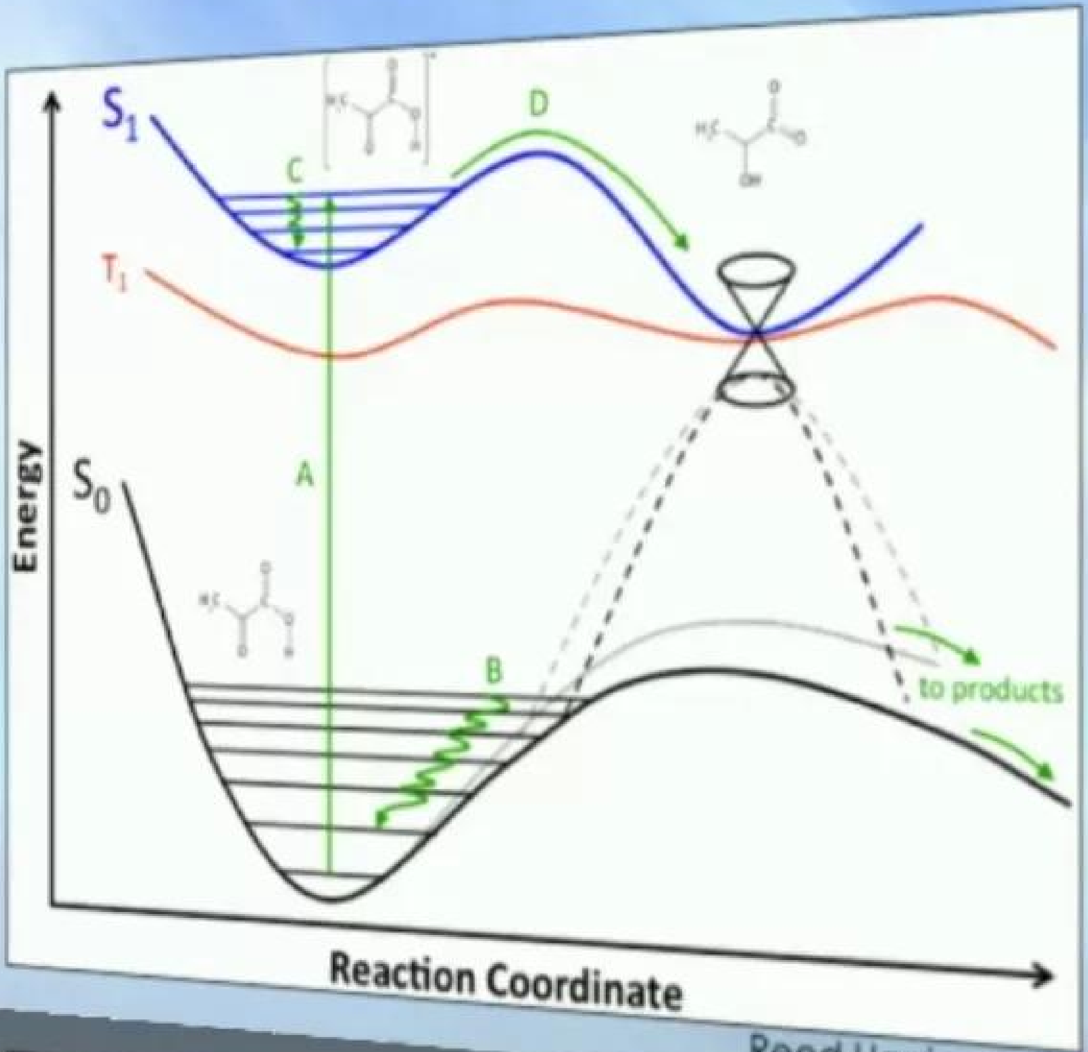
Pyruvic Acid



Reed Harris, et al. *In Prep.*

1
00:00:08,750 --> 00:00:05,829
[Music]

2
00:00:10,070 --> 00:00:08,760
I'm gonna be talking about prebiotic

3
00:00:12,020 --> 00:00:10,080
photochemistry today and we've actually

4
00:00:13,400 --> 00:00:12,030
heard quite a bit about photochemistry

5
00:00:15,980 --> 00:00:13,410
sauce one of the benefits of going

6
00:00:18,260 --> 00:00:15,990
towards the end of the conference I get

7
00:00:20,720 --> 00:00:18,270
to invoke a lot of what other people

8
00:00:22,130 --> 00:00:20,730
have already discussed and in particular

9
00:00:24,050 --> 00:00:22,140
I'm going to be talking about how we can

10
00:00:25,880 --> 00:00:24,060
use photo chemistry to build bigger

11
00:00:27,170 --> 00:00:25,890
molecules we've talked a lot about photo

12
00:00:28,730 --> 00:00:27,180
stability and how that can be really

13
00:00:31,279 --> 00:00:28,740

important so we don't break up molecules

14
00:00:34,580 --> 00:00:31,289
but I'm gonna be talking more about how

15
00:00:36,530 --> 00:00:34,590
we can make bigger molecules using photo

16
00:00:37,819 --> 00:00:36,540
chemistry so I think it's important to

17
00:00:40,910 --> 00:00:37,829
define what I mean when I'm talking

18
00:00:42,619 --> 00:00:40,920
about molecular complexity you can think

19
00:00:44,600 --> 00:00:42,629
about complexity as just having a large

20
00:00:47,000 --> 00:00:44,610
mixture of lots of molecules but in this

21
00:00:49,639 --> 00:00:47,010
case I really do mean forming bigger

22
00:00:52,520 --> 00:00:49,649
molecules so how do we form covalent

23
00:00:55,189 --> 00:00:52,530
bonds without biology in a prebiotic

24
00:00:57,560 --> 00:00:55,199
setting and so if you have simple

25
00:00:59,869 --> 00:00:57,570
molecules like our favorite fatty acids

26
00:01:01,939 --> 00:00:59,879
we've been talking about a lot how did

27
00:01:04,310 --> 00:01:01,949
we get from those simple prebiotic

28
00:01:06,320 --> 00:01:04,320
available molecules to the more complex

29
00:01:09,140 --> 00:01:06,330
biomolecules that are actually needed

30
00:01:12,410 --> 00:01:09,150
for life and so I'll be talking about

31
00:01:15,679 --> 00:01:12,420
quite a bit this model system for making

32
00:01:19,010 --> 00:01:15,689
simple double tailed lipids where we

33
00:01:21,410 --> 00:01:19,020
sort of are in an intermediate region of

34
00:01:23,899 --> 00:01:21,420
chemical space between these simple

35
00:01:26,420 --> 00:01:23,909
single tailed fatty acids and the much

36
00:01:28,219 --> 00:01:26,430
more complex phospholipids that are in

37
00:01:30,530 --> 00:01:28,229
modern cells and so there's a way of

38
00:01:32,929 --> 00:01:30,540

doing this photochemically using a very

39
00:01:34,370 --> 00:01:32,939
simple system but before I get into the

40
00:01:36,170 --> 00:01:34,380
specifics I want to step back a little

41
00:01:37,969 --> 00:01:36,180
bit and talk about both prebiotic

42
00:01:41,149 --> 00:01:37,979
chemistry and photo chemistry in general

43
00:01:43,160 --> 00:01:41,159
and so again we've heard a lot about how

44
00:01:44,990 --> 00:01:43,170
prebiotic chemistry is sort of how you

45
00:01:48,530 --> 00:01:45,000
go from simple systems to complex

46
00:01:51,109 --> 00:01:48,540
systems and that's great except that

47
00:01:53,899 --> 00:01:51,119
there's always the back reaction of

48
00:01:56,450 --> 00:01:53,909
going back from a complex system to a

49
00:01:59,990 --> 00:01:56,460
more simple one and so if we're thinking

50
00:02:02,179 --> 00:02:00,000
about a system that isn't being driven

51
00:02:03,530 --> 00:02:02,189
in some sense there's always going to be

52
00:02:04,660 --> 00:02:03,540
an equilibrium and even if your

53
00:02:07,639 --> 00:02:04,670
equilibrium is thermodynamically

54
00:02:09,410 --> 00:02:07,649
favoring this more complex system you're

55
00:02:12,710 --> 00:02:09,420
still kind of going to be stuck in this

56
00:02:13,100 --> 00:02:12,720
equilibrium state and so you generally

57
00:02:14,330 --> 00:02:13,110
need

58
00:02:17,090 --> 00:02:14,340
a driving force to maintain

59
00:02:20,360 --> 00:02:17,100
disequilibrium which is often an input

60
00:02:23,450 --> 00:02:20,370
of energy and so if you just think about

61
00:02:25,370 --> 00:02:23,460
going from simple processes to the more

62
00:02:29,180 --> 00:02:25,380
complex things including life you're

63
00:02:30,530 --> 00:02:29,190

maintaining disk equilibrium and so when

64
00:02:32,030 --> 00:02:30,540
we need to think about energy sources

65
00:02:34,940 --> 00:02:32,040
there are lots of different prebiotic

66
00:02:36,610 --> 00:02:34,950
energy sources you can pick and we've

67
00:02:40,190 --> 00:02:36,620
we've heard a lot about a lot of these

68
00:02:42,440 --> 00:02:40,200
but solar radiation is a really

69
00:02:44,240 --> 00:02:42,450
attractive energy source for a couple of

70
00:02:46,190 --> 00:02:44,250
different reasons one of which it's just

71
00:02:47,180 --> 00:02:46,200
a much larger energy source than

72
00:02:49,370 --> 00:02:47,190
anything else that would have been

73
00:02:50,960 --> 00:02:49,380
available this particular study was only

74
00:02:53,479 --> 00:02:50,970
looking at UV light that was less than

75
00:02:55,310 --> 00:02:53,489
250 nanometers which is clearly not all

76
00:02:59,390 --> 00:02:55,320
of the light in the system but even that

77
00:03:02,240 --> 00:02:59,400
is over a couple over magnitude more

78
00:03:06,290 --> 00:03:02,250
energy from the Sun than the other

79
00:03:08,930 --> 00:03:06,300
sources and it's also important to think

80
00:03:10,070 --> 00:03:08,940
about photo chemistry and light from the

81
00:03:11,540 --> 00:03:10,080
Sun because photo chemistry is

82
00:03:13,880 --> 00:03:11,550
fundamentally different than thermal

83
00:03:17,030 --> 00:03:13,890
chemistry thermo chemistry you have a

84
00:03:19,340 --> 00:03:17,040
bath of molecules in say an aqueous

85
00:03:21,289 --> 00:03:19,350
environment and you heat it up and

86
00:03:23,690 --> 00:03:21,299
you're all just jostling around the

87
00:03:26,330 --> 00:03:23,700
whole system is moving and it's

88
00:03:28,610 --> 00:03:26,340

generally not particularly specific

89
00:03:30,979 --> 00:03:28,620
whereas with photo chemistry you have a

90
00:03:33,380 --> 00:03:30,989
specific molecule that absorbs light at

91
00:03:35,240 --> 00:03:33,390
a certain energy range and you can

92
00:03:37,520 --> 00:03:35,250
excite a single molecule or a single

93
00:03:40,039 --> 00:03:37,530
type of molecule in a solution while the

94
00:03:41,770 --> 00:03:40,049
bath remains low and the other molecules

95
00:03:45,199 --> 00:03:41,780
are not necessarily excited and

96
00:03:47,420 --> 00:03:45,209
photochemistry is also sort of

97
00:03:49,699 --> 00:03:47,430
inherently a non equilibrium system

98
00:03:52,190 --> 00:03:49,709
because you're exciting the molecule and

99
00:03:54,470 --> 00:03:52,200
it's also very dependent on which

100
00:03:55,820 --> 00:03:54,480
molecule you choose what chemistry are

101
00:03:59,690 --> 00:03:55,830
going to get out if you're going to get

102
00:04:02,420 --> 00:03:59,700
out any chemistry all right so we've

103
00:04:05,330 --> 00:04:02,430
seen a plot from Parker that was based

104
00:04:06,680 --> 00:04:05,340
on a lot of the same data but what

105
00:04:07,970 --> 00:04:06,690
conditions are we talking about when

106
00:04:10,280 --> 00:04:07,980
we're talking about the young son during

107
00:04:12,140 --> 00:04:10,290
the prebiotic conditions so we have a

108
00:04:13,970 --> 00:04:12,150
few things on here so we have the sort

109
00:04:17,210 --> 00:04:13,980
of modern extraterrestrial solar

110
00:04:19,099 --> 00:04:17,220
spectrum outside the atmosphere and then

111
00:04:21,620 --> 00:04:19,109
we have this model of the young son of

112
00:04:23,510 --> 00:04:21,630
about 3.8 billion years ago and then

113
00:04:26,970 --> 00:04:23,520

I've also put the current surface

114
00:04:30,310 --> 00:04:26,980
spectrum on here so it's this

115
00:04:32,110 --> 00:04:30,320
son but looking at it sort of on the

116
00:04:34,210 --> 00:04:32,120
surface so what light is making it

117
00:04:36,940 --> 00:04:34,220
through and of course we see this really

118
00:04:38,590 --> 00:04:36,950
distinct cutoff at 290 nanometers which

119
00:04:41,320 --> 00:04:38,600
is where ozone is cutting off the UV

120
00:04:44,350 --> 00:04:41,330
light but you notice the changes we're

121
00:04:47,590 --> 00:04:44,360
seeing in the solar spectrum due to the

122
00:04:49,900 --> 00:04:47,600
atmosphere are sort of of the same order

123
00:04:52,930 --> 00:04:49,910
of magnitude for lack of a better word

124
00:04:55,270 --> 00:04:52,940
as the changes of several billion years

125
00:04:57,070 --> 00:04:55,280
of solar evolution and so it's really

126
00:04:58,780 --> 00:04:57,080
important to think about what prebiotic

127
00:05:01,690 --> 00:04:58,790
atmospheric filters we're going to have

128
00:05:03,520 --> 00:05:01,700
and the we have guesses for what the

129
00:05:05,260 --> 00:05:03,530
prebiotic atmosphere was and what

130
00:05:07,590 --> 00:05:05,270
filters there would be they're not I

131
00:05:11,440 --> 00:05:07,600
would say particularly well constrained

132
00:05:13,870 --> 00:05:11,450
but most people agree that most of the

133
00:05:15,640 --> 00:05:13,880
wavelengths of light at about less than

134
00:05:16,960 --> 00:05:15,650
200 nanometers would be pretty much

135
00:05:18,670 --> 00:05:16,970
filtered by the time you get to the

136
00:05:21,640 --> 00:05:18,680
surface of the earth and that there

137
00:05:24,460 --> 00:05:21,650
would be some attenuation between 200

138
00:05:26,410 --> 00:05:24,470

and 250 nanometers so we've heard a lot

139
00:05:28,300 --> 00:05:26,420
about sort of the more UV that's given

140
00:05:30,910 --> 00:05:28,310
off by the younger son but most of that

141
00:05:33,280 --> 00:05:30,920
it really is out in this higher UV range

142
00:05:34,690 --> 00:05:33,290
that wouldn't necessarily make it all

143
00:05:36,670 --> 00:05:34,700
the way down to the surface of the earth

144
00:05:39,460 --> 00:05:36,680
where we're at least considering doing

145
00:05:41,170 --> 00:05:39,470
useful photo chemistry but there is sort

146
00:05:45,700 --> 00:05:41,180
of this almost hundred nanometer range

147
00:05:49,840 --> 00:05:45,710
of sort of quote unquote useful UV near

148
00:05:55,840 --> 00:05:49,850
UV radiation that can do that can help

149
00:05:58,270 --> 00:05:55,850
build chemical complexity and so as I

150
00:05:59,790 --> 00:05:58,280
was saying photochemistry is molecule

151
00:06:02,710 --> 00:05:59,800
specific but it's also very

152
00:06:05,470 --> 00:06:02,720
environmental environmentally specific

153
00:06:07,900 --> 00:06:05,480
and so we were saying we don't

154
00:06:09,520 --> 00:06:07,910
necessarily know a lot about the early

155
00:06:11,950 --> 00:06:09,530
Earth conditions during this period of

156
00:06:13,090 --> 00:06:11,960
prebiotic chemistry I think we're all

157
00:06:17,230 --> 00:06:13,100
pretty well agreed that there were

158
00:06:19,690 --> 00:06:17,240
oceans or water of some variety we have

159
00:06:21,130 --> 00:06:19,700
guesses with nitrogen and co2 for what

160
00:06:22,150 --> 00:06:21,140
the atmosphere was there are different

161
00:06:24,760 --> 00:06:22,160
estimates of whether there would have

162
00:06:28,360 --> 00:06:24,770
been say organic Hayes's to help filter

163
00:06:30,670 --> 00:06:28,370

some of the UV light out and then other

164
00:06:33,670 --> 00:06:30,680
people have estimated sort of what

165
00:06:35,530 --> 00:06:33,680
minerals and land there would be but for

166
00:06:37,690 --> 00:06:35,540
our purposes we generally try to keep it

167
00:06:38,870 --> 00:06:37,700
really simple so we use aqueous

168
00:06:42,470 --> 00:06:38,880
environments and

169
00:06:45,320 --> 00:06:42,480
use sunlight and so one of the molecules

170
00:06:48,710 --> 00:06:45,330
we use is pyruvic acid here it's an oXXO

171
00:06:51,500 --> 00:06:48,720
acid and so it's got a carboxylic acid

172
00:06:53,600 --> 00:06:51,510
and then a ketone and most of your photo

173
00:06:55,040 --> 00:06:53,610
chemistry and where you absorb light is

174
00:06:56,690 --> 00:06:55,050
going to be controlled by what

175
00:06:59,840 --> 00:06:56,700
functional groups are in your molecule

176
00:07:03,320 --> 00:06:59,850
so here we see the absorption spectrum

177
00:07:05,570 --> 00:07:03,330
for the gas phase pyruvic acid and you

178
00:07:07,400 --> 00:07:05,580
notice that the aqueous phase pyruvic

179
00:07:11,270 --> 00:07:07,410
acid is blue shifted so where these

180
00:07:12,980 --> 00:07:11,280
electronic states are lying really does

181
00:07:16,220 --> 00:07:12,990
change as to whether it's a gas phase

182
00:07:19,040 --> 00:07:16,230
species or an aqueous phase species but

183
00:07:22,220 --> 00:07:19,050
if we use this longer tailed alkyl lock

184
00:07:25,280 --> 00:07:22,230
so acid - oh a it really hasn't changed

185
00:07:28,670 --> 00:07:25,290
much from the aqueous phase pyruvic acid

186
00:07:32,960 --> 00:07:28,680
so the alkyl tail isn't changing much of

187
00:07:34,850 --> 00:07:32,970
the electronic structure here and we got

188
00:07:36,710 --> 00:07:34,860

a good overview of your Blonsky diagrams

189
00:07:38,630 --> 00:07:36,720
earlier today so I won't have to go into

190
00:07:40,880 --> 00:07:38,640
it in too much detail but this is for

191
00:07:43,730 --> 00:07:40,890
pyruvic acid it's just a cartoon sketch

192
00:07:45,470 --> 00:07:43,740
of what goes on with the photo chemistry

193
00:07:47,750 --> 00:07:45,480
here but basically you absorb a light

194
00:07:51,620 --> 00:07:47,760
you go up to this singlet and PI star

195
00:07:56,030 --> 00:07:51,630
manifold and then in the gas phase you

196
00:07:58,280 --> 00:07:56,040
the molecule falls apart into methyl

197
00:08:00,620 --> 00:07:58,290
hydroxy carbon and then can go on to

198
00:08:02,930 --> 00:08:00,630
make small molecule products but as soon

199
00:08:05,210 --> 00:08:02,940
as you're in aqueous phase you now can

200
00:08:08,030 --> 00:08:05,220
inter system cross to this triplet state

201
00:08:11,030 --> 00:08:08,040
via a conical intersection and you can

202
00:08:12,530 --> 00:08:11,040
get really interesting products and so

203
00:08:15,020 --> 00:08:12,540
when we're talking about what the

204
00:08:18,170 --> 00:08:15,030
triplet state is doing it interacts with

205
00:08:19,670 --> 00:08:18,180
another pyruvic acid in this case this

206
00:08:21,710 --> 00:08:19,680
is the dial but there's an equilibrium

207
00:08:24,770 --> 00:08:21,720
between the pyruvic acid and the dial

208
00:08:27,290 --> 00:08:24,780
and equation and it D carboxylates and

209
00:08:32,180 --> 00:08:27,300
it generates two organic radicals and

210
00:08:35,000 --> 00:08:32,190
the organic radicals can go on to make a

211
00:08:37,400 --> 00:08:35,010
number of products but the one we're

212
00:08:40,100 --> 00:08:37,410
going to focus on in particular is this

213
00:08:41,810 --> 00:08:40,110

this is dimethyl tartaric acid so by

214
00:08:44,450 --> 00:08:41,820
absorbing light and a three carbon

215
00:08:47,240 --> 00:08:44,460
molecule decarboxylated and then making

216
00:08:48,890 --> 00:08:47,250
a radical we can recombine two of these

217
00:08:51,430 --> 00:08:48,900
radicals to form a six carbon molecule

218
00:08:53,769 --> 00:08:51,440
so you're making a carbon-carbon bond

219
00:08:57,550 --> 00:08:53,779
and you're you know essentially

220
00:08:59,829 --> 00:08:57,560
dimerizes a molecule and so that's cool

221
00:09:02,259 --> 00:08:59,839
for a lot of reasons but it's especially

222
00:09:03,579 --> 00:09:02,269
interesting if you stick alkyl tails on

223
00:09:06,009 --> 00:09:03,589
here instead of methyls

224
00:09:08,199 --> 00:09:06,019
because then suddenly you have a way of

225
00:09:10,030 --> 00:09:08,209
going from a simple single tailed

226
00:09:12,569 --> 00:09:10,040
surfactant that's prebiotic lee possible

227
00:09:17,590 --> 00:09:12,579
to a simple double tailed surfactant

228
00:09:19,420 --> 00:09:17,600
which is really interesting from because

229
00:09:21,670 --> 00:09:19,430
generally there hasn't been a great

230
00:09:23,800 --> 00:09:21,680
abiotic way of making double tailed

231
00:09:25,660 --> 00:09:23,810
lipids it's not a phospholipid but it's

232
00:09:28,869 --> 00:09:25,670
sort of in this region of chemical space

233
00:09:31,840 --> 00:09:28,879
in between the single tailed carboxylic

234
00:09:34,300 --> 00:09:31,850
acids and the phospholipids it's also

235
00:09:36,970 --> 00:09:34,310
really interesting because we start well

236
00:09:39,879 --> 00:09:36,980
below the aggregation concentration of

237
00:09:42,550 --> 00:09:39,889
the single tailed lipid the 208

238
00:09:45,040 --> 00:09:42,560

but upon fatah lysis and no further

239
00:09:47,410 --> 00:09:45,050
perturbation of the system you actually

240
00:09:51,480 --> 00:09:47,420
see this the solution turned cloudy and

241
00:09:53,679 --> 00:09:51,490
so we're getting self-assembly of these

242
00:09:55,929 --> 00:09:53,689
we're getting self-assembly as the

243
00:09:58,150 --> 00:09:55,939
photolysis proceeds as reforming these

244
00:09:59,410 --> 00:09:58,160
double tailed molecules because double

245
00:10:01,360 --> 00:09:59,420
tailed molecules generally have a lower

246
00:10:03,519 --> 00:10:01,370
critical sort of aggregation

247
00:10:05,439 --> 00:10:03,529
concentration and we've done a little

248
00:10:08,230 --> 00:10:05,449
bit of initial characterization of these

249
00:10:10,809 --> 00:10:08,240
guys they are pretty mono dispersed in

250
00:10:13,329 --> 00:10:10,819
size at about a hundred nanometers in

251
00:10:17,110 --> 00:10:13,339
radius and we can tell that they are

252
00:10:19,809 --> 00:10:17,120
spherical so basically they're too big

253
00:10:21,999 --> 00:10:19,819
to be micelles we haven't definitively

254
00:10:24,160 --> 00:10:22,009
proven that they're vesicles but they're

255
00:10:28,120 --> 00:10:24,170
of the correct size to be vesicles and

256
00:10:29,889 --> 00:10:28,130
even if they are just sort of ordered

257
00:10:31,990 --> 00:10:29,899
aggregates that's a really interesting

258
00:10:34,240 --> 00:10:32,000
phase of self-assembly to get something

259
00:10:35,559 --> 00:10:34,250
that's so mono dispersed in size so

260
00:10:37,780 --> 00:10:35,569
we're still working to characterize this

261
00:10:39,730 --> 00:10:37,790
but in the next couple of minutes I want

262
00:10:41,530 --> 00:10:39,740
to talk about this other chemistry or

263
00:10:43,600 --> 00:10:41,540

using the same idea of chemistry that

264
00:10:46,389 --> 00:10:43,610
we're really excited about right now so

265
00:10:49,660 --> 00:10:46,399
again we've got these organic radicals

266
00:10:51,850 --> 00:10:49,670
and when you're in a solution of pyruvic

267
00:10:54,819 --> 00:10:51,860
acid it makes sense that these two are

268
00:10:57,970 --> 00:10:54,829
going to recombine to make the molecules

269
00:10:59,949 --> 00:10:57,980
come together but in a prebiotic system

270
00:11:02,049 --> 00:10:59,959
you're not just going to have a single

271
00:11:04,210 --> 00:11:02,059
molecule floating around doing chemistry

272
00:11:04,530 --> 00:11:04,220
with itself and so if we can come up

273
00:11:07,620 --> 00:11:04,540
with

274
00:11:09,630 --> 00:11:07,630
way to use these photoactive organic

275
00:11:12,000 --> 00:11:09,640
radicals as drivers for further

276
00:11:14,040 --> 00:11:12,010
chemistry that's really interesting and

277
00:11:16,080 --> 00:11:14,050
so these are initial results that were

278
00:11:18,840 --> 00:11:16,090
we're finishing up right here but

279
00:11:21,030 --> 00:11:18,850
basically we can take pyruvic acid it

280
00:11:24,090 --> 00:11:21,040
also works for 200 a and we can take a

281
00:11:26,520 --> 00:11:24,100
short-tailed carboxylic acid so in this

282
00:11:29,520 --> 00:11:26,530
case hexanoic acid and we can hydrogen

283
00:11:32,610 --> 00:11:29,530
abstract from the hexanoic acid to form

284
00:11:35,420 --> 00:11:32,620
a radical here and then we do see it's a

285
00:11:38,910 --> 00:11:35,430
minor product given how our experimental

286
00:11:41,310 --> 00:11:38,920
constraints but we do see both the

287
00:11:43,920 --> 00:11:41,320
pyruvic and the hexanoic acid these

288
00:11:47,700 --> 00:11:43,930

radicals coming together and we see a

289
00:11:49,560 --> 00:11:47,710
mixed product between the two and so if

290
00:11:52,380 --> 00:11:49,570
that's the case then we really have

291
00:11:55,140 --> 00:11:52,390
developed sort of a primitive or a

292
00:11:57,360 --> 00:11:55,150
fairly robust system for generating

293
00:12:00,000 --> 00:11:57,370
primitive lipids double tailed lipids

294
00:12:03,900 --> 00:12:00,010
both with two oxoacids coming together

295
00:12:06,240 --> 00:12:03,910
but also being able to take a molecule

296
00:12:09,120 --> 00:12:06,250
like a carboxylic acid that it's not

297
00:12:11,040 --> 00:12:09,130
itself photo active and can't do photo

298
00:12:14,820 --> 00:12:11,050
chemistry but we can use the photo

299
00:12:17,430 --> 00:12:14,830
active species as drivers for further

300
00:12:18,450 --> 00:12:17,440
chemistry and with that I just want to

301
00:12:32,210 --> 00:12:18,460
thank everybody you've seen this picture

302
00:12:37,230 --> 00:12:34,950
so work better on ourselves or in both

303
00:12:40,530 --> 00:12:37,240
quit well yeah so I didn't talk about

304
00:12:42,390 --> 00:12:40,540
that today but so these molecules are

305
00:12:44,820 --> 00:12:42,400
surfactant molecules they are going to

306
00:12:46,320 --> 00:12:44,830
partition to the surface and we in our

307
00:12:48,360 --> 00:12:46,330
group an atmospheric chemistry group

308
00:12:50,940 --> 00:12:48,370
really like to think about aerosols

309
00:12:53,760 --> 00:12:50,950
which have a very large surface area to

310
00:12:56,640 --> 00:12:53,770
volume ratio and so you can get a much

311
00:12:58,350 --> 00:12:56,650
higher relative concentration in these

312
00:13:01,320 --> 00:12:58,360
little aerosols that have so much

313
00:13:02,820 --> 00:13:01,330

surface area and so probably I mean it's

314
00:13:04,770 --> 00:13:02,830
a surface area argument if you're

315
00:13:06,750 --> 00:13:04,780
fitting a you know concentration things

316
00:13:09,330 --> 00:13:06,760
so we would love to do it on their cells

317
00:13:10,740 --> 00:13:09,340
but this was all studies actually I'm

318
00:13:19,160 --> 00:13:10,750
used to seeing aerosols from your group

319
00:13:23,620 --> 00:13:22,020
all right another ferris wheel