --> 00:13:52,530
going on in the lower left-hand portion

378
00:13:56,180 --> 00:13:54,600
of this Network stuff that is really

379
00:13:59,540 --> 00:13:56,190
really above the bond dissociation

380
00:14:01,390 --> 00:13:59,550
energy and in between we have a range of

381
00:14:03,830 --> 00:14:01,400
geochemical chloride and nitrile

382
00:14:06,290 --> 00:14:03,840
reactions that are attenuating this

383
00:14:07,810 --> 00:14:06,300
energy kind of stepping it down from

384
00:14:11,000 --> 00:14:07,820
really far from equilibrium and

385
00:14:12,950 --> 00:14:11,010
eventually supporting a nest of

386
00:14:14,870 --> 00:14:12,960
reactions it's actually very very

387
00:14:16,820 --> 00:14:14,880
similar to that micro network that I

388
00:14:18,620 --> 00:14:16,830

first showed you that involves the

389
00:14:20,810 --> 00:14:18,630
abiotic assembly of a nucleotide

390
00:14:22,130 --> 00:14:20,820
compound and there's a couple of

391
00:14:24,290 --> 00:14:22,140
features that are interesting here one

392
00:14:26,810 --> 00:14:24,300
is that there are no parts of the

393
00:14:28,400 --> 00:14:26,820
nucleotide assembly equations that are

394
00:14:30,260 --> 00:14:28,410
really dependent or contingent upon

395
00:14:32,510 --> 00:14:30,270
these high-energy stuff they're kind of

396
00:14:34,610 --> 00:14:32,520
secondary and tertiary reactions that

397
00:14:36,260 --> 00:14:34,620
have already gone on so by the time the

398
00:14:38,090 --> 00:14:36,270
energy is here it's really not strong

399
00:14:41,840 --> 00:14:38,100
enough to disrupt or disturb the

400
00:14:43,550 --> 00:14:41,850
assembly process itself so let's look at

401
00:14:47,920 --> 00:14:43,560
what the inputs and outputs look like

402
00:14:49,940 --> 00:14:47,930
basically all of your environmental

403
00:14:51,920 --> 00:14:49,950
environmentally abundant molecules that

404
00:14:53,480 --> 00:14:51,930
drive the system undergird the system

405
00:14:56,390 --> 00:14:53,490
are all found kind of at the periphery

406
00:14:58,100 --> 00:14:56,400
and I pick out a couple of the outputs

407
00:15:01,580 --> 00:14:58,110
that are I think are interesting namely

408
00:15:04,520 --> 00:15:01,590
the assemble nucleotide and gypsum so

409
00:15:06,650 --> 00:15:04,530
gypsum has a a very interesting role

410
00:15:08,570 --> 00:15:06,660
here in that you're basically

411
00:15:10,820 --> 00:15:08,580
sequestering and dumping a bunch of

412
00:15:12,440 --> 00:15:10,830
oxygen into an insoluble phase that no

413
00:15:14,780 --> 00:15:12,450

longer participates in the free radical

414
00:15:17,240 --> 00:15:14,790
reactions what that means is that if you

415
00:15:19,910 --> 00:15:17,250
have a closed box and you have pyrite

416
00:15:21,470 --> 00:15:19,920
and you have apatite your sulfur and a

417
00:15:23,330 --> 00:15:21,480
lot of your oxygen is going to become

418
00:15:25,160 --> 00:15:23,340
locked up and it's going to drive the

419
00:15:27,410 --> 00:15:25,170
overall redox state of that system to a

420
00:15:29,720 --> 00:15:27,420
more reduced state over time without any

421
00:15:31,070 --> 00:15:29,730
external manipulation so what that means

422
00:15:33,050 --> 00:15:31,080
is that it really doesn't matter what

423
00:15:35,420 --> 00:15:33,060
the global redox state of the planet was

424
00:15:37,460 --> 00:15:35,430
if your box is smaller than a planet and

425
00:15:39,450 --> 00:15:37,470
this is a somewhat isolated system from

426
00:15:40,720 --> 00:15:39,460
that broader system

427
00:15:46,030 --> 00:15:40,730
[Music]

428
00:15:48,580 --> 00:15:46,040
Oh also what we see here also is that

429
00:15:51,340 --> 00:15:48,590
the dominant hubs the biggest hubs in

430
00:15:52,960 --> 00:15:51,350
this system are all water derived the

431
00:15:55,360 --> 00:15:52,970
biggest hub is actually the hydrogen

432
00:15:58,510 --> 00:15:55,370
radical right behind it water is here

433
00:16:00,070 --> 00:15:58,520
and a hydroxyl radical so you can kind

434
00:16:02,440 --> 00:16:00,080
of see in this radio lytic system that

435
00:16:04,750 --> 00:16:02,450
water is not just a solvent it's not

436
00:16:07,360 --> 00:16:04,760
just a remarkable solvent when you get

437
00:16:09,760 --> 00:16:07,370
really far from equilibrium water is

438
00:16:12,280 --> 00:16:09,770

channelizing your energy into very very

439
00:16:15,040 --> 00:16:12,290
specific compounds and very specific

440
00:16:17,500 --> 00:16:15,050
chemical outputs of the system so water

441
00:16:20,140 --> 00:16:17,510
in this sense is attenuating all of this

442
00:16:22,660 --> 00:16:20,150
energy and giving imparting some level

443
00:16:24,460 --> 00:16:22,670
of structure on the resulting network I

444
00:16:26,260 --> 00:16:24,470
think that's pretty remarkable it's it's

445
00:16:27,430 --> 00:16:26,270
a property of water that we normally

446
00:16:29,950 --> 00:16:27,440
wouldn't think about in a chemical

447
00:16:32,350 --> 00:16:29,960
context but there it is it jumps out

448
00:16:33,910 --> 00:16:32,360
plain as day in the network as being all

449
00:16:37,720 --> 00:16:33,920
of these major hubs around which

450
00:16:39,400 --> 00:16:37,730
everything else occurs the network

451
00:16:42,340 --> 00:16:39,410
connectivity histogram this has meaning

452
00:16:45,010 --> 00:16:42,350
for complex systems theorists people who

453
00:16:47,290 --> 00:16:45,020
know that when we plot out basically the

454
00:16:49,840 --> 00:16:47,300
relative occurrence and the connectivity

455
00:16:51,760 --> 00:16:49,850
of these different objects this pattern

456
00:16:54,760 --> 00:16:51,770
and the relatively linear slope in log

457
00:16:57,160 --> 00:16:54,770
log space is basically implying that

458
00:16:58,720 --> 00:16:57,170
it's possible that at least within the

459
00:17:00,760 --> 00:16:58,730
limits of resolution for this very core

460
00:17:02,500 --> 00:17:00,770
system this chemical system might be

461
00:17:06,280 --> 00:17:02,510
operating near a phase transition

462
00:17:08,170 --> 00:17:06,290
between chaos and order that doesn't

463
00:17:09,819 --> 00:17:08,180

really mean a lot of to us that study

464
00:17:12,340 --> 00:17:09,829
chemistry but what it means in terms of

465
00:17:14,380 --> 00:17:12,350
systems physics is that it should be a

466
00:17:16,960 --> 00:17:14,390
highly dynamic system it should maintain

467
00:17:19,660 --> 00:17:16,970
its overall cohesion even if you

468
00:17:21,490 --> 00:17:19,670
introduce disturbances perturbance azure

469
00:17:23,620 --> 00:17:21,500
even if you try to manipulate the

470
00:17:26,380 --> 00:17:23,630
external parameters of the system it

471
00:17:28,930 --> 00:17:26,390
should still recapitulate aspects of

472
00:17:30,910 --> 00:17:28,940
this broader Network framework in

473
00:17:33,160 --> 00:17:30,920
structure which is kind of like what

474
00:17:35,050 --> 00:17:33,170
life is right we're very versatile when

475
00:17:36,850 --> 00:17:35,060
we reproduce our child looks kind of

476
00:17:39,280 --> 00:17:36,860
like us but not exactly like us and you

477
00:17:41,110 --> 00:17:39,290
can you know we can go to the top of a

478
00:17:42,670 --> 00:17:41,120
mountain we can go swim in a lake we're

479
00:17:45,280 --> 00:17:42,680
still going to be our bodies and still

480
00:17:47,290 --> 00:17:45,290
maintain our structure so there's some

481
00:17:49,540 --> 00:17:47,300
aspect of dynamism and robustness hidden

482
00:17:52,450 --> 00:17:49,550
in here but when we dive into why this

483
00:17:54,130 --> 00:17:52,460
system might be robust I just picked out

484
00:17:55,930 --> 00:17:54,140
two of these lower level exchange

485
00:17:58,210 --> 00:17:55,940
which I think we can consider as closed

486
00:18:00,910 --> 00:17:58,220
sets of molecules they're kind of

487
00:18:02,860 --> 00:18:00,920
interlinked between H n o HC o and CN

488
00:18:05,280 --> 00:18:02,870

and basically these things are occurring

489
00:18:07,510 --> 00:18:05,290
very very quickly at the basal level if

490
00:18:08,980 --> 00:18:07,520
you go a level above that to the

491
00:18:11,200 --> 00:18:08,990
compounds that tend to accumulate over

492
00:18:14,080 --> 00:18:11,210
time and these radio lytic systems you

493
00:18:16,210 --> 00:18:14,090
see another level above it of more

494
00:18:18,490 --> 00:18:16,220
stable long-lived but still reactive

495
00:18:20,770 --> 00:18:18,500
compounds and we can if you look with

496
00:18:22,870 --> 00:18:20,780
the close eye you can discern a broader

497
00:18:25,060 --> 00:18:22,880
cycle of each of the compounds needed to

498
00:18:26,770 --> 00:18:25,070
assemble a sim single nucleotide all

499
00:18:29,200 --> 00:18:26,780
occurring at this kind of hierarchical

500
00:18:31,450 --> 00:18:29,210
level your condensing agents your

501
00:18:34,450 --> 00:18:31,460
nucleobases your polyphosphates and your

502
00:18:37,210 --> 00:18:34,460
sugar precursors and at a level even

503
00:18:39,130 --> 00:18:37,220
higher than that your condensing agents

504
00:18:40,840 --> 00:18:39,140
and imidazoles eveing agents can also be

505
00:18:43,210 --> 00:18:40,850
theoretically used to assemble your

506
00:18:45,070 --> 00:18:43,220
oligonucleotides at a level that even

507
00:18:47,110 --> 00:18:45,080
transcends and explores a phase space

508
00:18:50,380 --> 00:18:47,120
above even this kind of radio lytic

509
00:18:51,700 --> 00:18:50,390
chemistry so we think that it might have

510
00:18:53,050 --> 00:18:51,710
a lot of these properties that have been

511
00:18:55,780 --> 00:18:53,060
described or inferred to have been

512
00:18:57,040 --> 00:18:55,790
needed very much at the very beginning

513
00:18:59,320 --> 00:18:57,050

for the chemistry of the origins of life

514
00:19:02,860 --> 00:18:59,330
to yield a dynamic chemical system like

515
00:19:05,230 --> 00:19:02,870
life and the production of these

516
00:19:06,730 --> 00:19:05,240
compounds should be relatively as simple

517
00:19:08,620 --> 00:19:06,740
as a rock rolling down a hill in an

518
00:19:10,060 --> 00:19:08,630
energetic sense it's going to happen one

519
00:19:13,060 --> 00:19:10,070
way or the other it's just a question of

520
00:19:14,740 --> 00:19:13,070
what happens along the way and this

521
00:19:16,630 --> 00:19:14,750
where could this kind of network occur

522
00:19:18,310 --> 00:19:16,640
it really down selects two relatively

523
00:19:20,560 --> 00:19:18,320
few places in our universe where you

524
00:19:23,160 --> 00:19:20,570
could have both mixed phases of

525
00:19:26,650 --> 00:19:23,170
reactants gas liquid and solid and

526
00:19:29,440 --> 00:19:26,660
really high-energy radiation coming from

527
00:19:32,400 --> 00:19:29,450
either super solar flares radiation

528
00:19:35,980 --> 00:19:32,410
belts around large magnetic field

529
00:19:37,960 --> 00:19:35,990
planets and radioactive mineral seams in

530
00:19:41,710 --> 00:19:37,970
geologic formations with relatively

531
00:19:43,090 --> 00:19:41,720
mature crust mantle systems so there's a

532
00:19:45,130 --> 00:19:43,100
lot of questions looking forward about

533
00:19:46,540 --> 00:19:45,140
integrating all of these equations and

534
00:19:48,160 --> 00:19:46,550
asking whether or not this would be

535
00:19:50,470 --> 00:19:48,170
realized in a physical system and

536
00:19:52,360 --> 00:19:50,480
whether that system itself would exhibit

537
00:19:55,180 --> 00:19:52,370
these kind of emergent properties at a

538
00:19:56,800 --> 00:19:55,190

really top level this is version one of

539
00:19:58,270 --> 00:19:56,810
the network version two we're working on

540
00:20:00,640 --> 00:19:58,280
getting it out we'll have a preprint and

541
00:20:02,620 --> 00:20:00,650
chem archive soon and I thank you for

542
00:20:05,330 --> 00:20:02,630
your time

543
00:20:08,159 --> 00:20:05,340
[Music]

544
00:20:12,129 --> 00:20:08,169
[Applause]

545
00:20:14,489 --> 00:20:12,139
we as we don't have our final speaker we

546
00:20:18,579 --> 00:20:14,499
do have some time for questions and

547
00:20:21,989 --> 00:20:18,589
before you all head to lunch because we

548
00:20:24,699 --> 00:20:21,999
feel free to do so I've been very

549
00:20:26,979 --> 00:20:24,709
encouraged to promote this wonderful new

550
00:20:30,249 --> 00:20:26,989
publication from NASA it's the issue

551
00:20:32,079 --> 00:20:30,259
number seven of the astrobiology graphic

552
00:20:34,869 --> 00:20:32,089
novel series and it will be given away

553
00:20:37,029 --> 00:20:34,879
tonight at 7 o'clock in the poster

554
00:20:40,029 --> 00:20:37,039
session and several of you are pictured

555
00:20:42,639 --> 00:20:40,039
as here as cartoon characters so it's a

556
00:20:44,109 --> 00:20:42,649
wonderful telling of where life might be

557
00:20:46,769 --> 00:20:44,119
found in the universe and the origin of

558
00:20:49,899 --> 00:20:46,779
life questions beautifully creatively

559
00:20:54,310 --> 00:20:49,909
produced by Aaron who may be here in the

560
00:20:57,489 --> 00:20:54,320
room and with that let's just also an

561
00:20:59,949 --> 00:20:57,499
announcement that after lunch please

562
00:21:02,129 --> 00:20:59,959
return we're having the next part of the

563
00:21:03,999 --> 00:21:02,139

session session 2 is more complex

564
00:21:06,369 --> 00:21:04,009
environments polymerization and

565
00:21:07,899 --> 00:21:06,379
capsulation selection so that's how

566
00:21:09,579 --> 00:21:07,909
we're doing this we're going from the

567
00:21:11,709 --> 00:21:09,589
simple formation of the compounds all

568
00:21:14,319 --> 00:21:11,719
the way up to complex away from

569
00:21:16,539 --> 00:21:14,329
equilibrium systems so first question in

570
00:21:18,099 --> 00:21:16,549
the center here hi Mike Wong from the

571
00:21:20,469 --> 00:21:18,109
University of Washington this is really

572
00:21:22,569 --> 00:21:20,479
fascinating work so at the plenary this

573
00:21:24,310 --> 00:21:22,579
morning eric smith said that in the

574
00:21:25,989 --> 00:21:24,320
origin of life community were very state

575
00:21:28,089 --> 00:21:25,999
focused and we should probably be a

576
00:21:29,649 --> 00:21:28,099
little more process focused so i'm

577
00:21:32,829 --> 00:21:29,659
wondering if one of the takeaways from

578
00:21:36,639 --> 00:21:32,839
your talk is that we can sort of distill

579
00:21:39,669 --> 00:21:36,649
the process behind the network topology

580
00:21:42,459 --> 00:21:39,679
of life to essentially the properties of

581
00:21:45,459 --> 00:21:42,469
free radical chemistry and that of water

582
00:21:48,279 --> 00:21:45,469
is that is that a comprehensive take

583
00:21:50,709 --> 00:21:48,289
away or yeah I think that's a excellent

584
00:21:53,079 --> 00:21:50,719
summary I would specify a couple of

585
00:21:54,699 --> 00:21:53,089
things that I think whether you believe

586
00:21:56,259 --> 00:21:54,709
this participated in the origins of life

587
00:21:57,699 --> 00:21:56,269
or not I think there are some really

588
00:21:59,379 --> 00:21:57,709

interesting dynamical properties

589
00:22:01,569 --> 00:21:59,389
associated with this Network that should

590
00:22:03,369 --> 00:22:01,579
be investigated but what I think is an

591
00:22:05,289 --> 00:22:03,379
advantage of this particular Network and

592
00:22:07,029 --> 00:22:05,299
tying to the origin of life you can

593
00:22:09,339 --> 00:22:07,039
create a lot of tractable hypotheses

594
00:22:12,099 --> 00:22:09,349
that connect these two for example with

595
00:22:14,000 --> 00:22:12,109
these closed networks of of radicals as

596
00:22:16,130 --> 00:22:14,010
long as the network is closed and as

597
00:22:18,049 --> 00:22:16,140
as at a network level there's some sink

598
00:22:20,030 --> 00:22:18,059
for oxygen it really shouldn't matter

599
00:22:23,299 --> 00:22:20,040
what the redox state of say the carbon

600
00:22:24,830 --> 00:22:23,309
is or the sulfur or the nitrogen at some

601
00:22:26,840 --> 00:22:24,840
point the system will be driven to be

602
00:22:29,390 --> 00:22:26,850
reduced over time that's an example

603
00:22:32,210 --> 00:22:29,400
another is that this is an idea I've

604
00:22:34,010 --> 00:22:32,220
been working on recently is that in

605
00:22:36,730 --> 00:22:34,020
making this jump from the radio lytic

606
00:22:40,070 --> 00:22:36,740
chemistry to say an oligomers chemistry

607
00:22:42,980 --> 00:22:40,080
that's explored by the hutt group Irene

608
00:22:44,720 --> 00:22:42,990
Chen we can actually say maybe in terms

609
00:22:46,549 --> 00:22:44,730
of exploring what functionality means

610
00:22:48,230 --> 00:22:46,559
for oligomers if we're looking for

611
00:22:50,870 --> 00:22:48,240
biological functionality that might be a

612
00:22:53,840 --> 00:22:50,880
very limited way of viewing what those

613
00:22:56,270 --> 00:22:53,850

short polymers can do these oligomers

614
00:22:58,970 --> 00:22:56,280
might have some emergent functionality

615
00:23:00,500 --> 00:22:58,980
with notes that are located near its

616
00:23:01,430 --> 00:23:00,510
emergence within the the chemical

617
00:23:04,430 --> 00:23:01,440
Network that we haven't thought about

618
00:23:06,740 --> 00:23:04,440
either manipulating alternative solvents

619
00:23:09,530 --> 00:23:06,750
or turning them into particular

620
00:23:11,840 --> 00:23:09,540
substrates that might be useful so maybe

621
00:23:13,850 --> 00:23:11,850
looking in terms of a radio lytic

622
00:23:15,380 --> 00:23:13,860
chemical functionality as opposed to a

623
00:23:16,730 --> 00:23:15,390
biological functionality for these

624
00:23:20,600 --> 00:23:16,740
shorter lemur sequences might be

625
00:23:21,950 --> 00:23:20,610
productive yeah cool thank you I might

626
00:23:23,690 --> 00:23:21,960
try signing University of Minnesota

627
00:23:27,830 --> 00:23:23,700
thanks for their really interesting talk

628
00:23:29,720 --> 00:23:27,840
I have maybe sort of probably answered

629
00:23:31,220 --> 00:23:29,730
it but I'd like to hear you articulate a

630
00:23:32,630 --> 00:23:31,230
little bit better perhaps so you

631
00:23:33,980 --> 00:23:32,640
described a really interesting system

632
00:23:35,690 --> 00:23:33,990
where you have a high energy source and

633
00:23:37,039 --> 00:23:35,700
you're sort of down just with

634
00:23:38,840 --> 00:23:37,049
consequences of the high energy source

635
00:23:41,630 --> 00:23:38,850
that is right reminiscent of a life like

636
00:23:43,970 --> 00:23:41,640
system and I I kind of wonder how much

637
00:23:48,669 --> 00:23:43,980
more how much of this of your model is

638
00:23:51,380 --> 00:23:48,679

really a metaphor or a model for life

639
00:23:55,280 --> 00:23:51,390
that's interesting okay oh oh

640
00:23:57,289 --> 00:23:55,290
I will first state that this is a

641
00:23:59,780 --> 00:23:57,299
collection of equations these represent

642
00:24:01,430 --> 00:23:59,790
data so as much as an ecosystem is a

643
00:24:02,750 --> 00:24:01,440
collection of individuals for which we

644
00:24:05,690 --> 00:24:02,760
have never have complete information

645
00:24:08,870 --> 00:24:05,700
this is definitely a data-driven it's

646
00:24:09,860 --> 00:24:08,880
not a model but that's an I think that's

647
00:24:11,210 --> 00:24:09,870
an interesting way of looking at

648
00:24:12,770 --> 00:24:11,220
especially when it comes to how we think

649
00:24:14,450 --> 00:24:12,780
about these things and how we design

650
00:24:16,640 --> 00:24:14,460
experiments and we acknowledge the

651
00:24:19,010 --> 00:24:16,650
limits and bias that are implicit with

652
00:24:21,049 --> 00:24:19,020
any study like this at what point does

653
00:24:22,970 --> 00:24:21,059
it is it undergirded by a complete

654
00:24:24,150 --> 00:24:22,980
mechanistic description and at what

655
00:24:26,250 --> 00:24:24,160
point does it become

656
00:24:28,050 --> 00:24:26,260
inferred model I don't really have an

657
00:24:29,670 --> 00:24:28,060
answer except that there are a lot of

658
00:24:32,250 --> 00:24:29,680
other people working on questions like

659
00:24:33,900 --> 00:24:32,260
this that have better answers than I do

660
00:24:35,490 --> 00:24:33,910
and I'm sorry I can't give me one but

661
00:24:37,290 --> 00:24:35,500
but it's an interesting level of

662
00:24:39,240 --> 00:24:37,300
inference when we can actually distill

663
00:24:40,710 --> 00:24:39,250

rules that make sense and seem to be

664
00:24:42,960 --> 00:24:40,720
repeated there's something about

665
00:24:44,390 --> 00:24:42,970
hierarchy implicit in our ability to

666
00:24:48,660 --> 00:24:44,400
make that statement with some assurance

667
00:24:52,710 --> 00:24:48,670
Thanks Thank You Ralph Madrid's McMaster

668
00:24:54,360 --> 00:24:52,720
is there the kind of relations in the

669
00:24:56,550 --> 00:24:54,370
peril law relations that you have for

670
00:24:58,680 --> 00:24:56,560
these heavy tales you'd show two of them

671
00:25:00,810 --> 00:24:58,690
this one and the protein want to begin

672
00:25:03,390 --> 00:25:00,820
with are they do they have some real

673
00:25:06,480 --> 00:25:03,400
indices is there kind of universality

674
00:25:09,870 --> 00:25:06,490
here and these power laws or are they

675
00:25:12,660 --> 00:25:09,880
quite distinct actually so there there

676
00:25:14,550 --> 00:25:12,670
is some degree of universality when we

677
00:25:15,990 --> 00:25:14,560
get down to the basic nuts and bolts

678
00:25:18,810 --> 00:25:16,000
description for how these things can

679
00:25:20,670 --> 00:25:18,820
show up in a physical sense and I'll

680
00:25:22,290 --> 00:25:20,680
defer to Sarah because I know she

681
00:25:23,430 --> 00:25:22,300
studies these things a lot better if you

682
00:25:25,710 --> 00:25:23,440
have a follow-up question if I don't

683
00:25:28,560 --> 00:25:25,720
answer it sufficiently well but

684
00:25:30,120 --> 00:25:28,570
basically the the exponent is very very

685
00:25:31,500 --> 00:25:30,130
meaningful I also point to one Juan

686
00:25:33,960 --> 00:25:31,510
Perez Mercator is gonna give a talk

687
00:25:36,810 --> 00:25:33,970
later on with this kind of exponential

688
00:25:39,030 --> 00:25:36,820

relationship between objects

689
00:25:40,950 --> 00:25:39,040
it basically means like the system is

690
00:25:42,690 --> 00:25:40,960
not completely frozen and crystallized

691
00:25:44,220 --> 00:25:42,700
and rigid but it also means it's not

692
00:25:46,980 --> 00:25:44,230
completely chaotic and doing something

693
00:25:48,270 --> 00:25:46,990
different every time you perturb it so

694
00:25:49,800 --> 00:25:48,280
this should give us a number of very

695
00:25:52,290 --> 00:25:49,810
interesting qualities at a physical

696
00:25:54,540 --> 00:25:52,300
level such as there it might be possible

697
00:25:56,520 --> 00:25:54,550
that this isn't a realization of a

698
00:25:58,620 --> 00:25:56,530
chemical computation system for example

699
00:26:01,080 --> 00:25:58,630
there might be computational primitives

700
00:26:04,350 --> 00:26:01,090
that are extractable from certain modes

701
00:26:05,400 --> 00:26:04,360
of this system being excited there is so

702
00:26:07,890 --> 00:26:05,410
there's a kind of a class of

703
00:26:11,430 --> 00:26:07,900
universality whether it transfers to

704
00:26:13,530 --> 00:26:11,440
this and what those Universal attributes

705
00:26:15,270 --> 00:26:13,540
might be we really have to flesh it out

706
00:26:18,340 --> 00:26:15,280
and actually try to build it to to make

707
00:26:20,530 --> 00:26:18,350
those kind of conclusions thank you

708
00:26:23,530 --> 00:26:20,540
Vladimir Putin NASA Goddard Space Flight

709
00:26:25,960 --> 00:26:23,540
Center yeah I want to comment on the

710
00:26:27,880 --> 00:26:25,970
last question on the universality the

711
00:26:31,650 --> 00:26:27,890
point is that this is a nonlinear system

712
00:26:34,930 --> 00:26:31,660
that eventually you know leads to the

713
00:26:37,420 --> 00:26:34,940

self-organized criticality and the

714
00:26:39,910 --> 00:26:37,430
general signature of self-organized

715
00:26:42,610 --> 00:26:39,920
criticality is the parallel distribution

716
00:26:45,850 --> 00:26:42,620
and actually it's interesting that the

717
00:26:48,340 --> 00:26:45,860
index of the distribution 0.8 is very

718
00:26:50,980 --> 00:26:48,350
characteristic for the any kind of

719
00:26:53,920 --> 00:26:50,990
system that we observe let's say solar

720
00:26:56,850 --> 00:26:53,930
flares they go with the they're the

721
00:27:00,490 --> 00:26:56,860
result of the self-organized criticality

722
00:27:03,490 --> 00:27:00,500
with the index of 0.8 or earthquake

723
00:27:07,270 --> 00:27:03,500
salvo Oh point of quakes so this index

724
00:27:09,670 --> 00:27:07,280
is very very interesting yeah and I

725
00:27:11,170 --> 00:27:09,680
think I don't want to make an overly

726
00:27:12,970 --> 00:27:11,180
broad statement but what we're hoping is

727
00:27:15,280 --> 00:27:12,980
that this might be the first Organo

728
00:27:17,590 --> 00:27:15,290
synthetic system that also has these

729
00:27:22,810 --> 00:27:17,600
these power-law relationship and perhaps

730
00:27:24,430 --> 00:27:22,820
self-organized critical attributes hi am

731
00:27:25,810 --> 00:27:24,440
my name is Steven freed from Johns

732
00:27:26,710 --> 00:27:25,820
Hopkins and I really enjoyed your

733
00:27:28,870 --> 00:27:26,720
presentation was really

734
00:27:30,640 --> 00:27:28,880
thought-provoking and I really

735
00:27:33,700 --> 00:27:30,650
appreciated how your discussion

736
00:27:36,100 --> 00:27:33,710
emphasized that by fertilizing water

737
00:27:39,190 --> 00:27:36,110
with these high energy photons to

738
00:27:40,600 --> 00:27:39,200

generate HOH da and those basically give

739
00:27:43,750 --> 00:27:40,610
you ingredients to start to assemble

740
00:27:45,490 --> 00:27:43,760
larger things but I guess what may be

741
00:27:47,710 --> 00:27:45,500
your discussion didn't focus as much on

742
00:27:49,840 --> 00:27:47,720
as how if you have already have complex

743
00:27:52,150 --> 00:27:49,850
molecules than they get they absorb a

744
00:27:53,950 --> 00:27:52,160
gamma photon there's probably more ways

745
00:27:55,330 --> 00:27:53,960
for them to fall apart than for them to

746
00:27:57,310 --> 00:27:55,340
come back together so I guess my

747
00:27:58,740 --> 00:27:57,320
question is how do you balance you know

748
00:28:01,690 --> 00:27:58,750
you have this hi a source of energy

749
00:28:04,300 --> 00:28:01,700
entropy is generally going to favor you

750
00:28:05,800 --> 00:28:04,310
know complex molecules falling apart we

751
00:28:07,990 --> 00:28:05,810
can draw a network that doesn't really

752
00:28:09,490 --> 00:28:08,000
tell us much about yield and the

753
00:28:11,980 --> 00:28:09,500
efficiency of things kind of staying

754
00:28:13,270 --> 00:28:11,990
together versus you know kind of falling

755
00:28:15,130 --> 00:28:13,280
back apart and curious what your

756
00:28:17,290 --> 00:28:15,140
thoughts might be on that yeah this is a

757
00:28:18,910 --> 00:28:17,300
recurring question about I think it

758
00:28:21,340 --> 00:28:18,920
leads to a broader discussion of

759
00:28:23,710 --> 00:28:21,350
plausibility because at the end of the

760
00:28:25,810 --> 00:28:23,720
day it's not enough to presume that

761
00:28:27,520 --> 00:28:25,820
there's an assembled nucleotide on one

762
00:28:28,570 --> 00:28:27,530
side of the planet and another one on

763
00:28:30,190 --> 00:28:28,580

the other side of the planet from a

764
00:28:30,730 --> 00:28:30,200
statistical point of view they're never

765
00:28:32,530 --> 00:28:30,740
going to enter

766
00:28:34,240 --> 00:28:32,540
or form a polymer or anything like that

767
00:28:35,950 --> 00:28:34,250
and basically at that scale that's

768
00:28:39,010 --> 00:28:35,960
that's like it saved this scale and

769
00:28:41,350 --> 00:28:39,020
we're at the scale way down here what I

770
00:28:43,299 --> 00:28:41,360
see here is that you can have a regime

771
00:28:45,340 --> 00:28:43,309
within this enclosed box and you also

772
00:28:46,390 --> 00:28:45,350
have a gradient within that box like if

773
00:28:48,600 --> 00:28:46,400
you really want to start to tear it

774
00:28:51,310 --> 00:28:48,610
apart and you can have a really strong

775
00:28:53,799 --> 00:28:51,320
zone of radiolysis occurring within a

776
00:28:55,419 --> 00:28:53,809
sub volume there that is being

777
00:28:57,280 --> 00:28:55,429
attenuated more or less within that

778
00:28:59,020 --> 00:28:57,290
volume and the products are kind of

779
00:29:00,280 --> 00:28:59,030
spilling out the edge so I put up this

780
00:29:01,720 --> 00:29:00,290
plot I didn't talk about it

781
00:29:04,870 --> 00:29:01,730
but basically if you have a really

782
00:29:07,000 --> 00:29:04,880
concentrated zone or like a boundary

783
00:29:08,260 --> 00:29:07,010
condition where a lot of radiation is

784
00:29:10,419 --> 00:29:08,270
spilling in one side but then there are

785
00:29:12,549 --> 00:29:10,429
other parts that are very very low

786
00:29:14,260 --> 00:29:12,559
absorb dose rates or none all right

787
00:29:16,180 --> 00:29:14,270
basically these products would be

788
00:29:19,900 --> 00:29:16,190

expected to spill off the edge of that

789
00:29:22,450 --> 00:29:19,910
energy attenuation volume and accumulate

790
00:29:26,200 --> 00:29:22,460
in the system elsewhere yeah that leads

791
00:29:27,820 --> 00:29:26,210
to inferences about how plausible is the

792
00:29:30,160 --> 00:29:27,830
system would you see it say on a

793
00:29:32,650 --> 00:29:30,170
planetary scale with super solar flares

794
00:29:34,510 --> 00:29:32,660
and pinching on on a on a atmospheric

795
00:29:36,040 --> 00:29:34,520
envelope would it be raining down below

796
00:29:38,320 --> 00:29:36,050
whether you're out of reach of those

797
00:29:39,940 --> 00:29:38,330
things those are all types of

798
00:29:42,630 --> 00:29:39,950
environmental inferences that could be

799
00:29:49,440 --> 00:29:42,640
made presuming this kind of

800
00:29:54,340 --> 00:29:49,450
heterogeneity within the box itself your

801
00:29:56,080 --> 00:29:54,350
network is at a certain energy level you

802
00:29:58,810 --> 00:29:56,090
shows about six energy levels from

803
00:30:00,910 --> 00:29:58,820
infrared to gamma rays and was that

804
00:30:04,299 --> 00:30:00,920
network that you showed for just one of

805
00:30:07,350 --> 00:30:04,309
those energy levels or did you have all

806
00:30:11,590 --> 00:30:07,360
of them somehow imposed on one another

807
00:30:13,450 --> 00:30:11,600
there there was no finer binning of the

808
00:30:15,520 --> 00:30:13,460
photonic spectrum and it's really really

809
00:30:17,200 --> 00:30:15,530
coarse and I had admit that it has its

810
00:30:18,850 --> 00:30:17,210
limitations but we were just trying to

811
00:30:21,180 --> 00:30:18,860
account for these really gross

812
00:30:24,960 --> 00:30:21,190
transformations and entropy production

813
00:30:27,610 --> 00:30:24,970

so then the model has no finer division

814
00:30:29,799 --> 00:30:27,620
and I realized that for some species

815
00:30:32,560 --> 00:30:29,809
might be very UV sensitive and then

816
00:30:34,690 --> 00:30:32,570
completely opaque invisible or infrared

817
00:30:36,850 --> 00:30:34,700
or there might be some species that are

818
00:30:39,130 --> 00:30:36,860
sensitive within divisions of these bins

819
00:30:40,539 --> 00:30:39,140
that that really matter those are not

820
00:30:43,060 --> 00:30:40,549
accounted for in this plane

821
00:30:46,299 --> 00:30:43,070
yeah just a interesting point I notice

822
00:30:49,509 --> 00:30:46,309
your title slide had vials glass vials

823
00:30:53,769 --> 00:30:49,519
around a cobalt-60 source and the glass

824
00:30:56,560 --> 00:30:53,779
turns brown because the silicate in the

825
00:30:58,810 --> 00:30:56,570
glass is being activated by the gamma

826
00:31:01,779 --> 00:30:58,820
radiation so it's a visual indication of

827
00:31:03,849 --> 00:31:01,789
some of what you're talking about yeah

828
00:31:05,889 --> 00:31:03,859
very much those are fun experiments to

829
00:31:07,599 --> 00:31:05,899
run and basically at the end of the day

830
00:31:09,310 --> 00:31:07,609
those experiments are completely

831
00:31:11,289 --> 00:31:09,320
hands-off all of the experiments that we

832
00:31:13,389 --> 00:31:11,299
present are more or less hands-off and

833
00:31:15,249 --> 00:31:13,399
that's why we think this might be a

834
00:31:17,109 --> 00:31:15,259
self-organizing system if it has this

835
00:31:19,869 --> 00:31:17,119
structure and there's no further

836
00:31:21,339 --> 00:31:19,879
internal manipulation that should be the

837
00:31:23,379 --> 00:31:21,349
most likely outcome whether it's the

838
00:31:24,940 --> 00:31:23,389

actual outcome and a realized system we

839
00:31:26,409 --> 00:31:24,950
would have to kind of more statistically

840
00:31:27,219 --> 00:31:26,419
compare and conduct more experiments

841
00:31:30,519 --> 00:31:27,229
along those lines

842
00:31:33,180 --> 00:31:30,529
yeah thank you

843
00:31:37,389 --> 00:31:33,190
Zak so much our fascinating work and