2017 Astrobiology Graduate Conference

CHARLOTTESVILLE, VA

1
00:00:12,440 --> 00:00:10,310
ah good afternoon everybody

2
00:00:16,330 --> 00:00:12,450
I will be giving the warm-up talk for

3
00:00:19,609 --> 00:00:16,340
not only this afternoon session but our

4
00:00:22,040 --> 00:00:19,619
far evening session many many hours from

5
00:00:23,269 --> 00:00:22,050
now so make sure you remember everything

6
00:00:27,650 --> 00:00:23,279
that I'll tell you here it's very

7
00:00:30,200 --> 00:00:27,660
important all right so this warm-up talk

8
00:00:32,450 --> 00:00:30,210
is going to cover three kind of

9
00:00:34,760 --> 00:00:32,460
disparate areas but they're all part of

10
00:00:38,450 --> 00:00:34,770
the umbrella vaster biology so bio

11
00:00:40,010 --> 00:00:38,460
signatures proteins and lipids and it's

12
00:00:41,690 --> 00:00:40,020
an introduction if anybody doesn't know

13
00:00:44,060 --> 00:00:41,700

me I'm Brad Lieber car I'm a NASA

14
00:00:49,100 --> 00:00:44,070
postdoctoral fellow working at Georgia

15
00:00:52,040 --> 00:00:49,110
Tech so bio signatures

16
00:00:54,319 --> 00:00:52,050
I don't know everybody's background so

17
00:00:56,990 --> 00:00:54,329
I'll just start real simple what is a

18
00:01:00,260 --> 00:00:57,000
bio signature it's basically any

19
00:01:03,319 --> 00:01:00,270
substance like an element an isotope any

20
00:01:05,630 --> 00:01:03,329
sort of fossil that provides scientific

21
00:01:07,789 --> 00:01:05,640
scientific evidence that life was once

22
00:01:11,359 --> 00:01:07,799
there and so something that we all

23
00:01:14,330 --> 00:01:11,369
hopefully are aware of is fossils from

24
00:01:19,160 --> 00:01:14,340
dinosaurs or trilobite soar ancient life

25
00:01:21,380 --> 00:01:19,170
on Earth that falls in mud goes under

26
00:01:23,030 --> 00:01:21,390
and it leaves an impression and you look

27
00:01:26,450 --> 00:01:23,040
at it you clearly go huh

28
00:01:29,210 --> 00:01:26,460
life was here fantastic so it's pretty

29
00:01:31,069 --> 00:01:29,220
easy for these large animals but it

30
00:01:33,859 --> 00:01:31,079
becomes a really big problem when you're

31
00:01:35,749 --> 00:01:33,869
looking at life as a lot of us are

32
00:01:38,480 --> 00:01:35,759
trying to find where we look at

33
00:01:41,749 --> 00:01:38,490
bacterial life which is much much

34
00:01:45,649 --> 00:01:41,759
smaller than dinosaurs and starfish so

35
00:01:48,260 --> 00:01:45,659
it is you can see smaller than hair you

36
00:01:50,300 --> 00:01:48,270
are trying to find signs of life from

37
00:01:54,050 --> 00:01:50,310
before that is this small so it's very

38
00:01:55,370 --> 00:01:54,060

hard to maybe just look at fossils so

39
00:01:59,030 --> 00:01:55,380
what do you do if you're trying to find

40
00:02:01,160 --> 00:01:59,040
signs of life earlier on earth or on

41
00:02:05,780 --> 00:02:01,170
Mars or on any other body that you might

42
00:02:10,190 --> 00:02:05,790
be investigating first of all you have

43
00:02:13,190 --> 00:02:10,200
to ask yourself it's a very important

44
00:02:14,990 --> 00:02:13,200
question in bio signature detection

45
00:02:17,360 --> 00:02:15,000
whether or not what you're looking at is

46
00:02:19,070 --> 00:02:17,370
a biological product or an abiotic

47
00:02:22,369 --> 00:02:19,080
product something that's just made from

48
00:02:25,280 --> 00:02:22,379
like mineralization life would be great

49
00:02:28,339 --> 00:02:25,290
if it always existed like this into just

50
00:02:33,050 --> 00:02:28,349
very separate circles but sadly it looks

51
00:02:35,390 --> 00:02:33,060
more like this where crystallization and

52
00:02:37,910 --> 00:02:35,400
mineralization can leave signatures that

53
00:02:39,800 --> 00:02:37,920
look a lot like life and life can leave

54
00:02:41,839 --> 00:02:39,810
signatures that look a lot like crystals

55
00:02:45,110 --> 00:02:41,849
there is an awful lot of overlap and

56
00:02:47,120 --> 00:02:45,120
this is in my opinion the very important

57
00:02:49,220 --> 00:02:47,130
fundamental question a bio signature

58
00:02:52,069 --> 00:02:49,230
detection how you can look at a signal

59
00:02:54,410 --> 00:02:52,079
whatever signal you want and know that

60
00:02:57,289 --> 00:02:54,420
it is very distinctively in this green

61
00:02:59,000 --> 00:02:57,299
slice because that is the only way you

62
00:03:01,130 --> 00:02:59,010
can definitively prove that life was

63
00:03:02,750 --> 00:03:01,140

there rather than in this ambiguous

64
00:03:04,910 --> 00:03:02,760
slice which it might be really

65
00:03:05,990 --> 00:03:04,920
tantalizing we have no idea of what

66
00:03:10,940 --> 00:03:06,000
you're looking at is from a living

67
00:03:13,819 --> 00:03:10,950
organism so one of the historical ways

68
00:03:16,069 --> 00:03:13,829
that people have identified life is

69
00:03:21,020 --> 00:03:16,079
through morphological characterization

70
00:03:23,509 --> 00:03:21,030
and so these are some bacterial samples

71
00:03:26,030 --> 00:03:23,519
from about 3.5 billion years ago from

72
00:03:28,340 --> 00:03:26,040
slices of rock from a I believe these

73
00:03:31,879 --> 00:03:28,350
ones are from Greenland and these are

74
00:03:34,699 --> 00:03:31,889
the oldest morphological signs of life

75
00:03:36,680 --> 00:03:34,709
that we have seen and you can look at

76
00:03:38,509 --> 00:03:36,690
them and they look they're on the scale

77
00:03:40,789 --> 00:03:38,519
of what we would expect bacteria to look

78
00:03:44,569 --> 00:03:40,799
like and they have segmented morphology

79
00:03:47,150 --> 00:03:44,579
that is very similar to what we see in

80
00:03:50,090 --> 00:03:47,160
modern living organisms so here's some

81
00:03:52,520 --> 00:03:50,100
cyanobacteria comparison and so we can

82
00:03:54,470 --> 00:03:52,530
see cyanobacteria that has left fossils

83
00:03:56,000 --> 00:03:54,480
that look very much like this and we can

84
00:04:00,080 --> 00:03:56,010
see that it looks very much like modern

85
00:04:02,420 --> 00:04:00,090
Cylon bacteria so one of the bio

86
00:04:05,059 --> 00:04:02,430
signatures that you can use is hey maybe

87
00:04:09,370 --> 00:04:05,069
it looks like life but as I said looks

88
00:04:12,729 --> 00:04:09,380

can be deceiving as these are abiotic

89
00:04:15,650 --> 00:04:12,739
abiotic organic syntheses that can make

90
00:04:17,000 --> 00:04:15,660
patterns that are very extremely similar

91
00:04:19,909 --> 00:04:17,010
to what I just showed in the previous

92
00:04:22,159 --> 00:04:19,919
slide so you always need some sort of

93
00:04:24,740 --> 00:04:22,169
backup information some more tantalizing

94
00:04:26,930 --> 00:04:24,750
info and so you can look at chemical

95
00:04:29,960 --> 00:04:26,940
signatures and I'm not going to go

96
00:04:33,260 --> 00:04:29,970
into the wide breadth of what you can do

97
00:04:35,960 --> 00:04:33,270
but basically if you have an organism

98
00:04:37,400 --> 00:04:35,970
that deposits some chemical and you

99
00:04:40,520 --> 00:04:37,410
think you can use that as a bio

100
00:04:41,780 --> 00:04:40,530
signature go go forth try to do it try

101
00:04:43,220 --> 00:04:41,790
to make it happen and that's what some

102
00:04:46,220 --> 00:04:43,230
of the talks today will be talking about

103
00:04:47,870 --> 00:04:46,230
is there specific bio signature that

104
00:04:49,760 --> 00:04:47,880
they think is indicative of life and

105
00:04:51,410 --> 00:04:49,770
they'll argue why they think that this

106
00:04:53,600 --> 00:04:51,420
is appropriate and see if they can

107
00:04:55,370 --> 00:04:53,610
convince you but morphology plus

108
00:04:57,410 --> 00:04:55,380
chemical signatures is a great way to

109
00:05:02,990 --> 00:04:57,420
have two lines of evidence in order to

110
00:05:06,920 --> 00:05:03,000
back it up also if you're not looking at

111
00:05:09,500 --> 00:05:06,930
rock samples or possibly a samples that

112
00:05:12,010 --> 00:05:09,510
you have in hand you can be looking for

113
00:05:15,620 --> 00:05:12,020

bio signatures

114
00:05:17,510 --> 00:05:15,630
spectroscopically so life gives off

115
00:05:19,520 --> 00:05:17,520
chemical signatures we give off oxygen

116
00:05:21,680 --> 00:05:19,530
we give off methane as we were talking

117
00:05:23,720 --> 00:05:21,690
about yesterday and so one of the

118
00:05:25,730 --> 00:05:23,730
examples that was great from before was

119
00:05:28,040 --> 00:05:25,740
if you have ozone and oxygen methane

120
00:05:29,900 --> 00:05:28,050
together in an environment that's a

121
00:05:32,150 --> 00:05:29,910
great bio signature because those two

122
00:05:34,670 --> 00:05:32,160
should not be able to exist together so

123
00:05:36,110 --> 00:05:34,680
you can look spectroscopically for

124
00:05:37,430 --> 00:05:36,120
sources of life and that's what we're

125
00:05:42,200 --> 00:05:37,440
going to do eventually to look at

126
00:05:45,130 --> 00:05:42,210
exoplanet so the main thrust of bio

127
00:05:48,159 --> 00:05:45,140
signatures is you want non-ambiguous

128
00:05:51,650 --> 00:05:48,169
signals of multiple lines of evidence

129
00:05:55,400 --> 00:05:51,660
this is important because you run the

130
00:05:59,870 --> 00:05:55,410
risk of false detection so 1996 or

131
00:06:01,670 --> 00:05:59,880
actually 1984 we got this sample of a

132
00:06:03,530 --> 00:06:01,680
Martian meteorite this is one of the

133
00:06:08,320 --> 00:06:03,540
most famous rocks that we have in the in

134
00:06:12,409 --> 00:06:08,330
the collection of NASA so this is ale a

135
00:06:14,480 --> 00:06:12,419
alh84001 and inside this Martian

136
00:06:17,300 --> 00:06:14,490
meteorite is the sample that looks like

137
00:06:20,200 --> 00:06:17,310
its life and there are some chemical

138
00:06:25,670 --> 00:06:20,210

evidence that it was life and there were

139
00:06:27,560 --> 00:06:25,680
it was pretty popular in 1996 it was so

140
00:06:29,240 --> 00:06:27,570
tantalizing that it was life that

141
00:06:31,520 --> 00:06:29,250
President Clinton held a press

142
00:06:33,500 --> 00:06:31,530
conference that announced the world that

143
00:06:36,230 --> 00:06:33,510
we had discovered that life had arisen

144
00:06:37,190 --> 00:06:36,240
on Mars as well as on earth and if

145
00:06:38,659 --> 00:06:37,200
you're interested in that press

146
00:06:39,480 --> 00:06:38,669
conference you can actually watch the

147
00:06:43,140 --> 00:06:39,490
movie contact

148
00:06:45,180 --> 00:06:43,150
and in that movie they play that montage

149
00:06:48,300 --> 00:06:45,190
of him actually speaking as part of the

150
00:06:52,580 --> 00:06:48,310
movie but this turned out not to be true

151
00:06:55,350 --> 00:06:52,590
and it made him look crazy and go aliens

152
00:06:59,700 --> 00:06:55,360
so you've got to be careful before you

153
00:07:02,339 --> 00:06:59,710
make really big humiliating mistakes all

154
00:07:06,659 --> 00:07:02,349
right biosignatures let's move on to

155
00:07:08,670 --> 00:07:06,669
proteins so proteins are a very

156
00:07:11,899 --> 00:07:08,680
important part of modern living systems

157
00:07:14,430 --> 00:07:11,909
they do all of the basic heavy lifting

158
00:07:17,070 --> 00:07:14,440
biochemistry that we have and so it'd be

159
00:07:19,860 --> 00:07:17,080
helpful in a prebiotic world if you had

160
00:07:21,740 --> 00:07:19,870
proteins then too that could possibly do

161
00:07:25,230 --> 00:07:21,750
biochemistry that's important for

162
00:07:27,480 --> 00:07:25,240
nascent living organisms so how do you

163
00:07:29,219 --> 00:07:27,490

get proteins in the first place well

164
00:07:30,779 --> 00:07:29,229
you've got to start with amino acids

165
00:07:33,330 --> 00:07:30,789
which are the small building blocks of

166
00:07:36,059 --> 00:07:33,340
proteins and so chemically we can see

167
00:07:37,350 --> 00:07:36,069
that you can make certain atmospheres in

168
00:07:38,850 --> 00:07:37,360
one of the most famous prebiotic

169
00:07:41,730 --> 00:07:38,860
chemistry experiments the miller-urey

170
00:07:46,379 --> 00:07:41,740
experiment they took methane ammonia

171
00:07:47,790 --> 00:07:46,389
carbon dioxide and I believe some

172
00:07:49,920 --> 00:07:47,800
nitrogen mixed it together and just

173
00:07:51,899 --> 00:07:49,930
spark some electricity and they saw

174
00:07:53,640 --> 00:07:51,909
amino acids pop out of it people have

175
00:07:56,249 --> 00:07:53,650
spoke earlier this this is a very famous

176
00:07:59,580 --> 00:07:56,259
experiment from 1952 you can make amino

177
00:08:03,089 --> 00:07:59,590
acids through atmospheric chemistry also

178
00:08:05,070 --> 00:08:03,099
through astrochemistry you can also make

179
00:08:06,839 --> 00:08:05,080
amino acids so here's a piece of the

180
00:08:09,390 --> 00:08:06,849
Murchison meteorite which is a giant

181
00:08:11,850 --> 00:08:09,400
rocket carbon that fell in Australia

182
00:08:14,370 --> 00:08:11,860
that has been analyzed for its carbon

183
00:08:16,200 --> 00:08:14,380
content and you look inside of it and

184
00:08:17,879 --> 00:08:16,210
you see all these different amino acids

185
00:08:19,649 --> 00:08:17,889
that have been formed from space so

186
00:08:21,540 --> 00:08:19,659
great we apparently have no problem

187
00:08:24,629 --> 00:08:21,550
making amino acids I that are from space

188
00:08:25,200 --> 00:08:24,639

or on earth cool but how do you string

189
00:08:28,439 --> 00:08:25,210
them together

190
00:08:30,240 --> 00:08:28,449
that is a great prebiotic question which

191
00:08:32,760 --> 00:08:30,250
I don't think we are addressing at this

192
00:08:35,279 --> 00:08:32,770
conference but it is a very interesting

193
00:08:36,810 --> 00:08:35,289
issue bees you can't just mix amino

194
00:08:39,000 --> 00:08:36,820
acids together heat them up and have

195
00:08:41,730 --> 00:08:39,010
them come together we can talk about

196
00:08:43,409 --> 00:08:41,740
that after this talk if you want to is

197
00:08:45,930 --> 00:08:43,419
our lab actually does a lot of work on

198
00:08:48,930 --> 00:08:45,940
this this is why I work at but what we

199
00:08:52,650 --> 00:08:48,940
are focused on if you can find so if you

200
00:08:53,220 --> 00:08:52,660
can find some way to string them

201
00:08:55,980 --> 00:08:53,230
together

202
00:08:59,640 --> 00:08:55,990
and make these long polymers of pet of

203
00:09:01,200 --> 00:08:59,650
amino acids into peptides how do you

204
00:09:03,570 --> 00:09:01,210
fold them into structures that can

205
00:09:04,320 --> 00:09:03,580
actually do biochemistry so this is the

206
00:09:06,690 --> 00:09:04,330
tricky part

207
00:09:09,180 --> 00:09:06,700
we need structures that look like this

208
00:09:11,010 --> 00:09:09,190
in modern organisms to be able to

209
00:09:12,990 --> 00:09:11,020
interact with the other molecules in the

210
00:09:15,750 --> 00:09:13,000
environment but if you just have

211
00:09:17,850 --> 00:09:15,760
proteins in the environment so this is

212
00:09:19,230 --> 00:09:17,860
an energy diagram the lower on the

213
00:09:22,050 --> 00:09:19,240

energy is the more thermodynamically

214
00:09:23,970 --> 00:09:22,060
favorable product it's where the

215
00:09:27,600 --> 00:09:23,980
molecules will go if you just let them

216
00:09:30,090 --> 00:09:27,610
float about for eternity so they're most

217
00:09:34,650 --> 00:09:30,100
thermodynamically trapped products are a

218
00:09:37,650 --> 00:09:34,660
load fiber amyloid fibrils and amorphous

219
00:09:39,900 --> 00:09:37,660
aggregates these are non structural

220
00:09:41,550 --> 00:09:39,910
things that just clump together and bind

221
00:09:44,820 --> 00:09:41,560
up the proteins in two ways that you

222
00:09:48,300 --> 00:09:44,830
will have no use for them when instead

223
00:09:49,920 --> 00:09:48,310
we want proteins to be folded into these

224
00:09:51,840 --> 00:09:49,930
nice structures that can interact with

225
00:09:53,820 --> 00:09:51,850
molecules so one of our talks later

226
00:09:56,580 --> 00:09:53,830
today we'll be talking about protein

227
00:09:59,250 --> 00:09:56,590
folding on a prebiotic earth to see how

228
00:10:00,930 --> 00:09:59,260
this could happen and this is a problem

229
00:10:02,580 --> 00:10:00,940
because as I said the most structures

230
00:10:05,730 --> 00:10:02,590
are not the energetically favored

231
00:10:07,050 --> 00:10:05,740
products once formed only a very small

232
00:10:09,480 --> 00:10:07,060
amount of proteins will even

233
00:10:11,220 --> 00:10:09,490
spontaneously fold into any usable

234
00:10:13,530 --> 00:10:11,230
structure like beta sheets or alpha

235
00:10:14,880 --> 00:10:13,540
helixes so how do you get structurally

236
00:10:19,100 --> 00:10:14,890
useful proteins in a prebiotic

237
00:10:21,810 --> 00:10:19,110
environment this is a big question and

238
00:10:24,240 --> 00:10:21,820

lastly we will be talking about lipids

239
00:10:26,790 --> 00:10:24,250
in the origin of life and this is

240
00:10:28,830 --> 00:10:26,800
important if you believe that the early

241
00:10:33,870 --> 00:10:28,840
prebiotic molecules looked very similar

242
00:10:36,480 --> 00:10:33,880
to in some way to modern molecules so if

243
00:10:38,730 --> 00:10:36,490
you look at a modern cell wall you have

244
00:10:40,740 --> 00:10:38,740
all these proteins and enzymes are the

245
00:10:44,670 --> 00:10:40,750
things that are inside the cell wall but

246
00:10:47,970 --> 00:10:44,680
this cell wall itself is made up of a

247
00:10:50,400 --> 00:10:47,980
phospholipid so in life you have these

248
00:10:51,900 --> 00:10:50,410
big fatty fatty chains that are hooked

249
00:10:54,300 --> 00:10:51,910
down to glycerol with this phospho

250
00:10:56,640 --> 00:10:54,310
choline there that forms lipid bilayer

251
00:10:58,500 --> 00:10:56,650
that divides the inside of cells from

252
00:11:01,200 --> 00:10:58,510
the outside of cells is a fundamental

253
00:11:02,760 --> 00:11:01,210
part of life so compartmentalizing would

254
00:11:05,310 --> 00:11:02,770
have been really useful on prebiotic

255
00:11:06,960 --> 00:11:05,320
earth too but this molecule is too

256
00:11:09,329 --> 00:11:06,970
complicated to have prebiotic

257
00:11:11,220 --> 00:11:09,339
so we look at much more simple molecules

258
00:11:14,220 --> 00:11:11,230
that just have fatty acids without all

259
00:11:16,710 --> 00:11:14,230
of these other adornments here and you

260
00:11:20,009 --> 00:11:16,720
can attach them to some other prebiotic

261
00:11:22,410 --> 00:11:20,019
molecules that might make them end up to

262
00:11:23,610 --> 00:11:22,420
look more like this and that's what one

263
00:11:25,559 --> 00:11:23,620

of the talks we'll be talking about

264
00:11:28,949 --> 00:11:25,569
later is how we can get from possibly

265
00:11:33,269 --> 00:11:28,959
this to more structures that emulate

266
00:11:35,879 --> 00:11:33,279
that to form lipids ohms my cells and

267
00:11:37,740 --> 00:11:35,889
bilayer sheets which can come which can

268
00:11:39,449 --> 00:11:37,750
have nice little compartments in areas

269
00:11:41,790 --> 00:11:39,459
inside that you can actually do some

270
00:11:44,400 --> 00:11:41,800
nice chemistry with and there's some

271
00:11:48,119 --> 00:11:44,410
good animations from the Jack Shostak

272
00:11:49,800 --> 00:11:48,129
group in Harvard actually quite cool to

273
00:11:50,639 --> 00:11:49,810
demonstrate some of these lipid

274
00:12:05,580 --> 00:11:50,649
behaviors

275
00:12:23,880 --> 00:12:21,040
um on the keyboard yeah to result in the

276
00:12:26,710 --> 00:12:23,890
growth of hydrocarbon chains thank you

277
00:12:31,960 --> 00:12:26,720
from the mineral phase as fatty acids

278
00:12:33,970 --> 00:12:31,970
and related compounds plants from

279
00:12:35,860 --> 00:12:33,980
deep-sea black stones to land bound

280
00:12:37,840 --> 00:12:35,870
geysers may have been sites were

281
00:12:40,420 --> 00:12:37,850
prebiotic ly important molecules on

282
00:12:42,430 --> 00:12:40,430
early Earth were formed this animation

283
00:12:44,050 --> 00:12:42,440
shows the formation of fatty acids deep

284
00:12:46,210 --> 00:12:44,060
in the earth Aloha geyser

285
00:12:48,490 --> 00:12:46,220
mineral surfaces can catalyze the

286
00:12:51,640 --> 00:12:48,500
stepwise formation of hydrocarbon chains

287
00:12:53,080 --> 00:12:51,650
from carbon monoxide and hydrogen here

288
00:12:55,930 --> 00:12:53,090

hydrogen atoms are shown as white

289
00:12:58,570 --> 00:12:55,940
spheres carbon is gray and oxygen and

290
00:13:00,640 --> 00:12:58,580
rid the reaction results in the growth

291
00:13:02,350 --> 00:13:00,650
of hydrocarbon chains of various lengths

292
00:13:04,660 --> 00:13:02,360
that are eventually released from the

293
00:13:08,260 --> 00:13:04,670
mineral face as fatty acids and related

294
00:13:10,300 --> 00:13:08,270
compounds because the fatty acids are at

295
00:13:12,100 --> 00:13:10,310
low concentrations in the water they are

296
00:13:19,540 --> 00:13:12,110
unable to form higher-order structures

297
00:13:21,850 --> 00:13:19,550
such as micelles and membranes following

298
00:13:23,470 --> 00:13:21,860
the violent explosion of the geyser some

299
00:13:26,920 --> 00:13:23,480
water is released into the atmosphere as

300
00:13:28,630 --> 00:13:26,930
tiny microscopic droplets fatty acid

301
00:13:30,010 --> 00:13:28,640
synthesized along the mineral walls of

302
00:13:31,930 --> 00:13:30,020
the geyser are found in low

303
00:13:33,760 --> 00:13:31,940
concentration in these droplets with the

304
00:13:37,150 --> 00:13:33,770
longer fatty acids at the air water

305
00:13:39,070 --> 00:13:37,160
interface a gust of wind evaporates the

306
00:13:40,750 --> 00:13:39,080
water molecules in the water droplet

307
00:13:42,790 --> 00:13:40,760
causing the fatty acid to form

308
00:13:44,740 --> 00:13:42,800
lightweight airborne particulates that

309
00:13:47,110 --> 00:13:44,750
can be transported across the landscape

310
00:13:55,440 --> 00:13:47,120
perhaps eventually settling out and

311
00:14:01,660 --> 00:13:58,480
you can see that last shot there how

312
00:14:03,460 --> 00:14:01,670
they're forming nice little my cells and

313
00:14:07,230 --> 00:14:03,470

vesicles with the nice and capsulated

314
00:14:09,850 --> 00:14:07,240
space there from prebiotic chemistry and

315
00:14:10,990 --> 00:14:09,860
that will do it for the warm Botox for

316
00:14:12,670 --> 00:14:11,000
this session there's no time for

317
00:14:14,320 --> 00:14:12,680
questions so please ask any of the

318
00:14:17,140 --> 00:14:14,330
speakers any of the questions that you

319
00:14:19,030 --> 00:14:17,150
might have as we go on or track me down

320
00:14:22,070 --> 00:14:19,040
after and I'll answer whatever I can