
AbSciCon
2019

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

2
00:00:11,610 --> 00:00:09,380
[Applause]

3
00:00:13,080 --> 00:00:11,620
thank you so much Chris and thank you

4
00:00:15,600 --> 00:00:13,090
for the conveners and everyone here for

5
00:00:17,310 --> 00:00:15,610
having me so one of the central pillars

6
00:00:19,200 --> 00:00:17,320
of astrobiology is determining the

7
00:00:20,460 --> 00:00:19,210
distribution of life in the universe and

8
00:00:22,650 --> 00:00:20,470
so I'm just going to start my talk with

9
00:00:26,700 --> 00:00:22,660
the modest observation that most of the

10
00:00:28,500 --> 00:00:26,710
universe is outside the solar system and

11
00:00:29,940 --> 00:00:28,510
so we have a really actually very

12
00:00:32,400 --> 00:00:29,950
difficult question though is how would

13
00:00:34,860 --> 00:00:32,410

we recognize life on a distant exoplanet

14
00:00:36,810 --> 00:00:34,870
so this is an image of the earth that's

15
00:00:40,830 --> 00:00:36,820
that pale blue dot in on the lower right

16
00:00:42,630 --> 00:00:40,840
from the Cassini spacecraft and Saturn

17
00:00:44,160 --> 00:00:42,640
is 10 au away from the Sun or 10 times

18
00:00:47,729 --> 00:00:44,170
the distance between the Earth and the

19
00:00:49,290 --> 00:00:47,739
Sun and Proxima Centauri the nearest

20
00:00:52,290 --> 00:00:49,300
stars four point two light-years away

21
00:00:54,540 --> 00:00:52,300
which is 40 trillion kilometers away and

22
00:00:57,690 --> 00:00:54,550
that's the closest possible potentially

23
00:00:59,459 --> 00:00:57,700
habitable planet in the universe and so

24
00:01:01,560 --> 00:00:59,469
that's an incredible challenge because a

25
00:01:06,870 --> 00:01:01,570
planet that we're used to seeing as a

26
00:01:10,080 --> 00:01:06,880
verdant blue dot or sorry a verdant blue

27
00:01:12,270 --> 00:01:10,090
marble with clouds and vegetation and

28
00:01:13,980 --> 00:01:12,280
continents and ocean is going to be

29
00:01:17,520 --> 00:01:13,990
reduced to a spread point spread

30
00:01:19,649 --> 00:01:17,530
function on a CCD and so it's a it's an

31
00:01:21,539 --> 00:01:19,659
incredible challenge to then say how can

32
00:01:24,330 --> 00:01:21,549
we determine whether there are living

33
00:01:26,670 --> 00:01:24,340
processes on that planet in 2016 in the

34
00:01:28,109 --> 00:01:26,680
summer the nexus for exoplanet system

35
00:01:31,500 --> 00:01:28,119
science convened a team of

36
00:01:33,810 --> 00:01:31,510
astrobiologists to sort of compile all

37
00:01:36,240 --> 00:01:33,820
of the current knowledge on remotely

38
00:01:37,770 --> 00:01:36,250

detectable bio signatures and these are

39
00:01:39,960 --> 00:01:37,780
some of the fundamental questions that

40
00:01:42,929 --> 00:01:39,970
need to be answered what is life produce

41
00:01:46,260 --> 00:01:42,939
and accordingly what are the signatures

42
00:01:48,390 --> 00:01:46,270
of that of those products of life can

43
00:01:50,490 --> 00:01:48,400
abiotic processes fool us are there

44
00:01:52,469 --> 00:01:50,500
geochemical or photochemical processes

45
00:01:53,940 --> 00:01:52,479
that would mimic the kind of remote

46
00:01:56,370 --> 00:01:53,950
signatures we would expect from a

47
00:01:58,980 --> 00:01:56,380
planetary biosphere how do we term it

48
00:02:00,600 --> 00:01:58,990
determine the presence of life given

49
00:02:04,260 --> 00:02:00,610
limited gate data given that point

50
00:02:06,060 --> 00:02:04,270
spread function on a CCD and how do we

51
00:02:08,310 --> 00:02:06,070
quantify our uncertainties is there a

52
00:02:10,560 --> 00:02:08,320
way in which we actually survey dozens

53
00:02:12,180 --> 00:02:10,570
and dozens of planets and statistically

54
00:02:14,640 --> 00:02:12,190
infer the presence of life even though

55
00:02:16,770 --> 00:02:14,650
we can't say definitively it's it's it's

56
00:02:18,420 --> 00:02:16,780
on one planet or another so these are

57
00:02:20,490 --> 00:02:18,430
really really tough questions and they

58
00:02:22,050 --> 00:02:20,500
have a lot of input that's necessary

59
00:02:24,420 --> 00:02:22,060
from a wide variety of

60
00:02:27,360 --> 00:02:24,430
scientists geologists geochemists

61
00:02:28,890 --> 00:02:27,370
biologists astronomers data scientists

62
00:02:30,750 --> 00:02:28,900
and engineers who will actually

63
00:02:33,270 --> 00:02:30,760

determine what's possible in terms of

64
00:02:36,449 --> 00:02:33,280
signal-to-noise ratio and the types of

65
00:02:38,040 --> 00:02:36,459
gases we can detect and the lower limit

66
00:02:41,400 --> 00:02:38,050
on the abundance of those gases that we

67
00:02:43,050 --> 00:02:41,410
can detect and so one point I want to

68
00:02:45,300 --> 00:02:43,060
make really clearly is that we're not

69
00:02:47,430 --> 00:02:45,310
looking for life on exoplanets we're

70
00:02:49,740 --> 00:02:47,440
looking for planetary biospheres there

71
00:02:52,860 --> 00:02:49,750
needs to be a robust exchange of gases

72
00:02:55,320 --> 00:02:52,870
from the ocean and the surface produced

73
00:02:57,809 --> 00:02:55,330
by by life that need that signature

74
00:02:59,449 --> 00:02:57,819
needs to be global in extent the

75
00:03:02,520 --> 00:02:59,459
products of life need to produce

76
00:03:05,900 --> 00:03:02,530
observable features line absorption

77
00:03:08,250 --> 00:03:05,910
vapour rotational transitions

78
00:03:10,170 --> 00:03:08,260
dissociation cross-sections they need to

79
00:03:11,520 --> 00:03:10,180
be they need to build up to detectable

80
00:03:13,199 --> 00:03:11,530
amounts so they need to be robust of

81
00:03:14,880 --> 00:03:13,209
photochemistry that may change from star

82
00:03:16,800 --> 00:03:14,890
to star and they need to be separable

83
00:03:18,449 --> 00:03:16,810
from abiotic processes they may

84
00:03:20,610 --> 00:03:18,459
otherwise fool you into thinking that

85
00:03:22,979 --> 00:03:20,620
they're that this product is produced by

86
00:03:24,120 --> 00:03:22,989
life and so they're kind of two ways of

87
00:03:27,660 --> 00:03:24,130
looking at this there are earth-based

88
00:03:29,759 --> 00:03:27,670

approaches which is more top-down and an

89
00:03:31,110 --> 00:03:29,769
earth-based approaches for examples

90
00:03:32,970 --> 00:03:31,120
looking at the modern earth and noticing

91
00:03:35,580 --> 00:03:32,980
that we have oxygen and high chemical

92
00:03:36,930 --> 00:03:35,590
disequilibrium in our atmosphere and so

93
00:03:39,180 --> 00:03:36,940
you automatically pass many of these

94
00:03:40,800 --> 00:03:39,190
tests for global planetary bio signature

95
00:03:42,840 --> 00:03:40,810
so there's a heritage of existing data

96
00:03:44,880 --> 00:03:42,850
will always have more information about

97
00:03:47,280 --> 00:03:44,890
the earth and we can leverage really

98
00:03:48,750 --> 00:03:47,290
rich geochemical archives about the

99
00:03:51,300 --> 00:03:48,760
changing chemical composition of our

100
00:03:53,250 --> 00:03:51,310
atmosphere the limitations are that

101
00:03:54,809 --> 00:03:53,260
we're limited by the environment by the

102
00:03:56,400 --> 00:03:54,819
fact that there's the earth has a

103
00:03:58,590 --> 00:03:56,410
certain composition then it's not

104
00:04:00,690 --> 00:03:58,600
universal and also that there's

105
00:04:01,830 --> 00:04:00,700
historical contingencies evolutionary

106
00:04:03,809 --> 00:04:01,840
contingencies in the evolution of

107
00:04:04,979 --> 00:04:03,819
metabolisms on earth so the other way of

108
00:04:07,559 --> 00:04:04,989
looking at this is sort of an agnostic

109
00:04:10,979 --> 00:04:07,569
or ground-up approach so looking at

110
00:04:14,670 --> 00:04:10,989
generalized met models for thermodynamic

111
00:04:17,190 --> 00:04:14,680
equilibrium looking at all the molecules

112
00:04:19,409 --> 00:04:17,200
that could be produced by life and and

113
00:04:21,330 --> 00:04:19,419

and and then going and being very

114
00:04:23,700 --> 00:04:21,340
careful about thinking about what their

115
00:04:25,170 --> 00:04:23,710
what their ability to build up in an

116
00:04:26,820 --> 00:04:25,180
atmosphere would be and what their

117
00:04:28,379 --> 00:04:26,830
observable signatures would be and

118
00:04:30,060 --> 00:04:28,389
you're not constrained necessarily by

119
00:04:31,620 --> 00:04:30,070
earth history that way you have a

120
00:04:33,210 --> 00:04:31,630
broader universe of potential signatures

121
00:04:34,860 --> 00:04:33,220
but there's a lot of modeling work that

122
00:04:38,939 --> 00:04:34,870
needs to be done to advance that

123
00:04:41,520 --> 00:04:38,949
so I wanted to show this this graphic

124
00:04:44,280 --> 00:04:41,530
Dave mentioned a bio signature as a

125
00:04:46,800 --> 00:04:44,290
substance object or pattern whose origin

126
00:04:49,620 --> 00:04:46,810
specifically requires a biological agent

127
00:04:50,879 --> 00:04:49,630
and I left our process there which is

128
00:04:52,980 --> 00:04:50,889
really important because when we're

129
00:04:55,379 --> 00:04:52,990
looking at exoplanet bio signatures we'd

130
00:04:57,090 --> 00:04:55,389
be looking at a spectral feature we're

131
00:04:59,670 --> 00:04:57,100
inferring the presence of a gas based on

132
00:05:02,070 --> 00:04:59,680
that feature or surface signature and

133
00:05:05,969 --> 00:05:02,080
then we're inferring further a process

134
00:05:07,590 --> 00:05:05,979
that created that and so one one really

135
00:05:09,420 --> 00:05:07,600
important examples oxygenic

136
00:05:10,250 --> 00:05:09,430
photosynthesis which uses really

137
00:05:13,230 --> 00:05:10,260
available

138
00:05:15,420 --> 00:05:13,240

cosmically abundant substrates water and

139
00:05:18,540 --> 00:05:15,430
carbon dioxide and light to create

140
00:05:20,010 --> 00:05:18,550
organic matter and oxygen that oxygen

141
00:05:22,469 --> 00:05:20,020
produces a spectrally observable

142
00:05:24,030 --> 00:05:22,479
signature and it's further process in

143
00:05:28,170 --> 00:05:24,040
the atmosphere - ozone which also

144
00:05:29,610 --> 00:05:28,180
produces his own signature so there are

145
00:05:31,260 --> 00:05:29,620
other types of bio signatures that

146
00:05:33,210 --> 00:05:31,270
depend on the kind of observation mode

147
00:05:34,890 --> 00:05:33,220
we may have so surface signatures one

148
00:05:36,540 --> 00:05:34,900
example that's been discussed a lot is

149
00:05:38,370 --> 00:05:36,550
the vegetation red edge which is the

150
00:05:40,529 --> 00:05:38,380
difference between effectively

151
00:05:42,900 --> 00:05:40,539
chlorophyll absorption in the in the

152
00:05:44,580 --> 00:05:42,910
optical and the intracellular scattering

153
00:05:47,100 --> 00:05:44,590
by vegetation in the infrared and

154
00:05:49,050 --> 00:05:47,110
creates incredible jump in the

155
00:05:51,510 --> 00:05:49,060
reflectance of leaves and other

156
00:05:53,040 --> 00:05:51,520
photosynthetic organisms and could be

157
00:05:55,020 --> 00:05:53,050
observed by space it's used to map

158
00:05:56,670 --> 00:05:55,030
vegetation on earth and if it were

159
00:05:59,219 --> 00:05:56,680
present an analogue were present on

160
00:06:01,320 --> 00:05:59,229
exoplanets astute if acun coverage it

161
00:06:03,690 --> 00:06:01,330
would also be a remote signature and

162
00:06:05,190 --> 00:06:03,700
then those either of those gases or

163
00:06:07,409 --> 00:06:05,200

surface signatures may change as a

164
00:06:10,290 --> 00:06:07,419
function of time and that may give you

165
00:06:12,150 --> 00:06:10,300
additional information so there are many

166
00:06:14,250 --> 00:06:12,160
different gases and surface signatures

167
00:06:16,589 --> 00:06:14,260
that have been discussed importantly not

168
00:06:19,469 --> 00:06:16,599
all of them will be observable for for

169
00:06:21,810 --> 00:06:19,479
every inhabited exoplanet even our own

170
00:06:24,000 --> 00:06:21,820
planet has limitations in this respect

171
00:06:26,850 --> 00:06:24,010
so this is a this is a earth shine

172
00:06:28,409 --> 00:06:26,860
spectrum of earth it's obtained from

173
00:06:30,300 --> 00:06:28,419
reflected light from the moon reflected

174
00:06:32,129 --> 00:06:30,310
back to the earth and it sort of

175
00:06:35,219 --> 00:06:32,139
represents a disc average spectrum of

176
00:06:37,950 --> 00:06:35,229
the earth and from this spectrum from

177
00:06:39,360 --> 00:06:37,960
the interaction of the molecules in the

178
00:06:41,159 --> 00:06:39,370
atmosphere and from from the reflectance

179
00:06:42,779 --> 00:06:41,169
of the surface and then and then and

180
00:06:45,060 --> 00:06:42,789
then and then the transmission out to

181
00:06:46,740 --> 00:06:45,070
remote observer reflection out to remote

182
00:06:48,060 --> 00:06:46,750
remote observer we can infer the

183
00:06:48,540 --> 00:06:48,070
presence of water vapor in our

184
00:06:50,760 --> 00:06:48,550
atmosphere

185
00:06:52,320 --> 00:06:50,770
a sign of habitability the blueness of

186
00:06:56,339 --> 00:06:52,330
the sky tells us about our atmospheric

187
00:07:00,450 --> 00:06:56,349
mass the vegetation jump is present in

188
00:07:02,490 --> 00:07:00,460

the in the near infrared signatures from

189
00:07:04,020 --> 00:07:02,500
oxygen and ozone there are small

190
00:07:06,119 --> 00:07:04,030
signatures in this reflected light

191
00:07:08,430 --> 00:07:06,129
spectrum from methane and carbon dioxide

192
00:07:10,710 --> 00:07:08,440
but they're sort of small and that's

193
00:07:12,659 --> 00:07:10,720
because we have low abundances of those

194
00:07:14,129 --> 00:07:12,669
gases in the modern atmosphere wasn't

195
00:07:18,270 --> 00:07:14,139
necessarily always that always the case

196
00:07:20,430 --> 00:07:18,280
so one way of expanding our template of

197
00:07:21,330 --> 00:07:20,440
potential bio signatures is to look at

198
00:07:24,330 --> 00:07:21,340
Earth history

199
00:07:25,890 --> 00:07:24,340
so Earth has gone through Titanic shifts

200
00:07:28,499 --> 00:07:25,900
in its chemical composition both in the

201
00:07:30,510 --> 00:07:28,509
atmosphere in the oceans for half of

202
00:07:33,629 --> 00:07:30,520
Earth history there was no oxygen in the

203
00:07:35,070 --> 00:07:33,639
atmosphere and for a substantial part of

204
00:07:37,230 --> 00:07:35,080
Earth history 40% of Earth history

205
00:07:39,120 --> 00:07:37,240
oxygen was present but it may have been

206
00:07:41,010 --> 00:07:39,130
much much lower than today so if you

207
00:07:42,149 --> 00:07:41,020
were to travel back in time for most of

208
00:07:44,760 --> 00:07:42,159
Earth history couldn't breathe the

209
00:07:46,740 --> 00:07:44,770
atmosphere but that has an incredible

210
00:07:48,930 --> 00:07:46,750
impact on the remote signatures of that

211
00:07:51,420 --> 00:07:48,940
planet if you were a remote observer so

212
00:07:53,850 --> 00:07:51,430
in the Archaean you can infer the high

213
00:07:56,370 --> 00:07:53,860

presence of methane but you would have

214
00:07:59,520 --> 00:07:56,380
no detectable oxygen in the Proterozoic

215
00:08:01,580 --> 00:07:59,530
you may see ozone but not oxygen whereas

216
00:08:03,480 --> 00:08:01,590
today oxygen and ozone are very

217
00:08:05,519 --> 00:08:03,490
detectable but in our reflected light

218
00:08:09,120 --> 00:08:05,529
spectrum methane is is has a weak

219
00:08:11,089 --> 00:08:09,130
signature but this shows the importance

220
00:08:13,019 --> 00:08:11,099
of Earth's geochemical archive in

221
00:08:15,899 --> 00:08:13,029
informing the potential remote

222
00:08:17,249 --> 00:08:15,909
signatures of exoplanets because we will

223
00:08:19,080 --> 00:08:17,259
all have that geochemical

224
00:08:23,279 --> 00:08:19,090
archive for the earth and not for any

225
00:08:25,350 --> 00:08:23,289
exoplanet so this is a simulation by

226
00:08:27,360 --> 00:08:25,360
giada Arnie characterizing an anoxic

227
00:08:29,100 --> 00:08:27,370
potential biosphere so this is where it

228
00:08:31,649 --> 00:08:29,110
were early in Earth history and we're

229
00:08:33,839 --> 00:08:31,659
looking at and our Qian type earth with

230
00:08:35,790 --> 00:08:33,849
high methane and high co2 and the

231
00:08:38,399 --> 00:08:35,800
methane bands are much stronger than

232
00:08:40,440 --> 00:08:38,409
they are on the modern earth and if the

233
00:08:42,569 --> 00:08:40,450
methane to co2 ratio exceeded a certain

234
00:08:44,460 --> 00:08:42,579
value we would actually have a

235
00:08:46,949 --> 00:08:44,470
hydrocarbon haze similar to that on

236
00:08:50,730 --> 00:08:46,959
Titan which would have its own UV

237
00:08:53,550 --> 00:08:50,740
signature if we look in the Middle Earth

238
00:08:55,800 --> 00:08:53,560

history and the Proterozoic Eon as I

239
00:08:57,780 --> 00:08:55,810
said oxygen is probably much lower

240
00:09:00,379 --> 00:08:57,790
perhaps as low as 0.1 percent of present

241
00:09:02,150 --> 00:09:00,389
atmospheric level if that were true

242
00:09:04,699 --> 00:09:02,160
then the oxygen aybe and the most

243
00:09:06,949 --> 00:09:04,709
remotely detectable signature of oxygen

244
00:09:09,289 --> 00:09:06,959
our atmosphere would not be detectable

245
00:09:11,600 --> 00:09:09,299
by a future space-based telescope but

246
00:09:13,759 --> 00:09:11,610
ozone would be own absorbs an

247
00:09:15,619 --> 00:09:13,769
ultraviolet there-there's unique

248
00:09:17,239 --> 00:09:15,629
technical challenges in looking at the

249
00:09:20,150 --> 00:09:17,249
ultraviolet and the near-infrared where

250
00:09:22,910 --> 00:09:20,160
water would would absorb and so this is

251
00:09:25,280 --> 00:09:22,920
sort of an example of Earth history and

252
00:09:27,289 --> 00:09:25,290
our extrapolation for Earth history in

253
00:09:30,919 --> 00:09:27,299
forming the technical requirements on

254
00:09:33,470 --> 00:09:30,929
the search for life elsewhere there are

255
00:09:35,329 --> 00:09:33,480
other approaches as I said a pioneered

256
00:09:37,789 --> 00:09:35,339
by Sarah Seger's group including William

257
00:09:39,079 --> 00:09:37,799
Bane's which is to look again instead of

258
00:09:42,079 --> 00:09:39,089
from the top-down approach from the

259
00:09:43,699 --> 00:09:42,089
bottom-up approach and and and and think

260
00:09:46,340 --> 00:09:43,709
about all of the molecules that could be

261
00:09:47,749 --> 00:09:46,350
produced by life whether they're stable

262
00:09:50,809 --> 00:09:47,759
in an atmosphere

263
00:09:52,460 --> 00:09:50,819

what biomass is required to for them to

264
00:09:54,650 --> 00:09:52,470
build up to detectable abundances and

265
00:09:56,030 --> 00:09:54,660
whether they would have geophysical

266
00:09:57,979 --> 00:09:56,040
false positives and you can group

267
00:10:00,530 --> 00:09:57,989
existing bio signatures in this way and

268
00:10:02,780 --> 00:10:00,540
you can also potentially uncover new

269
00:10:05,689 --> 00:10:02,790
ones and then and then have a motivation

270
00:10:07,249 --> 00:10:05,699
to go measure their laboratory spectra

271
00:10:09,439 --> 00:10:07,259
and put them in your photochemical

272
00:10:11,509 --> 00:10:09,449
models etc and so this is also an

273
00:10:13,280 --> 00:10:11,519
important perspective in in on the

274
00:10:16,970 --> 00:10:13,290
frontiers of exoplanet bio signature

275
00:10:18,679 --> 00:10:16,980
science I want to really make clear a

276
00:10:20,210 --> 00:10:18,689
point which is that photochemistry and

277
00:10:21,949 --> 00:10:20,220
stellar context is going to be really

278
00:10:24,439 --> 00:10:21,959
really important for characterizing

279
00:10:28,039 --> 00:10:24,449
potential remote bio signatures okay and

280
00:10:29,869 --> 00:10:28,049
and and so the the UV spectrum of stars

281
00:10:31,639 --> 00:10:29,879
can change by orders of magnitude

282
00:10:33,889 --> 00:10:31,649
depending on the on the temperature and

283
00:10:35,449 --> 00:10:33,899
the activity of that star and the

284
00:10:36,169 --> 00:10:35,459
ultraviolet radiation is what drives the

285
00:10:38,749 --> 00:10:36,179
photochemistry

286
00:10:41,359 --> 00:10:38,759
and so one example of this is if you

287
00:10:43,579 --> 00:10:41,369
took earth and you instead of kept the

288
00:10:45,199 --> 00:10:43,589

atmospheric composition constant you

289
00:10:46,429 --> 00:10:45,209
kept the boundary conditions constant

290
00:10:48,559 --> 00:10:46,439
and changed the star and put it around

291
00:10:51,379 --> 00:10:48,569
an m-type star which was representative

292
00:10:52,519 --> 00:10:51,389
of 70% of the stars in the galaxy then

293
00:10:54,049 --> 00:10:52,529
your methane abundance would be a

294
00:10:56,119 --> 00:10:54,059
thousand times higher and that could

295
00:10:57,889 --> 00:10:56,129
have an incredible consequence for

296
00:11:00,739 --> 00:10:57,899
remotely detectable signatures both in

297
00:11:04,850 --> 00:11:00,749
transmission spectroscopy and in

298
00:11:06,409 --> 00:11:04,860
reflected light spectroscopy so so so

299
00:11:08,569 --> 00:11:06,419
self-consistent photochemical models are

300
00:11:11,840 --> 00:11:08,579
also incredibly important considerations

301
00:11:12,980 --> 00:11:11,850
I mentioned abiotic processes so there

302
00:11:13,700 --> 00:11:12,990
are there have been many grew

303
00:11:15,830 --> 00:11:13,710
independent group

304
00:11:17,450 --> 00:11:15,840
from a variety of disciplines of

305
00:11:19,370 --> 00:11:17,460
research groups and backgrounds who have

306
00:11:21,230 --> 00:11:19,380
put forward potential ways that you

307
00:11:22,700 --> 00:11:21,240
could make for example oxygen and

308
00:11:24,980 --> 00:11:22,710
atmosphere abiotic lis either through

309
00:11:27,170 --> 00:11:24,990
Fatah lysis or for the rapid escape of

310
00:11:29,360 --> 00:11:27,180
hydrogen and depends on the evolutionary

311
00:11:31,160 --> 00:11:29,370
history of the host star not everyone

312
00:11:33,920 --> 00:11:31,170
thinks that these mechanisms are

313
00:11:36,740 --> 00:11:33,930

possible importantly though we can

314
00:11:39,350 --> 00:11:36,750
predict the spectral implications of

315
00:11:43,610 --> 00:11:39,360
those processes so if you if you if you

316
00:11:46,010 --> 00:11:43,620
generate your your your abiotic oxygen

317
00:11:47,360 --> 00:11:46,020
to the photolysis of carbon dioxide then

318
00:11:50,450 --> 00:11:47,370
you would expect no methane and high

319
00:11:52,430 --> 00:11:50,460
abundances of carbon monoxide and so we

320
00:11:55,340 --> 00:11:52,440
can use the predictions from these

321
00:11:56,720 --> 00:11:55,350
models to sort of inform the technical

322
00:12:00,530 --> 00:11:56,730
requirements for discriminating against

323
00:12:02,330 --> 00:12:00,540
these false positive scenarios there's

324
00:12:04,190 --> 00:12:02,340
also advances in chemical disequilibrium

325
00:12:06,770 --> 00:12:04,200
so this is just a really quick plug for

326
00:12:08,570 --> 00:12:06,780
work by Josh Kristensen Totten who's

327
00:12:10,490 --> 00:12:08,580
looked both at modern earth and our key

328
00:12:13,030 --> 00:12:10,500
and earth and looked at the Gibbs free

329
00:12:15,320 --> 00:12:13,040
energy of the system and how that

330
00:12:16,640 --> 00:12:15,330
relates to potential bio signatures so

331
00:12:18,830 --> 00:12:16,650
everyone is familiar with the oxygen

332
00:12:21,080 --> 00:12:18,840
methane a chemical disequilibrium couple

333
00:12:22,910 --> 00:12:21,090
bike by free energy that's not actually

334
00:12:24,920 --> 00:12:22,920
the largest it's it's it's the

335
00:12:27,290 --> 00:12:24,930
coexistence of nitrogen oxygen and

336
00:12:29,870 --> 00:12:27,300
liquid water in our atmosphere so these

337
00:12:32,030 --> 00:12:29,880
calculations can be done in a and they

338
00:12:34,130 --> 00:12:32,040

imply that if we for a modern type earth

339
00:12:35,600 --> 00:12:34,140
saw nitrogen oxygen and liquid water

340
00:12:37,640 --> 00:12:35,610
that there would be a strong BIOS

341
00:12:39,560 --> 00:12:37,650
signature methane carbon dioxide and

342
00:12:42,170 --> 00:12:39,570
water are also strong bio signatures for

343
00:12:45,080 --> 00:12:42,180
that reason and so I'll end with this

344
00:12:48,260 --> 00:12:45,090
sort of hope this comprehensive model

345
00:12:49,610 --> 00:12:48,270
put forward by David Catlin and in

346
00:12:51,110 --> 00:12:49,620
advance also by Sarah Walker in the

347
00:12:52,910 --> 00:12:51,120
series of review papers sponsored by

348
00:12:55,310 --> 00:12:52,920
Nexus which is that we can combine all

349
00:12:57,890 --> 00:12:55,320
of this information the context of the

350
00:13:01,010 --> 00:12:57,900
of the stellar system the data that we

351
00:13:02,270 --> 00:13:01,020
retrieve the forward models that can

352
00:13:04,880 --> 00:13:02,280
incorporate self consistently

353
00:13:08,870 --> 00:13:04,890
photochemistry and we can put that all

354
00:13:12,430 --> 00:13:08,880
together and and get a certificate

355
00:13:15,260 --> 00:13:12,440
likelihood of whether that planet has a

356
00:13:18,710 --> 00:13:15,270
compelling bio signature or not and that

357
00:13:20,090 --> 00:13:18,720
is iterative based on just not just the

358
00:13:22,370 --> 00:13:20,100
advances of our models but the continued

359
00:13:24,080 --> 00:13:22,380
observations that we will receive in the

360
00:13:26,270 --> 00:13:24,090
future and so I'll end with just a

361
00:13:27,020 --> 00:13:26,280
summary of those nexus review papers and

362
00:13:28,580 --> 00:13:27,030
other review pay

363
00:13:31,040 --> 00:13:28,590

by prominent people in the field

364
00:13:32,690 --> 00:13:31,050
including Sara Seager and Lisa Calton