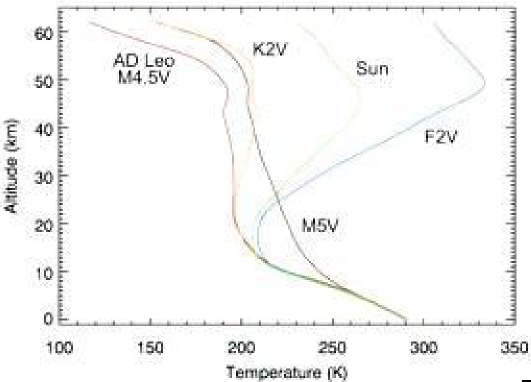
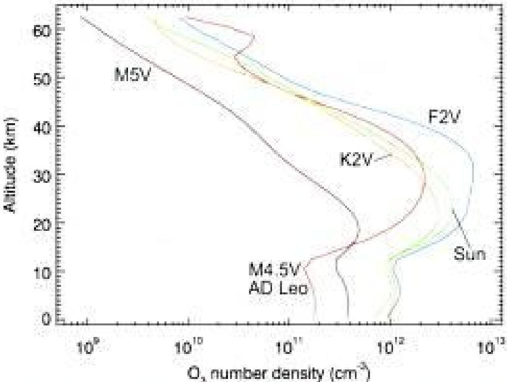
Surface UV Radiation





- For 1PAL of O_2, more UV results in more O_3, and maintains habitable levels of surface radiation.
- The critical threshold for O_2 to provide a planetary UV shield is typically ~10^{-2} PAL.

Segura et al. (2003, 2005)

Parent star	O_3 column depth (cm^{-2})	DNA Damage
Sun	8.4×10^{18}	1.0
F2V	1.6×10^{19}	0.38
K2V	6.6×10^{18}	0.50
AD Leo	4.4×10^{18}	
M 3100	1.2×10^{18}	

1
00:00:08,240 --> 00:00:04,280
so sorry for the delay welcome to the

2
00:00:10,339 --> 00:00:08,250
astrobiology seminars we're not having a

3
00:00:12,709 --> 00:00:10,349
full series this quarter we will have

4
00:00:14,780 --> 00:00:12,719
one in the spring quarter but we are

5
00:00:16,099 --> 00:00:14,790
going to be having three candidate

6
00:00:19,490 --> 00:00:16,109
business this is the first of them for

7
00:00:21,590 --> 00:00:19,500
the astrobiology faculty position Vicki

8
00:00:23,090 --> 00:00:21,600
if she came here we'd be both in

9
00:00:26,540 --> 00:00:23,100
astrobiology and sitting in the

10
00:00:27,950 --> 00:00:26,550
Astronomy Department so we're really

11
00:00:31,910 --> 00:00:27,960
working here because you gave a talk to

12
00:00:33,200 --> 00:00:31,920
be strongly Department just 12 30 so

13
00:00:35,900 --> 00:00:33,210

we're hoping over her voice will hold

14
00:00:37,940 --> 00:00:35,910
out but Vicki got her PhD in 1994 at

15
00:00:39,260 --> 00:00:37,950
Sydney University where she was a

16
00:00:41,810 --> 00:00:39,270
student of David Allen one of the

17
00:00:45,410 --> 00:00:41,820
pioneers of down based infrared

18
00:00:47,590 --> 00:00:45,420
astronomy and she came to JPL after that

19
00:00:50,660 --> 00:00:47,600
and has been in the States ever since

20
00:00:53,389 --> 00:00:50,670
primarily working on Venus but other

21
00:00:54,860 --> 00:00:53,399
solar system projects too and we've

22
00:00:57,580 --> 00:00:54,870
noted very well in the astrobiology

23
00:01:00,860 --> 00:00:57,590
program because she has been one of the

24
00:01:02,420 --> 00:01:00,870
leaders of the so called nodes or

25
00:01:05,030 --> 00:01:02,430
research groups that the NASA

26
00:01:07,130 --> 00:01:05,040
astrobiologist who has sponsored over

27
00:01:09,410 --> 00:01:07,140
the years just as it has here at the UW

28
00:01:11,300 --> 00:01:09,420
and so she's calling that we've known

29
00:01:13,730 --> 00:01:11,310
for many years and we're delighted to

30
00:01:16,760 --> 00:01:13,740
have her here for this visit and for

31
00:01:19,280 --> 00:01:16,770
anything she's going to be talking about

32
00:01:21,890 --> 00:01:19,290
what that nose is all about the virtual

33
00:01:24,140 --> 00:01:21,900
planetary laboratory which is a

34
00:01:26,090 --> 00:01:24,150
marvelous simulation of what other

35
00:01:27,440 --> 00:01:26,100
terrestrial planets might look like to

36
00:01:31,190 --> 00:01:27,450
something like the terrestrial planet

37
00:01:32,960 --> 00:01:31,200
finder so particularly thank you okay so

38
00:01:36,859 --> 00:01:32,970

thank you all for coming and especially

39
00:01:39,140 --> 00:01:36,869
those on webex virtually as well hi so

40
00:01:40,730 --> 00:01:39,150
now my name is dr. Vickie meadows I was

41
00:01:43,130 --> 00:01:40,740
the principal investigator for the

42
00:01:45,410 --> 00:01:43,140
virtual planetary league team which we

43
00:01:46,940 --> 00:01:45,420
now call an alumni team or a former

44
00:01:49,999 --> 00:01:46,950
member of the nasa astrobiology

45
00:01:51,830 --> 00:01:50,009
institute and we are 40 people at a

46
00:01:54,109 --> 00:01:51,840
total of eighteen different institutions

47
00:01:56,510 --> 00:01:54,119
so this not more than two or three of us

48
00:01:57,859 --> 00:01:56,520
with any given institution and but

49
00:02:00,289 --> 00:01:57,869
nonetheless we managed to collaborate

50
00:02:03,170 --> 00:02:00,299
virtually by email and and meetings and

51
00:02:05,719 --> 00:02:03,180
visitor collaborations so what I'm going

52
00:02:07,760 --> 00:02:05,729
to talk to you today about of four major

53
00:02:09,889 --> 00:02:07,770
topics first I'm going to review

54
00:02:11,630 --> 00:02:09,899
so-called habitability markers and bio

55
00:02:12,130 --> 00:02:11,640
signatures what we would look for in the

56
00:02:13,900 --> 00:02:12,140
spectrum

57
00:02:14,920 --> 00:02:13,910
planta de Renner to the star to try and

58
00:02:17,199 --> 00:02:14,930
understand what its planetary

59
00:02:18,790 --> 00:02:17,209
environment is like I'm then going to

60
00:02:21,160 --> 00:02:18,800
talk about work that we've done already

61
00:02:22,990 --> 00:02:21,170
on taking earth ripping away the Sun

62
00:02:25,090 --> 00:02:23,000
throwing it away and replacing it with

63
00:02:27,309 --> 00:02:25,100

some other type of star and looking at

64
00:02:29,110 --> 00:02:27,319
how the Earth's atmosphere would respond

65
00:02:31,690 --> 00:02:29,120
to the different radiation that's coming

66
00:02:33,550 --> 00:02:31,700
in and what that does to fix me a

67
00:02:35,800 --> 00:02:33,560
massacre and the spectrum of the planet

68
00:02:37,630 --> 00:02:35,810
I'm going to also talk about new work

69
00:02:40,000 --> 00:02:37,640
that we've done on hike high carbon

70
00:02:42,010 --> 00:02:40,010
dioxide early Earth's are specifically

71
00:02:44,410 --> 00:02:42,020
looking to try and produce oxygen from

72
00:02:46,570 --> 00:02:44,420
these atmospheres by doing all sorts of

73
00:02:49,420 --> 00:02:46,580
things adding UV radiation vulcanism

74
00:02:50,770 --> 00:02:49,430
various different things and I'll show

75
00:02:53,050 --> 00:02:50,780
you some of the results from that and

76
00:02:55,030 --> 00:02:53,060
what we found and finally I'm going to

77
00:02:57,490 --> 00:02:55,040
cap off with some very new work that's

78
00:03:00,160 --> 00:02:57,500
coming out in march on extrasolar

79
00:03:02,140 --> 00:03:00,170
photosynthesis and trying to understand

80
00:03:03,940 --> 00:03:02,150
what the preferential pigments for

81
00:03:06,250 --> 00:03:03,950
photosynthesis would be like on planets

82
00:03:09,400 --> 00:03:06,260
around other stars by looking at the

83
00:03:11,199 --> 00:03:09,410
places in the spectrum of radiation on

84
00:03:12,520 --> 00:03:11,209
the surface of the planet where a plant

85
00:03:17,170 --> 00:03:12,530
would really get the best value for

86
00:03:20,020 --> 00:03:17,180
photosynthesis and first of all if you

87
00:03:22,300 --> 00:03:20,030
like to talk vinit I usually take like

88
00:03:24,340 --> 00:03:22,310

to begin these hooks by talking about

89
00:03:26,229 --> 00:03:24,350
the fact that the planets that we find

90
00:03:28,449 --> 00:03:26,239
the extra solar terrestrial planets even

91
00:03:29,800 --> 00:03:28,459
though we've never detected one yet it's

92
00:03:31,870 --> 00:03:29,810
highly probable that they're going to be

93
00:03:33,699 --> 00:03:31,880
very different to the three examples of

94
00:03:36,069 --> 00:03:33,709
terrestrial planets with the atmospheres

95
00:03:37,660 --> 00:03:36,079
that we have in our own solar system so

96
00:03:39,100 --> 00:03:37,670
when we talk about you know learning

97
00:03:40,750 --> 00:03:39,110
about what these might be like or how to

98
00:03:42,850 --> 00:03:40,760
characterize them we have to keep in

99
00:03:45,640 --> 00:03:42,860
mind that these planets are likely to be

100
00:03:47,590 --> 00:03:45,650
very alien and they may span a range of

101
00:03:50,890 --> 00:03:47,600
characteristics that's just not seen in

102
00:03:52,690 --> 00:03:50,900
our own planetary system so to get a

103
00:03:54,759 --> 00:03:52,700
handle on what these might be like we

104
00:03:56,530 --> 00:03:54,769
really do have to resort to modeling we

105
00:03:58,240 --> 00:03:56,540
don't yet have the observations we've

106
00:03:59,890 --> 00:03:58,250
got a few examples in our solar system

107
00:04:01,630 --> 00:03:59,900
but it really is modeling that will

108
00:04:04,270 --> 00:04:01,640
allow us to push that face spaced out

109
00:04:05,830 --> 00:04:04,280
and explore in a virtual way what these

110
00:04:08,259 --> 00:04:05,840
planets might be like and what we might

111
00:04:10,509 --> 00:04:08,269
expect to see so that the plot that we

112
00:04:13,930 --> 00:04:10,519
have up here planetary system diversity

113
00:04:15,789 --> 00:04:13,940

Marco is show some of the results from

114
00:04:18,640 --> 00:04:15,799
the Raymond Quinn and lunin modeling of

115
00:04:20,650 --> 00:04:18,650
different types of planetary systems so

116
00:04:22,029 --> 00:04:20,660
these are planet formation models and

117
00:04:23,650 --> 00:04:22,039
what they show is a whole series of

118
00:04:25,750 --> 00:04:23,660
colored dots here which represent

119
00:04:27,400 --> 00:04:25,760
planets where the color is

120
00:04:29,920 --> 00:04:27,410
the volatile abundance and in particular

121
00:04:31,930 --> 00:04:29,930
water abundance in the planet where blue

122
00:04:34,690 --> 00:04:31,940
is very water rich red is very water

123
00:04:37,930 --> 00:04:34,700
poor and the black circles donate the

124
00:04:39,550 --> 00:04:37,940
iron fraction in the planet so you can

125
00:04:41,770 --> 00:04:39,560
see in these plots the semi-major axis

126
00:04:43,810 --> 00:04:41,780
is plotted on the bottom so that's the

127
00:04:46,030 --> 00:04:43,820
distance from its parent star and then

128
00:04:49,300 --> 00:04:46,040
the e centricity how much it varies from

129
00:04:51,280 --> 00:04:49,310
a circle is plotted on the y-axis so in

130
00:04:53,050 --> 00:04:51,290
these planetary models they do make a

131
00:04:55,270 --> 00:04:53,060
menagerie of different types of planets

132
00:04:57,580 --> 00:04:55,280
with varying abundances of water are

133
00:04:59,920 --> 00:04:57,590
different to the earth Venus and Mars in

134
00:05:01,840 --> 00:04:59,930
our own case and so we anticipate that

135
00:05:03,700 --> 00:05:01,850
when we go out and look with something

136
00:05:05,200 --> 00:05:03,710
like the terrestrial planet finder that

137
00:05:07,030 --> 00:05:05,210
we're going to find really strange and

138
00:05:08,860 --> 00:05:07,040

wonderful things and so the virtual

139
00:05:10,570 --> 00:05:08,870
planetary laboratory as i said is trying

140
00:05:14,710 --> 00:05:10,580
to explore what those strange wonderful

141
00:05:16,810 --> 00:05:14,720
things might look like so when we

142
00:05:19,030 --> 00:05:16,820
remotely detect our planet around

143
00:05:20,910 --> 00:05:19,040
another star it's going to be unresolved

144
00:05:23,290 --> 00:05:20,920
we're not going to be able to see

145
00:05:25,060 --> 00:05:23,300
spatial information on it we won't be

146
00:05:26,830 --> 00:05:25,070
able to see continents or clouds or

147
00:05:29,610 --> 00:05:26,840
oceans directly in our astronomical

148
00:05:32,710 --> 00:05:29,620
images it will look like a pixel and

149
00:05:34,800 --> 00:05:32,720
hopefully a nice blue pixel by pixel is

150
00:05:37,000 --> 00:05:34,810
pretty much all we're going to get so

151
00:05:38,740 --> 00:05:37,010
everything we learn about this planet

152
00:05:41,560 --> 00:05:38,750
must be obtained from what we call disc

153
00:05:44,200 --> 00:05:41,570
average data so the the disc of the

154
00:05:45,940 --> 00:05:44,210
planet is essentially squished down no

155
00:05:48,430 --> 00:05:45,950
spatial resolution but we can get

156
00:05:51,130 --> 00:05:48,440
spectral resolution so we have a disc

157
00:05:53,470 --> 00:05:51,140
averaged observation of the planet but

158
00:05:57,150 --> 00:05:53,480
at different wavelengths and from that

159
00:05:59,560 --> 00:05:57,160
we have to draw it try and decompose

160
00:06:03,520 --> 00:05:59,570
what the planet is like whether it has

161
00:06:05,290 --> 00:06:03,530
oceans or clouds or different types of

162
00:06:09,280 --> 00:06:05,300
surface features where time steps are

163
00:06:11,650 --> 00:06:09,290

not working here so sorry about that so

164
00:06:12,880 --> 00:06:11,660
in essence not only do we have to

165
00:06:14,290 --> 00:06:12,890
understand the environment from the disc

166
00:06:16,360 --> 00:06:14,300
average but whether or not there is life

167
00:06:18,880 --> 00:06:16,370
on it must also be determined from this

168
00:06:20,860 --> 00:06:18,890
disc average so the signs of life must

169
00:06:22,420 --> 00:06:20,870
be a global phenomenon on this planet or

170
00:06:25,300 --> 00:06:22,430
we really don't have a very good chance

171
00:06:27,280 --> 00:06:25,310
of detecting them so when we talk about

172
00:06:29,170 --> 00:06:27,290
the habitability zone when we look at

173
00:06:30,700 --> 00:06:29,180
planets around other stars we're really

174
00:06:32,860 --> 00:06:30,710
talking about what we call a classic

175
00:06:34,519 --> 00:06:32,870
habitability zone which is the range at

176
00:06:36,799 --> 00:06:34,529
which liquid water can remain

177
00:06:39,259 --> 00:06:36,809
so sorry the water can remain liquid on

178
00:06:41,179 --> 00:06:39,269
the surface of the planet and I know

179
00:06:42,559 --> 00:06:41,189
that a lot of people here work on Europa

180
00:06:44,299 --> 00:06:42,569
and other types of environments that are

181
00:06:46,099 --> 00:06:44,309
outside of this classic habitable zone

182
00:06:47,749 --> 00:06:46,109
where none nonetheless life may be

183
00:06:50,209 --> 00:06:47,759
possible but these would be very

184
00:06:52,999 --> 00:06:50,219
difficult to detect remotely so we don't

185
00:06:56,899 --> 00:06:53,009
include them in our definition of a

186
00:06:58,399 --> 00:06:56,909
habitable zone region so I also want to

187
00:06:59,869 --> 00:06:58,409
say that when we try and characterize

188
00:07:02,149 --> 00:06:59,879

the planet and learn about it our

189
00:07:03,739 --> 00:07:02,159
ability to do that will only be as good

190
00:07:05,719 --> 00:07:03,749
as the effective emitting layer of the

191
00:07:08,149 --> 00:07:05,729
planet so essentially at the wavelengths

192
00:07:09,979 --> 00:07:08,159
that we choose how far we can penetrate

193
00:07:12,229 --> 00:07:09,989
into the planet's atmosphere is is all

194
00:07:13,399 --> 00:07:12,239
we're going to get so if the planet for

195
00:07:15,709 --> 00:07:13,409
example is completely covered with

196
00:07:18,049 --> 00:07:15,719
clouds as Venus's and we observe in the

197
00:07:20,029 --> 00:07:18,059
visible and we can only characterize the

198
00:07:21,829 --> 00:07:20,039
the atmosphere above the clouds and

199
00:07:23,179 --> 00:07:21,839
that's all we will have so there will be

200
00:07:25,009 --> 00:07:23,189
instances where we might find an

201
00:07:26,509 --> 00:07:25,019
extremely interesting planet but we may

202
00:07:28,609 --> 00:07:26,519
not have the capability to actually

203
00:07:30,019 --> 00:07:28,619
probe all the way to the surface to find

204
00:07:31,579 --> 00:07:30,029
out if it can in fact support liquid

205
00:07:32,869 --> 00:07:31,589
water so these are the kind of

206
00:07:35,329 --> 00:07:32,879
challenges we have when trying to

207
00:07:38,179 --> 00:07:35,339
remotely characterize an entire entire

208
00:07:40,009 --> 00:07:38,189
world so the things that we will look

209
00:07:42,139 --> 00:07:40,019
for when we find our terrestrial planet

210
00:07:43,489 --> 00:07:42,149
around another star you know what are

211
00:07:45,679 --> 00:07:43,499
the planetary system environmental

212
00:07:48,139 --> 00:07:45,689
characteristics of course the parent

213
00:07:50,179 --> 00:07:48,149

star like is it a nice parent star is it

214
00:07:52,129 --> 00:07:50,189
fairly stable or is it actively flaring

215
00:07:54,559 --> 00:07:52,139
all the time and being difficult under

216
00:07:56,299 --> 00:07:54,569
other planets in the solar system that

217
00:07:57,469 --> 00:07:56,309
might improve the chances of the planet

218
00:07:59,839 --> 00:07:57,479
that we found being habitable for

219
00:08:02,329 --> 00:07:59,849
example a nice stable Jovian planet in

220
00:08:04,339 --> 00:08:02,339
an outer solar system orbit will also

221
00:08:07,219 --> 00:08:04,349
look for math and orbital parameters and

222
00:08:10,069 --> 00:08:07,229
with the suite of missions that nASA has

223
00:08:11,329 --> 00:08:10,079
planned the best instrumentation for

224
00:08:14,899 --> 00:08:11,339
doing that is something called the space

225
00:08:16,269 --> 00:08:14,909
interferometry mission or sin so sim may

226
00:08:19,369 --> 00:08:16,279
be able to get us mass and orbital

227
00:08:22,009 --> 00:08:19,379
parameters for planets that are a maybe

228
00:08:23,299 --> 00:08:22,019
as as small as three earth masses so we

229
00:08:24,919 --> 00:08:23,309
would like to have that mission to at

230
00:08:26,269 --> 00:08:24,929
least have already gotten us our mass in

231
00:08:27,769 --> 00:08:26,279
orbit before we go after with

232
00:08:29,569 --> 00:08:27,779
terrestrial planet finder to try to get

233
00:08:30,799 --> 00:08:29,579
a spectrum so we will look for

234
00:08:32,689 --> 00:08:30,809
terrestrial planets in the so-called

235
00:08:34,790 --> 00:08:32,699
habitable zone in this classic habitable

236
00:08:36,499 --> 00:08:34,800
zone but to do that we really will have

237
00:08:38,239 --> 00:08:36,509
to have the orbit to know whether it's

238
00:08:40,850 --> 00:08:38,249

circular and a planet stays in the

239
00:08:42,919 --> 00:08:40,860
habitable zone or whether it's eccentric

240
00:08:43,510 --> 00:08:42,929
and there may be slight excursions from

241
00:08:45,490 --> 00:08:43,520
the habitable

242
00:08:47,920 --> 00:08:45,500
but it's very important to have that

243
00:08:49,510 --> 00:08:47,930
orbital information and terrestrial

244
00:08:52,570 --> 00:08:49,520
planet finder by the way may not be very

245
00:08:54,160 --> 00:08:52,580
good at that so photometric

246
00:08:55,330 --> 00:08:54,170
characteristics is the next thing we

247
00:08:57,970 --> 00:08:55,340
will look for because of course we're

248
00:08:59,590 --> 00:08:57,980
very starved for photons here so we'll

249
00:09:00,880 --> 00:08:59,600
try and look at colors first we'll look

250
00:09:02,770 --> 00:09:00,890
at the brightness and color of the

251
00:09:05,140 --> 00:09:02,780
target so how much radiation is coming

252
00:09:06,430 --> 00:09:05,150
in at different wavelengths and look and

253
00:09:09,460 --> 00:09:06,440
see if there's any temporal variability

254
00:09:11,170 --> 00:09:09,470
that might hint it inhomogeneity and on

255
00:09:12,790 --> 00:09:11,180
the other planet you know whether or not

256
00:09:15,460 --> 00:09:12,800
you've seen continents and clouds and

257
00:09:17,050 --> 00:09:15,470
oceans things moving around and then

258
00:09:18,820 --> 00:09:17,060
finally the most powerful tool that we

259
00:09:20,260 --> 00:09:18,830
have will be spectra and these are the

260
00:09:23,190 --> 00:09:20,270
most difficult observations to get

261
00:09:26,470 --> 00:09:23,200
because we must take already photon poor

262
00:09:28,960 --> 00:09:26,480
ray radiation information and then

263
00:09:30,760 --> 00:09:28,970

disperse it even further but nonetheless

264
00:09:32,410 --> 00:09:30,770
if we can get good spectra of these

265
00:09:34,480 --> 00:09:32,420
planets that's our most powerful tool

266
00:09:35,770 --> 00:09:34,490
for working out what they're like and in

267
00:09:38,500 --> 00:09:35,780
their spectral will look for things like

268
00:09:40,300 --> 00:09:38,510
carbon dioxide which lets me know that I

269
00:09:43,060 --> 00:09:40,310
probably have a terrestrial planet with

270
00:09:45,010 --> 00:09:43,070
an atmosphere it's not common to see a

271
00:09:46,960 --> 00:09:45,020
lot of carbon dioxide in a Jovian planet

272
00:09:49,450 --> 00:09:46,970
around the sphere in fact three planets

273
00:09:51,070 --> 00:09:49,460
we have Venus Earth and Mars all have

274
00:09:52,390 --> 00:09:51,080
strong carbon dioxide absorptions that's

275
00:09:54,880 --> 00:09:52,400
considered characteristic of terrestrial

276
00:09:56,230 --> 00:09:54,890
planet we'll look for water vapor which

277
00:09:58,360 --> 00:09:56,240
may be a good indicator that there's

278
00:09:59,890 --> 00:09:58,370
liquid water on the surface not always

279
00:10:02,050 --> 00:09:59,900
but it's usually a pretty good indicator

280
00:10:03,880 --> 00:10:02,060
that we have it will look for signs that

281
00:10:06,460 --> 00:10:03,890
there's an ultraviolet shield somewhere

282
00:10:07,990 --> 00:10:06,470
in the atmosphere so you look for signs

283
00:10:10,210 --> 00:10:08,000
that there's something we recognized as

284
00:10:12,910 --> 00:10:10,220
a UV shield like ozone our famous ozone

285
00:10:15,160 --> 00:10:12,920
layer so either look directly for ozone

286
00:10:17,140 --> 00:10:15,170
in the spectrum or we will look for what

287
00:10:19,030 --> 00:10:17,150
we call secondary signs of a UV shield

288
00:10:21,580 --> 00:10:19,040

and that is looking for the temperature

289
00:10:23,950 --> 00:10:21,590
effect of ozone in the absorption band

290
00:10:26,320 --> 00:10:23,960
of other molecules so carbon dioxide for

291
00:10:28,300 --> 00:10:26,330
example has a central peak in it which

292
00:10:30,550 --> 00:10:28,310
denotes our hot stratosphere and that

293
00:10:32,590 --> 00:10:30,560
stratosphere is hot because of ozone so

294
00:10:34,060 --> 00:10:32,600
even if we didn't detect ozone we would

295
00:10:35,170 --> 00:10:34,070
look for that hot central peak that says

296
00:10:37,030 --> 00:10:35,180
hey there's something up high in the

297
00:10:38,590 --> 00:10:37,040
atmosphere absorbing UV radiation and

298
00:10:41,710 --> 00:10:38,600
that's a good thing because it protects

299
00:10:43,509 --> 00:10:41,720
the life underneath other potential life

300
00:10:45,249 --> 00:10:43,519
and then of course we will do a spectral

301
00:10:47,590 --> 00:10:45,259
determination o is the longest

302
00:10:49,389 --> 00:10:47,600
wavelength range we possibly can to try

303
00:10:51,069 --> 00:10:49,399
and get a census of what gases are in

304
00:10:52,840 --> 00:10:51,079
the atmosphere and whether they are

305
00:10:55,329 --> 00:10:52,850
greenhouse gases and how much of them

306
00:10:56,710 --> 00:10:55,339
there are because ultimately being able

307
00:10:58,470 --> 00:10:56,720
to measure the surface temperature of

308
00:11:00,699 --> 00:10:58,480
the planet that's the holy grail of

309
00:11:01,990 --> 00:11:00,709
habitability can we determine the

310
00:11:03,069 --> 00:11:02,000
surface temperature and pressure and

311
00:11:05,110 --> 00:11:03,079
know that there's liquid water on the

312
00:11:06,730 --> 00:11:05,120
surface that measurement directly is

313
00:11:08,710 --> 00:11:06,740

highly unlikely what will probably

314
00:11:10,389 --> 00:11:08,720
happen is that we will measure some

315
00:11:12,730 --> 00:11:10,399
temperature we won't know exactly where

316
00:11:14,439 --> 00:11:12,740
in the atmosphere it is but will then

317
00:11:15,999 --> 00:11:14,449
need to know to have a look at these

318
00:11:17,619 --> 00:11:16,009
other gases and their passages to work

319
00:11:20,230 --> 00:11:17,629
out where we might be sampling it and

320
00:11:22,569 --> 00:11:20,240
more importantly to determine how much

321
00:11:24,699 --> 00:11:22,579
greenhouse warming this planet can can

322
00:11:26,889 --> 00:11:24,709
provide to then try and infer the

323
00:11:28,059 --> 00:11:26,899
surface temperature from that so that

324
00:11:32,110 --> 00:11:28,069
service temperature is probably going to

325
00:11:33,910 --> 00:11:32,120
be a model to derived parameter so when

326
00:11:36,280 --> 00:11:33,920
we look at x 0 signatures they fall into

327
00:11:37,629 --> 00:11:36,290
three basic categories first of all the

328
00:11:39,309 --> 00:11:37,639
biasing itches we're looking at and not

329
00:11:40,660 --> 00:11:39,319
like the Institute biosignatures we pick

330
00:11:42,610 --> 00:11:40,670
up a rock and you sample it and try and

331
00:11:44,470 --> 00:11:42,620
tell if it has life in it these are

332
00:11:46,449 --> 00:11:44,480
signs of life that are observable by a

333
00:11:48,790 --> 00:11:46,459
telescope so we call them astronomical

334
00:11:51,369 --> 00:11:48,800
biosignatures and so these have to be

335
00:11:53,110 --> 00:11:51,379
global scale photometric spectral or

336
00:11:56,319 --> 00:11:53,120
temporal features that are indicative of

337
00:11:58,559 --> 00:11:56,329
life that's the three classes so as we

338
00:12:00,610 --> 00:11:58,569

can see in this this upper plot here

339
00:12:01,900 --> 00:12:00,620
life can provide global scale

340
00:12:05,769 --> 00:12:01,910
modification of a planet's atmosphere

341
00:12:08,170 --> 00:12:05,779
and for our own planet oxygen is the the

342
00:12:12,939 --> 00:12:08,180
most obvious marker of that as my

343
00:12:14,740 --> 00:12:12,949
pointer so up here we have a very strong

344
00:12:17,110 --> 00:12:14,750
band of oxygen the oxygen a band in the

345
00:12:18,369 --> 00:12:17,120
in the optical that much oxygen in the

346
00:12:20,259 --> 00:12:18,379
atmosphere is considered to be

347
00:12:22,929 --> 00:12:20,269
indicative of life so that's an

348
00:12:25,329 --> 00:12:22,939
atmospheric bio signature down here we

349
00:12:27,129 --> 00:12:25,339
have a surface bio signature and this is

350
00:12:28,780 --> 00:12:27,139
in fact a spectrum taken down through

351
00:12:30,790 --> 00:12:28,790
the Earth's atmosphere over a conifer

352
00:12:33,069 --> 00:12:30,800
forest and what it shows is a very

353
00:12:34,780 --> 00:12:33,079
characteristic rise in the red at about

354
00:12:38,230 --> 00:12:34,790
point seven microns it's called the red

355
00:12:40,179 --> 00:12:38,240
edge it's a reflective property of

356
00:12:42,280 --> 00:12:40,189
leaves longwood of point seven microns

357
00:12:44,530 --> 00:12:42,290
and so its characteristic of surface

358
00:12:46,119 --> 00:12:44,540
vegetation and that signature can be

359
00:12:47,710 --> 00:12:46,129
seen from space and it can be seen in

360
00:12:49,140 --> 00:12:47,720
the disk average although it's quite

361
00:12:51,150 --> 00:12:49,150
difficult in that

362
00:12:53,160 --> 00:12:51,160
case now the other thing we look at is

363
00:12:54,930 --> 00:12:53,170

are there any changes in the planets

364
00:12:58,200 --> 00:12:54,940
appearance over time that might be

365
00:12:59,760 --> 00:12:58,210
indicative of life cycles and one of

366
00:13:02,370 --> 00:12:59,770
these in our Earth's atmosphere

367
00:13:03,960 --> 00:13:02,380
admittedly very subtle and difficult to

368
00:13:05,250 --> 00:13:03,970
detect but we'd have to try and hope

369
00:13:07,200 --> 00:13:05,260
that maybe on another planet might be

370
00:13:08,760 --> 00:13:07,210
more obvious but in our own Earth's

371
00:13:10,860 --> 00:13:08,770
atmosphere we have the cycling of

372
00:13:12,540 --> 00:13:10,870
methane and carbon dioxide in the

373
00:13:15,720 --> 00:13:12,550
northern atmosphere due to the

374
00:13:18,390 --> 00:13:15,730
production and decay of vegetation in

375
00:13:20,820 --> 00:13:18,400
the northern atmosphere and in fact life

376
00:13:23,180 --> 00:13:20,830
in general so we see this annual cycling

377
00:13:25,170 --> 00:13:23,190
over time for methane and carbon dioxide

378
00:13:27,180 --> 00:13:25,180
but one thing we have to fundamentally

379
00:13:29,160 --> 00:13:27,190
remember as to the people who do

380
00:13:30,810 --> 00:13:29,170
instituto signatures is that to

381
00:13:32,010 --> 00:13:30,820
recognize a bio signature you really

382
00:13:33,930 --> 00:13:32,020
have to have a good idea of the

383
00:13:35,610 --> 00:13:33,940
environment you're studying because bio

384
00:13:38,760 --> 00:13:35,620
students must always be identified in

385
00:13:40,740 --> 00:13:38,770
the context of their environment and for

386
00:13:42,630 --> 00:13:40,750
example earth methane is in an

387
00:13:44,880 --> 00:13:42,640
environment that is very rich in oxygen

388
00:13:46,140 --> 00:13:44,890

and oxygen and methane don't

389
00:13:47,790 --> 00:13:46,150
particularly like each other they don't

390
00:13:49,830 --> 00:13:47,800
hang around long for a long time

391
00:13:51,840 --> 00:13:49,840
together unless there are active sources

392
00:13:55,200 --> 00:13:51,850
of them and in this particular cases

393
00:13:57,960 --> 00:13:55,210
active sources are both life driven and

394
00:13:59,910 --> 00:13:57,970
so earth methane in the presence of

395
00:14:02,310 --> 00:13:59,920
oxygen is a bio signature but on Titan

396
00:14:04,470 --> 00:14:02,320
methane is just one of the main

397
00:14:07,200 --> 00:14:04,480
constituents or main trace gases of the

398
00:14:08,460 --> 00:14:07,210
atmosphere and so in titan case we don't

399
00:14:12,270 --> 00:14:08,470
think that a methane is actually

400
00:14:14,250 --> 00:14:12,280
indicative of life so what the virtual

401
00:14:16,380 --> 00:14:14,260
planetary laboratory does and what we

402
00:14:19,080 --> 00:14:16,390
have done is that we model planetary

403
00:14:21,600 --> 00:14:19,090
environments and their spectra so we

404
00:14:24,420 --> 00:14:21,610
have developed a suite of models of

405
00:14:26,070 --> 00:14:24,430
planetary environments including 1d

406
00:14:27,900 --> 00:14:26,080
spectral models of planets with known

407
00:14:30,270 --> 00:14:27,910
environments so that was the easiest

408
00:14:32,400 --> 00:14:30,280
thing to do so we have models of Venus

409
00:14:34,200 --> 00:14:32,410
Earth and Mars the beauty of a model

410
00:14:35,760 --> 00:14:34,210
even though we've got it observed all

411
00:14:37,410 --> 00:14:35,770
these planets as the model can run from

412
00:14:38,940 --> 00:14:37,420
the UV to the fire infrared with no

413
00:14:41,760 --> 00:14:38,950

dropouts due to the fact that we haven't

414
00:14:44,430 --> 00:14:41,770
got the data sources there so what we do

415
00:14:46,230 --> 00:14:44,440
is we can generate the model calibrate

416
00:14:48,120 --> 00:14:46,240
it validated against regions of the

417
00:14:49,560 --> 00:14:48,130
spectrum we have observed and then use

418
00:14:50,940 --> 00:14:49,570
physics and chemistry to predict what

419
00:14:53,820 --> 00:14:50,950
the rest of the spectrum will look like

420
00:14:56,580 --> 00:14:53,830
throughout the entire range we also have

421
00:14:57,810 --> 00:14:56,590
3d spectral models of planets in our own

422
00:15:00,300 --> 00:14:57,820
solar system namely

423
00:15:02,280 --> 00:15:00,310
Earth and Mars so these are models that

424
00:15:04,140 --> 00:15:02,290
where we input the atmospheric

425
00:15:07,710 --> 00:15:04,150
parameters of Earth and Mars and

426
00:15:09,330 --> 00:15:07,720
generate spectra for all the positions

427
00:15:10,890 --> 00:15:09,340
for a whole suite of positions on the

428
00:15:12,690 --> 00:15:10,900
planet so this three dimensional

429
00:15:15,480 --> 00:15:12,700
spectral model can be played around with

430
00:15:17,370 --> 00:15:15,490
and it was specifically designed to try

431
00:15:19,350 --> 00:15:17,380
and understand how detectable vegetation

432
00:15:20,820 --> 00:15:19,360
might be in the disk average but it can

433
00:15:22,350 --> 00:15:20,830
also be used to analyze things like

434
00:15:24,900 --> 00:15:22,360
earthshine data which is the disk

435
00:15:28,110 --> 00:15:24,910
average radiation that is reflected from

436
00:15:29,610 --> 00:15:28,120
the moon of the earth but we can also do

437
00:15:32,460 --> 00:15:29,620
fun things with the Mars model we've

438
00:15:34,920 --> 00:15:32,470

covered Mars sick consecutively with ice

439
00:15:36,570 --> 00:15:34,930
we had the polar ice cap work its way

440
00:15:38,070 --> 00:15:36,580
right down the planet and had a look at

441
00:15:42,060 --> 00:15:38,080
how the mass spectrum would evolve with

442
00:15:43,590 --> 00:15:42,070
time with that change in the co2 wife

443
00:15:45,180 --> 00:15:43,600
and interestingly you can in fact see

444
00:15:47,330 --> 00:15:45,190
the signature of co2 ice in the disk

445
00:15:50,280 --> 00:15:47,340
average even for the current ice caps

446
00:15:51,570 --> 00:15:50,290
but when when the ice comes down you

447
00:15:54,780 --> 00:15:51,580
definitely get a much stronger signature

448
00:15:56,940 --> 00:15:54,790
for co2 ice other things we've done that

449
00:15:59,340 --> 00:15:56,950
our main things that we like to work on

450
00:16:01,860 --> 00:15:59,350
our a 1d couple climate chemical models

451
00:16:03,240 --> 00:16:01,870
of plausible extrasolar environments so

452
00:16:05,430 --> 00:16:03,250
these are models that are based on

453
00:16:07,470 --> 00:16:05,440
models of planets in our own solar

454
00:16:10,140 --> 00:16:07,480
system but that are made sufficiently

455
00:16:12,300 --> 00:16:10,150
general that we can in fact model other

456
00:16:14,190 --> 00:16:12,310
types of environments and the things I'm

457
00:16:16,350 --> 00:16:14,200
going to talk about here are our early

458
00:16:19,860 --> 00:16:16,360
earth like environments and also

459
00:16:22,140 --> 00:16:19,870
earth-like planets around other stars so

460
00:16:24,390 --> 00:16:22,150
here are models of terrestrial planets

461
00:16:26,100 --> 00:16:24,400
in the visible and we're just going to

462
00:16:28,140 --> 00:16:26,110
run through these so that you'll learn

463
00:16:29,670 --> 00:16:28,150

in and be able to recognize some of the

464
00:16:31,860 --> 00:16:29,680
major features of the spectra I'm going

465
00:16:36,090 --> 00:16:31,870
to talk about in subsequent mr. the

466
00:16:38,910 --> 00:16:36,100
truck so Venus Earth and Mars these two

467
00:16:41,010 --> 00:16:38,920
planets Venus Venus and Mars actually

468
00:16:43,070 --> 00:16:41,020
are dominated by carbon dioxide

469
00:16:45,750 --> 00:16:43,080
absorption especially from the

470
00:16:47,400 --> 00:16:45,760
near-infrared outwards and that it might

471
00:16:48,720 --> 00:16:47,410
be difficult to tell but these are in

472
00:16:50,700 --> 00:16:48,730
fact the same features here at

473
00:16:52,620 --> 00:16:50,710
carbondale clay so that's what you see

474
00:16:56,100 --> 00:16:52,630
dominating the spectrum of these two

475
00:16:59,190 --> 00:16:56,110
planets for the Upper earth though is

476
00:17:01,710 --> 00:16:59,200
extremely different and it is dominated

477
00:17:04,890 --> 00:17:01,720
by water vapor throughout and then by

478
00:17:06,840 --> 00:17:04,900
oxygen the oxygen a band which is which

479
00:17:08,050 --> 00:17:06,850
is there and the other thing that you

480
00:17:09,970 --> 00:17:08,060
can see on this planet

481
00:17:12,280 --> 00:17:09,980
is that in a relatively cloud-free earth

482
00:17:14,770 --> 00:17:12,290
you do have a tune up to the blue word

483
00:17:16,480 --> 00:17:14,780
end of the spectrum of earth that is due

484
00:17:19,300 --> 00:17:16,490
to Rayleigh scattering from molecules in

485
00:17:21,580 --> 00:17:19,310
our atmosphere and in the case of Venus

486
00:17:22,930 --> 00:17:21,590
even though this is often used as an

487
00:17:25,120 --> 00:17:22,940
indicator of atmospheric pressure by the

488
00:17:26,610 --> 00:17:25,130

way but for Venus even though its

489
00:17:28,990 --> 00:17:26,620
atmospheric pressure is higher overall

490
00:17:31,810 --> 00:17:29,000
again we're only sampling the atmosphere

491
00:17:34,840 --> 00:17:31,820
above the cloud deck which is much much

492
00:17:36,550 --> 00:17:34,850
has much less mathematics fear and I

493
00:17:38,350 --> 00:17:36,560
think close to 30 millibars or something

494
00:17:40,720 --> 00:17:38,360
like that and so you really don't see as

495
00:17:41,980 --> 00:17:40,730
much of an upward turn here plus Venus

496
00:17:44,500 --> 00:17:41,990
also has this thing called the unknown

497
00:17:45,970 --> 00:17:44,510
UV absorber which is a UV absorber which

498
00:17:48,130 --> 00:17:45,980
we don't know what it is hence it's

499
00:17:49,960 --> 00:17:48,140
called the others over and the unknown

500
00:17:52,570 --> 00:17:49,970
UV absorber does in fact tend to absorb

501
00:17:54,610 --> 00:17:52,580
that blue Orenda way so it masks

502
00:17:56,380 --> 00:17:54,620
anywhere Lee's getting more thing on

503
00:17:58,480 --> 00:17:56,390
Mars the situation is even worse in his

504
00:18:00,370 --> 00:17:58,490
innocence Mars has strong absorption

505
00:18:02,260 --> 00:18:00,380
from iron oxide on the surface of the

506
00:18:04,600 --> 00:18:02,270
planet and its weak Rayleigh scattering

507
00:18:06,820 --> 00:18:04,610
atmosphere is no match for for that

508
00:18:08,020 --> 00:18:06,830
absorption features so when Mars let me

509
00:18:10,120 --> 00:18:08,030
have it looks like a negative really

510
00:18:12,250 --> 00:18:10,130
effect but that's of course not possible

511
00:18:14,860 --> 00:18:12,260
and what you're seeing as in fact I

512
00:18:17,080 --> 00:18:14,870
off-site absorption on the surface so if

513
00:18:18,730 --> 00:18:17,090

we go to the mid-infrared so this is

514
00:18:21,940 --> 00:18:18,740
just a different wavelength regime same

515
00:18:23,620 --> 00:18:21,950
plants you can see this thing I was

516
00:18:25,510 --> 00:18:23,630
talking about the carbon dioxide feature

517
00:18:27,850 --> 00:18:25,520
which is extremely strong on all of them

518
00:18:30,100 --> 00:18:27,860
and that's kind of going to be the

519
00:18:31,630 --> 00:18:30,110
easiest thing for a telescope to detect

520
00:18:32,830 --> 00:18:31,640
not that any of this is easy but a

521
00:18:35,380 --> 00:18:32,840
relatively if you think them in to

522
00:18:37,510 --> 00:18:35,390
detect is this this broad carbon dioxide

523
00:18:39,550 --> 00:18:37,520
band to say yes I have a planet with an

524
00:18:40,990 --> 00:18:39,560
atmosphere it's probably terrestrial so

525
00:18:43,240 --> 00:18:41,000
one of the things we'll look for you

526
00:18:45,040 --> 00:18:43,250
also have water vapor in all of these

527
00:18:46,480 --> 00:18:45,050
atmosphere so in Venus and Mars very

528
00:18:48,850 --> 00:18:46,490
small amounts and you can see that the

529
00:18:51,490 --> 00:18:48,860
the h2o water vapor continuum down here

530
00:18:54,460 --> 00:18:51,500
is far more depressed than these other

531
00:18:56,530 --> 00:18:54,470
two but what you also see is that the

532
00:18:58,840 --> 00:18:56,540
again the earth spectrum is the most

533
00:19:00,490 --> 00:18:58,850
complicated of all of them and it is

534
00:19:02,170 --> 00:19:00,500
reviewthe wavelength regime down here

535
00:19:04,390 --> 00:19:02,180
was sensitive to a number of different

536
00:19:06,640 --> 00:19:04,400
metabolites so things out things that

537
00:19:09,310 --> 00:19:06,650
life outputs like nitrous oxide and

538
00:19:11,620 --> 00:19:09,320

methane and ozone which is used as a

539
00:19:14,030 --> 00:19:11,630
proxy for oxygen so you can see the

540
00:19:16,070 --> 00:19:14,040
strong ozone band here

541
00:19:18,230 --> 00:19:16,080
maybe this is the wavelength regime here

542
00:19:20,330 --> 00:19:18,240
where marcio to ice absorbs and that's

543
00:19:21,950 --> 00:19:20,340
where we would look for say a planet

544
00:19:24,020 --> 00:19:21,960
that he may be undergone have this very

545
00:19:25,670 --> 00:19:24,030
collapse and frozen its atmosphere out

546
00:19:29,810 --> 00:19:25,680
of the surface you might look for that

547
00:19:32,960 --> 00:19:29,820
fun on in there so I've been showing all

548
00:19:35,270 --> 00:19:32,970
these lovely spectra zero noise and you

549
00:19:36,620 --> 00:19:35,280
know lovely special resolution but an

550
00:19:38,270 --> 00:19:36,630
actual fact when we look for planets

551
00:19:41,810 --> 00:19:38,280
around other stars we will be photon

552
00:19:44,000 --> 00:19:41,820
starved as I said and so the the

553
00:19:45,680 --> 00:19:44,010
resolution of our spectrographs is not

554
00:19:48,110 --> 00:19:45,690
going to be very high so because we need

555
00:19:49,640 --> 00:19:48,120
to bend as many photons as possible into

556
00:19:51,260 --> 00:19:49,650
the individual business to get enough

557
00:19:53,450 --> 00:19:51,270
signal to noise to be able to detect a

558
00:19:56,750 --> 00:19:53,460
feature so what I've plotted here this

559
00:19:58,370 --> 00:19:56,760
is still zero noise but it shows the

560
00:20:00,760 --> 00:19:58,380
type of special resolution we might

561
00:20:03,290 --> 00:20:00,770
expect with an instrument called T PFC

562
00:20:04,610 --> 00:20:03,300
which is going to be a large telescope

563
00:20:09,080 --> 00:20:04,620

that is sensitive to light in the

564
00:20:10,970 --> 00:20:09,090
optical type CCD type sensitivities and

565
00:20:12,910 --> 00:20:10,980
from there you can see that even from

566
00:20:16,010 --> 00:20:12,920
Venus several of these features

567
00:20:17,630 --> 00:20:16,020
including a strong co2 bands I become a

568
00:20:21,320 --> 00:20:17,640
little bit washed out but still that's

569
00:20:23,060 --> 00:20:21,330
the 1 point 1 05 micron co2 man that's

570
00:20:24,860 --> 00:20:23,070
still probably going to be detectable a

571
00:20:26,990 --> 00:20:24,870
treasonable signal to noise there's the

572
00:20:29,480 --> 00:20:27,000
earth's oxygen land but one thing I like

573
00:20:30,920 --> 00:20:29,490
to show in this plot is that it's very

574
00:20:32,120 --> 00:20:30,930
important to have a wide wavelength

575
00:20:34,550 --> 00:20:32,130
range when you're trying to characterize

576
00:20:37,880 --> 00:20:34,560
these things because at this wavelength

577
00:20:40,130 --> 00:20:37,890
point 7 25 depending on your planet the

578
00:20:42,530 --> 00:20:40,140
dip you see is either carbon dioxide

579
00:20:44,810 --> 00:20:42,540
water vapor or methane at these

580
00:20:46,700 --> 00:20:44,820
resolutions okay so it's very important

581
00:20:48,770 --> 00:20:46,710
to have more wavelength range around

582
00:20:50,600 --> 00:20:48,780
this area and this would be the area we

583
00:20:52,400 --> 00:20:50,610
would choose to try and get B be able to

584
00:20:54,890 --> 00:20:52,410
do bad you will need more wavelengths

585
00:20:57,140 --> 00:20:54,900
around that area to to capture you know

586
00:20:59,090 --> 00:20:57,150
second and third absorptions are the

587
00:21:02,270 --> 00:20:59,100
same species to confirm the detection of

588
00:21:04,340 --> 00:21:02,280

the thing you think you're seeing okay

589
00:21:06,080 --> 00:21:04,350
so now we'll move on to some of the the

590
00:21:08,180 --> 00:21:06,090
vpl modeling how that we've been doing

591
00:21:10,970 --> 00:21:08,190
this is work that's been led by our

592
00:21:13,610 --> 00:21:10,980
postdoc and second Isidoro who has just

593
00:21:15,830 --> 00:21:13,620
recently left us for a university job at

594
00:21:18,800 --> 00:21:15,840
you nom she says her dream job so we're

595
00:21:20,230 --> 00:21:18,810
very happy for her there and I just

596
00:21:22,060 --> 00:21:20,240
listed the names of

597
00:21:24,520 --> 00:21:22,070
real people who were intimately involved

598
00:21:26,049 --> 00:21:24,530
in doing this work and just showed their

599
00:21:28,870 --> 00:21:26,059
expertise to show you that this is a

600
00:21:30,660 --> 00:21:28,880
truly interdisciplinary effort we have

601
00:21:33,010 --> 00:21:30,670
you know still a radiation experts

602
00:21:34,870 --> 00:21:33,020
dealing with biology experts and then

603
00:21:38,830 --> 00:21:34,880
the climate chemistry and planetary

604
00:21:42,610 --> 00:21:38,840
modelers as well so what we've done here

605
00:21:45,040 --> 00:21:42,620
is taken one day photochemical models

606
00:21:46,240 --> 00:21:45,050
and radiative convective models and have

607
00:21:48,120 --> 00:21:46,250
them coupled together so that they

608
00:21:51,070 --> 00:21:48,130
interact with each other to produce

609
00:21:53,560 --> 00:21:51,080
self-consistent environments and what I

610
00:21:55,510 --> 00:21:53,570
mean by that is that when the radiation

611
00:21:58,330 --> 00:21:55,520
from the star comes into the atmosphere

612
00:22:00,549 --> 00:21:58,340
and heats it up due to absorption from

613
00:22:02,799 --> 00:22:00,559

species in the atmosphere we run the

614
00:22:04,540 --> 00:22:02,809
models so that that heating then affects

615
00:22:06,220 --> 00:22:04,550
the chemistry and the resultant

616
00:22:07,690 --> 00:22:06,230
chemistry that affects the heating so

617
00:22:10,210 --> 00:22:07,700
the whole thing is coupled till it

618
00:22:11,680 --> 00:22:10,220
becomes a self-consistent state so I

619
00:22:13,210 --> 00:22:11,690
haven't just you know throw an oxygen up

620
00:22:14,710 --> 00:22:13,220
into this ozone up into the atmosphere

621
00:22:15,790 --> 00:22:14,720
and expected that but nothing would

622
00:22:17,560 --> 00:22:15,800
change in the temperature structure

623
00:22:19,180 --> 00:22:17,570
because I know ozone will absorb UV and

624
00:22:20,440 --> 00:22:19,190
it will heat it up so that's the

625
00:22:22,360 --> 00:22:20,450
self-consistent climate chemical

626
00:22:24,430 --> 00:22:22,370
modeling that we do once we've actually

627
00:22:26,169 --> 00:22:24,440
gotten an environmental state using this

628
00:22:30,010 --> 00:22:26,179
we run it through the smart radiative

629
00:22:32,620 --> 00:22:30,020
transfer model and that then helps us to

630
00:22:34,419 --> 00:22:32,630
generate is simple spectra of what the

631
00:22:36,760 --> 00:22:34,429
environment would look like so we can

632
00:22:39,480 --> 00:22:36,770
see what a telescope would see if it was

633
00:22:42,910 --> 00:22:39,490
looking at this particular environment

634
00:22:44,500 --> 00:22:42,920
so the first step in doing this modeling

635
00:22:46,150 --> 00:22:44,510
because it's earth around other stars is

636
00:22:48,640 --> 00:22:46,160
to make sure we have really good input

637
00:22:50,140 --> 00:22:48,650
stellar spectra and so instead of

638
00:22:51,640 --> 00:22:50,150

approximating these as a black body

639
00:22:53,080 --> 00:22:51,650
which would cause Martin CO and our

640
00:22:56,169 --> 00:22:53,090
collaborator to collapse with a heart

641
00:22:58,120 --> 00:22:56,179
attack we have used realistic stellar

642
00:23:00,640 --> 00:22:58,130
spectra with from real stars with names

643
00:23:03,520 --> 00:23:00,650
and gathered as much data as we possibly

644
00:23:04,810 --> 00:23:03,530
can and Martin has worked with us to to

645
00:23:06,310 --> 00:23:04,820
so all of this together along with

646
00:23:08,830 --> 00:23:06,320
next-gen models and a bunch of other

647
00:23:10,419 --> 00:23:08,840
things to get the best possible full

648
00:23:12,850 --> 00:23:10,429
wavelength range spectrum of the star we

649
00:23:14,799 --> 00:23:12,860
possibly can and in this particular case

650
00:23:16,630 --> 00:23:14,809
having accurate representation of the UV

651
00:23:18,760 --> 00:23:16,640
is really important because the UV is

652
00:23:20,770 --> 00:23:18,770
what drives the photochemistry and I

653
00:23:22,980 --> 00:23:20,780
noticed we choose TPF target stars based

654
00:23:25,210 --> 00:23:22,990
on their their optical classifications

655
00:23:26,500 --> 00:23:25,220
but it turns out that the you fee is

656
00:23:28,480 --> 00:23:26,510
actually going to be in the main

657
00:23:29,880 --> 00:23:28,490
indicator of what you're going to see

658
00:23:32,160 --> 00:23:29,890
and what the planet is going to be

659
00:23:33,540 --> 00:23:32,170
and that may not be the same even for

660
00:23:36,300 --> 00:23:33,550
something in the same spectral class

661
00:23:38,490 --> 00:23:36,310
determined in the visible so the Stars

662
00:23:41,130 --> 00:23:38,500
we used for this where the Sun an

663
00:23:44,100 --> 00:23:41,140

obvious one to start with we use an f2

664
00:23:45,600 --> 00:23:44,110
star K 2 star K 2 dwarfs and then we

665
00:23:47,640 --> 00:23:45,610
used a dealio which is probably one of

666
00:23:49,380 --> 00:23:47,650
the most active M stars known so that

667
00:23:52,170 --> 00:23:49,390
was an extreme end of it and then we

668
00:23:54,450 --> 00:23:52,180
also used a model of a similar spectral

669
00:23:55,920 --> 00:23:54,460
type but that had no activity it

670
00:23:57,090 --> 00:23:55,930
actually doesn't have a chromis fear and

671
00:23:59,640 --> 00:23:57,100
yes I know this is completely

672
00:24:01,950 --> 00:23:59,650
unrealistic however it serves as a lower

673
00:24:04,890 --> 00:24:01,960
bound on the type of UV activity we're

674
00:24:06,210 --> 00:24:04,900
going to see from these stars and so

675
00:24:08,670 --> 00:24:06,220
there are the stellar spectra we used

676
00:24:09,960 --> 00:24:08,680
and there you be activity and it's

677
00:24:15,300 --> 00:24:09,970
interesting too but the more active

678
00:24:17,070 --> 00:24:15,310
stars like 80 Leo for example where she

679
00:24:19,440 --> 00:24:17,080
do get a lot of UV that's almost

680
00:24:24,120 --> 00:24:19,450
comparable with the Sun at the shorter

681
00:24:25,770 --> 00:24:24,130
wavelengths so one thing we looked at as

682
00:24:27,930 --> 00:24:25,780
far as habitability is concerned as is

683
00:24:30,660 --> 00:24:27,940
we put these planets around stars a

684
00:24:32,880 --> 00:24:30,670
different spectral type and around their

685
00:24:35,040 --> 00:24:32,890
their temperature structures and looked

686
00:24:37,200 --> 00:24:35,050
at how for example things like the ozone

687
00:24:39,090 --> 00:24:37,210
would adjust within the atmosphere as

688
00:24:40,860 --> 00:24:39,100

are these different colors even though

689
00:24:42,450 --> 00:24:40,870
they're labeled by star named are

690
00:24:44,820 --> 00:24:42,460
actually the planets around that star

691
00:24:46,830 --> 00:24:44,830
and each planet was put around its star

692
00:24:49,710 --> 00:24:46,840
in the habitable zone so we gave it that

693
00:24:52,260 --> 00:24:49,720
much of a chance and what you're seeing

694
00:24:55,170 --> 00:24:52,270
here is the formation an extremely hot

695
00:24:56,880 --> 00:24:55,180
stratosphere in the f star because this

696
00:24:59,700 --> 00:24:56,890
is earthed remember it has oxygen in it

697
00:25:02,160 --> 00:24:59,710
so we created ozone very very strong

698
00:25:04,800 --> 00:25:02,170
ozone meijer in this particular case in

699
00:25:06,210 --> 00:25:04,810
the nstar case we didn't create as much

700
00:25:08,790 --> 00:25:06,220
of an ozone layer so you don't see as

701
00:25:11,790 --> 00:25:08,800
much stress for heating there but what

702
00:25:13,590 --> 00:25:11,800
we also did was then look at how much of

703
00:25:15,750 --> 00:25:13,600
the UV radiation actually came through

704
00:25:17,310 --> 00:25:15,760
the planetary atmosphere and hit the

705
00:25:19,410 --> 00:25:17,320
surface of the planet and what that

706
00:25:22,080 --> 00:25:19,420
would do in the way of DNA damage for

707
00:25:23,880 --> 00:25:22,090
these these various types of planets so

708
00:25:26,220 --> 00:25:23,890
it turns out that the interaction of the

709
00:25:28,830 --> 00:25:26,230
UV radiation from the star with the

710
00:25:30,600 --> 00:25:28,840
oxygen in our atmosphere reduced ozone

711
00:25:33,510 --> 00:25:30,610
layers that just seemed to almost full a

712
00:25:36,190 --> 00:25:33,520
Goldilocks principle in the center

713
00:25:38,170 --> 00:25:36,200

even for the F star with a lot of UV

714
00:25:40,060 --> 00:25:38,180
radiation it formed a super ozone layer

715
00:25:41,740 --> 00:25:40,070
and was able to block most of the

716
00:25:43,420 --> 00:25:41,750
dangerous UV radiation computing the

717
00:25:45,940 --> 00:25:43,430
surface of the planet so the actual

718
00:25:48,790 --> 00:25:45,950
percentage DNA damage a relative DNA

719
00:25:50,770 --> 00:25:48,800
damage relative to the earth was in fact

720
00:25:53,470 --> 00:25:50,780
less slightly less in this particular

721
00:25:56,410 --> 00:25:53,480
case and also for the case even though

722
00:25:58,300 --> 00:25:56,420
it didn't produce as as thicken ozone

723
00:26:00,280 --> 00:25:58,310
layer as the earth it still managed to

724
00:26:02,830 --> 00:26:00,290
feel the surface of the planet pretty

725
00:26:04,510 --> 00:26:02,840
well so we discovered that you know

726
00:26:07,480 --> 00:26:04,520
earth is actually pretty robust to

727
00:26:09,700 --> 00:26:07,490
changes in the UV flux inspection with

728
00:26:11,380 --> 00:26:09,710
the parent star so there's this reason

729
00:26:13,990 --> 00:26:11,390
to hope that a box genic photosynthesis

730
00:26:16,060 --> 00:26:14,000
develops and you do have the oxygen no

731
00:26:18,760 --> 00:26:16,070
matter what spectral type it's your star

732
00:26:20,950 --> 00:26:18,770
is you can still have an ozone shield so

733
00:26:23,350 --> 00:26:20,960
we we then calculated we then cut the

734
00:26:24,460 --> 00:26:23,360
ozone by factors of 10 and calculated at

735
00:26:26,140 --> 00:26:24,470
which point we really wouldn't want to

736
00:26:27,610 --> 00:26:26,150
go out and go sunbathing and we

737
00:26:30,340 --> 00:26:27,620
discovered that the critical threshold

738
00:26:32,200 --> 00:26:30,350

for oxygen ride a UV planetary shield is

739
00:26:34,390 --> 00:26:32,210
probably about 1% of the current level

740
00:26:36,220 --> 00:26:34,400
we have in our atmosphere so even at one

741
00:26:38,050 --> 00:26:36,230
percent of the current level that's

742
00:26:41,380 --> 00:26:38,060
still moderately reasonable on the

743
00:26:43,240 --> 00:26:41,390
surface of the planet for UV flux we

744
00:26:44,890 --> 00:26:43,250
also looked at what happened to other

745
00:26:46,330 --> 00:26:44,900
bio signatures in the atmosphere when

746
00:26:49,270 --> 00:26:46,340
the planet went around a star of a

747
00:26:51,460 --> 00:26:49,280
different spectral type so we looked at

748
00:26:52,960 --> 00:26:51,470
three major biomarkers to you've

749
00:26:54,790 --> 00:26:52,970
probably heard of methane and nitrous

750
00:26:57,910 --> 00:26:54,800
oxide but the new one was methyl

751
00:27:00,610 --> 00:26:57,920
chloride which is in fact produced by

752
00:27:02,290 --> 00:27:00,620
biomass burning on our planet this also

753
00:27:04,350 --> 00:27:02,300
comes from the oceans and I think it's

754
00:27:06,670 --> 00:27:04,360
supposed to be part of algae or perhaps

755
00:27:08,530 --> 00:27:06,680
producing insulin but it's something

756
00:27:10,660 --> 00:27:08,540
that was in the climate chemical model

757
00:27:12,790 --> 00:27:10,670
which we had been taken out to model

758
00:27:14,110 --> 00:27:12,800
straight spectrally before and we just

759
00:27:15,970 --> 00:27:14,120
decided well what the heck you know even

760
00:27:17,380 --> 00:27:15,980
though it's not that detectable in the

761
00:27:18,760 --> 00:27:17,390
Earth's atmosphere who knows how

762
00:27:21,250 --> 00:27:18,770
detectable it might be on a planet

763
00:27:23,500 --> 00:27:21,260

around another star and so what we did

764
00:27:25,300 --> 00:27:23,510
what we're showing here is insert the

765
00:27:26,830 --> 00:27:25,310
mixing ratio of these different gases

766
00:27:28,330 --> 00:27:26,840
how much of these different gases are in

767
00:27:31,240 --> 00:27:28,340
the atmospheres of these planets and how

768
00:27:33,360 --> 00:27:31,250
they drop off with Alta tube and this

769
00:27:35,950 --> 00:27:33,370
drop off of course is probably due to UV

770
00:27:36,580 --> 00:27:35,960
fotosis and or chemical removal in the

771
00:27:39,519 --> 00:27:36,590
case

772
00:27:43,210 --> 00:27:39,529
in the upper atmosphere but what you see

773
00:27:45,010 --> 00:27:43,220
here is a very big dichotomy between you

774
00:27:48,669 --> 00:27:45,020
know the abundance of methane on stars

775
00:27:51,430 --> 00:27:48,679
around fgk on planets on FG k and then

776
00:27:53,560 --> 00:27:51,440
how much you get in the atmospheres of M

777
00:27:55,690 --> 00:27:53,570
star planners and in all cases these

778
00:27:57,460 --> 00:27:55,700
biomarkers tended to build up in the

779
00:28:00,010 --> 00:27:57,470
atmospheres of MCR planets because they

780
00:28:01,600 --> 00:28:00,020
had much longer lifetimes there so if

781
00:28:03,490 --> 00:28:01,610
you look at the lifetimes is certainly a

782
00:28:07,120 --> 00:28:03,500
transition when you go from the FD k

783
00:28:08,529 --> 00:28:07,130
through to the M stars dramatic

784
00:28:11,409 --> 00:28:08,539
increases in the lifetimes of some

785
00:28:13,230 --> 00:28:11,419
things but interestingly the methane and

786
00:28:16,710 --> 00:28:13,240
methyl chloride er actually scrubbed out

787
00:28:20,049 --> 00:28:16,720
by o-h production in the no sig let D

788
00:28:23,440 --> 00:28:20,059

which requires certain UV radiation to

789
00:28:25,480 --> 00:28:23,450
initiate that reaction and so they in

790
00:28:27,100 --> 00:28:25,490
fact have longer lifetimes relative to

791
00:28:29,620 --> 00:28:27,110
something like nitrous oxide which is

792
00:28:31,720 --> 00:28:29,630
just simply fertilized in the atmosphere

793
00:28:34,330 --> 00:28:31,730
so we found that in fact nitrous oxide

794
00:28:36,039 --> 00:28:34,340
didn't build up your quite as rapidly as

795
00:28:38,440 --> 00:28:36,049
we would have liked practic to between

796
00:28:41,470 --> 00:28:38,450
here and here instead of new a factor of

797
00:28:43,779 --> 00:28:41,480
a thousand for the methyl chloride and

798
00:28:46,570 --> 00:28:43,789
methane build-up so certainly for M star

799
00:28:49,060 --> 00:28:46,580
planets around planets around M stars

800
00:28:50,919 --> 00:28:49,070
you would tend to get we believe a

801
00:28:54,430 --> 00:28:50,929
buildup of these methylated compounds in

802
00:28:56,049 --> 00:28:54,440
the atmosphere so what we did then was

803
00:28:58,360 --> 00:28:56,059
model what the spectra of these planets

804
00:29:01,269 --> 00:28:58,370
would look like and the black line here

805
00:29:03,700 --> 00:29:01,279
is earth just for reference and the red

806
00:29:05,789 --> 00:29:03,710
line is the planet around a dealio so

807
00:29:08,880 --> 00:29:05,799
this is the active flaring M star and

808
00:29:11,049 --> 00:29:08,890
this is what we saw in the final

809
00:29:12,700 --> 00:29:11,059
atmosphere what we saw was greatly

810
00:29:14,560 --> 00:29:12,710
enhanced methane absorption which as

811
00:29:17,680 --> 00:29:14,570
I've just described in my expect because

812
00:29:19,690 --> 00:29:17,690
the mech own lifetime went up and we see

813
00:29:21,970 --> 00:29:19,700

because the game around an M star we

814
00:29:23,830 --> 00:29:21,980
don't have too much ozone in the upper

815
00:29:25,600 --> 00:29:23,840
atmosphere being produced so you're not

816
00:29:28,359 --> 00:29:25,610
seeing a hot stratosphere here like you

817
00:29:31,249 --> 00:29:28,369
would on the earth so that's also good

818
00:29:33,919 --> 00:29:31,259
but we also saw nitrous oxide detection

819
00:29:36,109 --> 00:29:33,929
beard this is methyl chloride here and

820
00:29:37,519 --> 00:29:36,119
here and a little bit over here but we

821
00:29:39,109 --> 00:29:37,529
were able to see that in the spectrum

822
00:29:40,369 --> 00:29:39,119
now she methyl chloride is very

823
00:29:42,649 --> 00:29:40,379
interesting when I first plotted its

824
00:29:44,239 --> 00:29:42,659
absorption spectrum it actually has a

825
00:29:47,840 --> 00:29:44,249
very strong absorption right here in the

826
00:29:49,279 --> 00:29:47,850
ozone as well same wavelength so it

827
00:29:52,159 --> 00:29:49,289
actually mimics a lot of our bio

828
00:29:57,940 --> 00:29:52,169
signatures in one molecule so it can be

829
00:30:00,379 --> 00:29:57,950
hard to pull out from from the others so

830
00:30:02,269 --> 00:30:00,389
what we also looked at is of course the

831
00:30:05,810 --> 00:30:02,279
FG k planetary spectra and how they

832
00:30:07,609 --> 00:30:05,820
change essentially what we were seeing

833
00:30:09,259 --> 00:30:07,619
here was again the change in the

834
00:30:10,820 --> 00:30:09,269
strength of the ozone layer and heating

835
00:30:12,859 --> 00:30:10,830
of the stratosphere was was present in

836
00:30:15,229 --> 00:30:12,869
the carbon dioxide and again you saw

837
00:30:17,450 --> 00:30:15,239
that in the euro zone itself the direct

838
00:30:18,529 --> 00:30:17,460

measure over in the visible the only

839
00:30:20,619 --> 00:30:18,539
thing that really changed in the

840
00:30:23,629 --> 00:30:20,629
spectrum was the ozone ship we bands

841
00:30:25,249 --> 00:30:23,639
between point five and point seven they

842
00:30:28,970 --> 00:30:25,259
changed his strength again depending on

843
00:30:30,499 --> 00:30:28,980
the ozone level in the atmosphere and

844
00:30:32,629 --> 00:30:30,509
here's just a blow-up of that showing

845
00:30:35,659 --> 00:30:32,639
exactly what was going on this was very

846
00:30:39,649 --> 00:30:35,669
intriguing it turned out that the the

847
00:30:41,330 --> 00:30:39,659
ozone absorption for the G&K stars was

848
00:30:42,919 --> 00:30:41,340
almost the same level of detectability

849
00:30:45,379 --> 00:30:42,929
even though the case Tara had far less

850
00:30:47,659 --> 00:30:45,389
ozone in its atmosphere and this week

851
00:30:49,849 --> 00:30:47,669
was because the cupboard had far less

852
00:30:52,460 --> 00:30:49,859
ozone and strong sphere wasn't as hot

853
00:30:53,899 --> 00:30:52,470
and so the coolest stratosphere relative

854
00:30:55,580 --> 00:30:53,909
to the surface of the planet meant that

855
00:30:57,470 --> 00:30:55,590
we got more absorption more bang for the

856
00:30:59,450 --> 00:30:57,480
buck an absorption for a smaller amount

857
00:31:02,419 --> 00:30:59,460
of material because of that temperature

858
00:31:04,220 --> 00:31:02,429
difference conversely for the estar we

859
00:31:06,349 --> 00:31:04,230
had loads of ozone in the atmosphere but

860
00:31:07,580 --> 00:31:06,359
that heated up the stratosphere and so

861
00:31:09,109 --> 00:31:07,590
we didn't get as much of a temperature

862
00:31:11,690 --> 00:31:09,119
differential with the surface and so

863
00:31:13,999 --> 00:31:11,700

that absorption was in fact less so so

864
00:31:15,619 --> 00:31:14,009
the point I want to make here is greater

865
00:31:16,729 --> 00:31:15,629
than any of you know the strength of

866
00:31:18,289 --> 00:31:16,739
your absorption feature and how

867
00:31:20,479 --> 00:31:18,299
detectable it would be to a telescope

868
00:31:22,639 --> 00:31:20,489
depends not only on the amount of

869
00:31:24,259 --> 00:31:22,649
material you have but on the temperature

870
00:31:26,029 --> 00:31:24,269
structure that material is embedded in

871
00:31:27,619 --> 00:31:26,039
that's really important when we're

872
00:31:30,169 --> 00:31:27,629
trying to pull out the characteristics

873
00:31:32,450 --> 00:31:30,179
of these planets and then the methane we

874
00:31:33,950 --> 00:31:32,460
saw predictably on the later type star

875
00:31:35,840 --> 00:31:33,960
the case they are not as much methane

876
00:31:37,330 --> 00:31:35,850
described destruction and so a stronger

877
00:31:40,490 --> 00:31:37,340
mapping feature

878
00:31:42,110 --> 00:31:40,500
so here and this is a bit much to get

879
00:31:45,770 --> 00:31:42,120
into but i'll try and we have the

880
00:31:48,680 --> 00:31:45,780
salient points that this was what

881
00:31:50,299 --> 00:31:48,690
happens when we took the oxygen in the

882
00:31:51,590 --> 00:31:50,309
atmosphere from present atmospheric

883
00:31:53,299 --> 00:31:51,600
level which is what we currently have on

884
00:31:55,400 --> 00:31:53,309
the earth and brought it down by factors

885
00:31:57,650 --> 00:31:55,410
of 10 successively we then looked at the

886
00:32:00,110 --> 00:31:57,660
detectability of oxygen and ozone when

887
00:32:02,900 --> 00:32:00,120
we did that on the planet so for planets

888
00:32:04,490 --> 00:32:02,910

around F G and K stars with different

889
00:32:07,280 --> 00:32:04,500
oxygen abundances and their atmospheres

890
00:32:10,370 --> 00:32:07,290
what we saw again was the GPS nails are

891
00:32:12,590 --> 00:32:10,380
pretty similar the f star for the ozone

892
00:32:14,780 --> 00:32:12,600
was pathological because of this release

893
00:32:16,580 --> 00:32:14,790
super hot stratosphere and so what we

894
00:32:18,080 --> 00:32:16,590
found there was in fact if you had the

895
00:32:20,270 --> 00:32:18,090
current level of oxygen in our

896
00:32:22,430 --> 00:32:20,280
atmosphere the ozone was less detectable

897
00:32:24,260 --> 00:32:22,440
than if you had only one percent of the

898
00:32:25,700 --> 00:32:24,270
current oxygen in our atmosphere that

899
00:32:26,870 --> 00:32:25,710
was actually the sweet spot at one

900
00:32:29,360 --> 00:32:26,880
percent of the current level of oxygen

901
00:32:30,500 --> 00:32:29,370
and the UV of the f star that was the

902
00:32:33,500 --> 00:32:30,510
point in which we got the strongest

903
00:32:35,720 --> 00:32:33,510
detection of ozone swamis Legion after

904
00:32:37,340 --> 00:32:35,730
oxygen there look identical right across

905
00:32:38,960 --> 00:32:37,350
the board so the spectrum of the parent

906
00:32:43,310 --> 00:32:38,970
star didn't really change her ability to

907
00:32:45,860 --> 00:32:43,320
detect the oxygen at all and essentially

908
00:32:48,140 --> 00:32:45,870
we were sensitive down to about one part

909
00:32:49,970 --> 00:32:48,150
in 10 to the minus 3 here for these

910
00:32:52,130 --> 00:32:49,980
types being able to take something below

911
00:32:54,640 --> 00:32:52,140
that really very difficult to the state

912
00:32:56,960 --> 00:32:54,650
but down here probably only one part and

913
00:32:58,520 --> 00:32:56,970

10 to the minus 2 1 percent of the

914
00:33:00,919 --> 00:32:58,530
current oxygen level is going to be

915
00:33:03,890 --> 00:33:00,929
something we battle for and even that it

916
00:33:07,490 --> 00:33:03,900
would be quite hard to detect so for the

917
00:33:08,570 --> 00:33:07,500
active mstar planets we also looked at

918
00:33:12,230 --> 00:33:08,580
the difference in the spectrum between

919
00:33:14,330 --> 00:33:12,240
Earth which is the black line and a PPO

920
00:33:16,549 --> 00:33:14,340
which is the red line here this is the

921
00:33:18,080 --> 00:33:16,559
active n star the main difference we saw

922
00:33:21,830 --> 00:33:18,090
was in the methane the methane buildup

923
00:33:23,750 --> 00:33:21,840
in the atmosphere around the M star and

924
00:33:25,430 --> 00:33:23,760
there for some reason I have this methyl

925
00:33:27,080 --> 00:33:25,440
chloride slide out of sequence apologize

926
00:33:30,440 --> 00:33:27,090
for that so again the one you've already

927
00:33:32,600 --> 00:33:30,450
just seen of the features are in the mid

928
00:33:33,120 --> 00:33:32,610
infrared with that methyl chloride in

929
00:33:36,570 --> 00:33:33,130
here

930
00:33:39,810 --> 00:33:36,580
very strong feature from methyl chloride

931
00:33:41,010 --> 00:33:39,820
right there and so here is a plot

932
00:33:43,860 --> 00:33:41,020
showing you where methyl chloride

933
00:33:45,660 --> 00:33:43,870
absorbs what I've done is we modeled a

934
00:33:46,590 --> 00:33:45,670
dealio without the methyl chloride so

935
00:33:48,360 --> 00:33:46,600
that's what it's affection would have

936
00:33:50,250 --> 00:33:48,370
looked like a blue one and then we

937
00:33:52,170 --> 00:33:50,260
modeled it Oh with the methyl chloride

938
00:33:55,470 --> 00:33:52,180

that's the red one and you can see the

939
00:33:57,180 --> 00:33:55,480
regions in which it absorbs so that's a

940
00:33:58,410 --> 00:33:57,190
potential new biomarker to look for

941
00:34:02,370 --> 00:33:58,420
which have not previously been

942
00:34:04,110 --> 00:34:02,380
considered and then finally again back

943
00:34:05,700 --> 00:34:04,120
to reality these are the type of

944
00:34:08,129 --> 00:34:05,710
resolutions we might expect from the

945
00:34:10,260 --> 00:34:08,139
first generation of TPF I which is the

946
00:34:12,000 --> 00:34:10,270
interferometer in the mid infrared so

947
00:34:13,020 --> 00:34:12,010
resolution about 20 across that

948
00:34:15,540 --> 00:34:13,030
wavelength range I've just been showing

949
00:34:17,340 --> 00:34:15,550
you nonetheless it's tough but

950
00:34:19,169 --> 00:34:17,350
nonetheless we still might be able to

951
00:34:22,050 --> 00:34:19,179
pick up the ozone even if anyone picks

952
00:34:24,149 --> 00:34:22,060
up here um and we can also look if we

953
00:34:25,710 --> 00:34:24,159
get good enough signal to noise to look

954
00:34:28,560 --> 00:34:25,720
for that central peak that would

955
00:34:31,290 --> 00:34:28,570
indicate an ozone or UV absorber of some

956
00:34:33,180 --> 00:34:31,300
kind in the co2 band so it's gonna be

957
00:34:37,320 --> 00:34:33,190
tough but you know those things may well

958
00:34:40,530 --> 00:34:37,330
be observable if we if we integrate

959
00:34:42,840 --> 00:34:40,540
flung enough so moving on to this face

960
00:34:48,629 --> 00:34:42,850
my fear too early earth-like planets how

961
00:34:50,550 --> 00:34:48,639
am i going for time woody Tom I mean we

962
00:34:53,520 --> 00:34:50,560
started late so 15 were later 15 more

963
00:34:57,930 --> 00:34:53,530

minutes okay so what we did here was in

964
00:35:02,430 --> 00:34:57,940
fact a model a high co2 early Earth's up

965
00:35:05,640 --> 00:35:02,440
to three bars atmospheres using solar

966
00:35:07,530 --> 00:35:05,650
analog spectrum ek draw is a g star like

967
00:35:10,320 --> 00:35:07,540
the Sun but in a very early stage of its

968
00:35:11,700 --> 00:35:10,330
evolution it has a lot of UV so what we

969
00:35:14,640 --> 00:35:11,710
were trying to do was test the

970
00:35:16,470 --> 00:35:14,650
hypothesis that you could in fact from a

971
00:35:18,990 --> 00:35:16,480
co2 rich atmosphere produce a lot of

972
00:35:20,340 --> 00:35:19,000
oxygen within the habitable zone and

973
00:35:21,840 --> 00:35:20,350
that this would be a false positive for

974
00:35:23,250 --> 00:35:21,850
life it would be a way of producing lots

975
00:35:26,070 --> 00:35:23,260
of oxygen that had nothing to do with

976
00:35:28,650 --> 00:35:26,080
life however Jim Cassidy noticed that

977
00:35:29,910 --> 00:35:28,660
when this hypothesis first came out that

978
00:35:31,800 --> 00:35:29,920
the model was used didn't actually

979
00:35:34,350 --> 00:35:31,810
include rain out of oxidized species

980
00:35:37,230 --> 00:35:34,360
which would affect the hydrogen budget

981
00:35:38,820 --> 00:35:37,240
within the planet environment so we went

982
00:35:40,470 --> 00:35:38,830
back and we modified our climate model

983
00:35:42,090 --> 00:35:40,480
or in fact I think he already had it in

984
00:35:43,560 --> 00:35:42,100
there to include the rain out of the

985
00:35:44,950 --> 00:35:43,570
oxidized species and we ran these

986
00:35:48,140 --> 00:35:44,960
experiments again

987
00:35:51,830 --> 00:35:48,150
and so we modeled planets with varying

988
00:35:54,770 --> 00:35:51,840

amounts of o2 very amounts of co2 in

989
00:35:58,190 --> 00:35:54,780
their atmosphere and also early earth

990
00:36:00,620 --> 00:35:58,200
like methane fluxes and around this this

991
00:36:03,740 --> 00:36:00,630
early start so unfortunately this is the

992
00:36:05,060 --> 00:36:03,750
slide I don't think time steps yeah so

993
00:36:07,250 --> 00:36:05,070
they would have been effective under

994
00:36:08,720 --> 00:36:07,260
here I have shown you but I'll just talk

995
00:36:12,580 --> 00:36:08,730
a little bit about this minute red one

996
00:36:16,160 --> 00:36:12,590
here what we saw was that predictably

997
00:36:18,890 --> 00:36:16,170
for the higher co2 fraction planets we

998
00:36:19,970 --> 00:36:18,900
saw very strong absorption from co2 in

999
00:36:21,710 --> 00:36:19,980
the middle read that you wouldn't

1000
00:36:24,560 --> 00:36:21,720
normally see for example in present-day

1001
00:36:26,390 --> 00:36:24,570
earth and leaves these are from hot

1002
00:36:27,650 --> 00:36:26,400
bands and isotopic bands and that was

1003
00:36:29,780 --> 00:36:27,660
also very interesting these were very

1004
00:36:32,270 --> 00:36:29,790
strong signals from either topic bansal

1005
00:36:35,780 --> 00:36:32,280
co2 where the oxygen was actually

1006
00:36:37,220 --> 00:36:35,790
changing its isotope value and so

1007
00:36:39,050 --> 00:36:37,230
potentially this is a way of even

1008
00:36:41,810 --> 00:36:39,060
getting a handle on oxygen isotope

1009
00:36:44,690 --> 00:36:41,820
ratios in the in the atmosphere of the

1010
00:36:46,670 --> 00:36:44,700
stars so the bottom line of all of this

1011
00:36:47,900 --> 00:36:46,680
is we we threw everything we could at

1012
00:36:49,870 --> 00:36:47,910
this planet we gave it every single

1013
00:36:53,810 --> 00:36:49,880

possible chance to create oxygen for us

1014
00:36:56,840 --> 00:36:53,820
we switched off volcanism we we gave it

1015
00:36:59,060 --> 00:36:56,850
a very high UV star we put loads of co2

1016
00:37:00,710 --> 00:36:59,070
in there but with that rain out of

1017
00:37:02,000 --> 00:37:00,720
oxidized species in there there was no

1018
00:37:03,950 --> 00:37:02,010
way we can actually generate a

1019
00:37:06,320 --> 00:37:03,960
reasonable amount of o2 from this model

1020
00:37:08,570 --> 00:37:06,330
so here's the oxygen a van for prison

1021
00:37:10,190 --> 00:37:08,580
earth and here's the oxygen a band for

1022
00:37:12,410 --> 00:37:10,200
every single thing we models so you can

1023
00:37:15,770 --> 00:37:12,420
see that we really couldn't generate any

1024
00:37:17,450 --> 00:37:15,780
detectable signature whatsoever so we're

1025
00:37:19,640 --> 00:37:17,460
kind of a little kick in here in the

1026
00:37:21,650 --> 00:37:19,650
tuber case but nothing nothing

1027
00:37:23,870 --> 00:37:21,660
significant so we could never generate

1028
00:37:26,390 --> 00:37:23,880
anything more than one part in 10 to the

1029
00:37:30,920 --> 00:37:26,400
five of oxygen and the column depth or

1030
00:37:32,300 --> 00:37:30,930
one point and before in the ozone so the

1031
00:37:33,470 --> 00:37:32,310
conclusion the overall conclusion is

1032
00:37:35,480 --> 00:37:33,480
that for planets in the habitable zone

1033
00:37:37,460 --> 00:37:35,490
with an active hydrological cycle is

1034
00:37:40,820 --> 00:37:37,470
probably unlikely we will build up this

1035
00:37:42,230 --> 00:37:40,830
kind of abiotic oxygen and so here's

1036
00:37:43,340 --> 00:37:42,240
sort of like inspection they got

1037
00:37:46,190 --> 00:37:43,350
occluded that I couldn't share

1038
00:37:48,320 --> 00:37:46,200

this is this is the results for planets

1039
00:37:51,520 --> 00:37:48,330
with different amounts of co2 in the

1040
00:37:54,140 --> 00:37:51,530
atmosphere and you notice the the actual

1041
00:37:56,600 --> 00:37:54,150
huge increase in in rayleigh scattering

1042
00:37:58,310 --> 00:37:56,610
for our to barb planet even that's two

1043
00:38:00,170 --> 00:37:58,320
bars of co2 it's actually a totally

1044
00:38:03,170 --> 00:38:00,180
three bar planet because it has almost a

1045
00:38:04,520 --> 00:38:03,180
bar of nitrogen in it as well and so

1046
00:38:07,190 --> 00:38:04,530
this was this was our sort of exotic

1047
00:38:09,620 --> 00:38:07,200
tree bark plant and we see this very

1048
00:38:11,600 --> 00:38:09,630
high Rayleigh scattering you note but at

1049
00:38:13,460 --> 00:38:11,610
point seven six you do not see the

1050
00:38:16,010 --> 00:38:13,470
oxygen a band here we don't see that

1051
00:38:18,200 --> 00:38:16,020
what we do see is lots of signatures

1052
00:38:20,480 --> 00:38:18,210
from the outside as we go into the near

1053
00:38:22,700 --> 00:38:20,490
infrared end of the spectrum in

1054
00:38:25,130 --> 00:38:22,710
particular this one here which I fought

1055
00:38:27,770 --> 00:38:25,140
to get on TPF for a long time are the

1056
00:38:29,600 --> 00:38:27,780
one point 05 micron co2 band which we

1057
00:38:32,930 --> 00:38:29,610
also saw in Venus even at low resolution

1058
00:38:34,910 --> 00:38:32,940
that would be a nice indicator if you

1059
00:38:36,980 --> 00:38:34,920
were to see even if you were to see a

1060
00:38:38,990 --> 00:38:36,990
false positive of oxygen this is fairly

1061
00:38:40,190 --> 00:38:39,000
strong for high co2 atmosphere so you

1062
00:38:43,040 --> 00:38:40,200
might be able to pick that out and know

1063
00:38:44,840 --> 00:38:43,050

that you were being being fooled but but

1064
00:38:47,450 --> 00:38:44,850
in these regions here very strong and

1065
00:38:48,590 --> 00:38:47,460
methane and carbon dioxide and almost to

1066
00:38:50,510 --> 00:38:48,600
the point where you don't even have an

1067
00:38:54,680 --> 00:38:50,520
atmosphere window over large fractions

1068
00:39:00,089 --> 00:38:54,690
of this range of the spectrum so was

1069
00:39:04,420 --> 00:39:02,199
this is the planet in the mid-infrared

1070
00:39:06,429 --> 00:39:04,430
red earth which you should recognize by

1071
00:39:08,319 --> 00:39:06,439
now and then the black spectrum is the

1072
00:39:11,469 --> 00:39:08,329
spectrum of this this three bar to bar

1073
00:39:13,959 --> 00:39:11,479
co2 atmosphere and again we've seen the

1074
00:39:17,109 --> 00:39:13,969
strong bands of isotopes of carbon

1075
00:39:18,939 --> 00:39:17,119
dioxide in it and here this is the only

1076
00:39:20,439 --> 00:39:18,949
atmospheric window we have left where we

1077
00:39:21,670 --> 00:39:20,449
can get deep into the atmosphere and try

1078
00:39:24,309 --> 00:39:21,680
to determine the temperature of the

1079
00:39:25,870 --> 00:39:24,319
planet so on the earth we consider the

1080
00:39:27,880 --> 00:39:25,880
attic window to the right across here

1081
00:39:30,279 --> 00:39:27,890
from eight to thirteen microns but on a

1082
00:39:34,599 --> 00:39:30,289
CO 2 planets narrowed to a tiny tiny

1083
00:39:36,670 --> 00:39:34,609
little range around about 29 microns but

1084
00:39:38,380 --> 00:39:36,680
you note the perviness even though it

1085
00:39:41,349 --> 00:39:38,390
has very similar features as venus is

1086
00:39:42,670 --> 00:39:41,359
also a high co2 atmosphere the depth of

1087
00:39:44,349 --> 00:39:42,680
these features is nowhere near as strong

1088
00:39:46,209 --> 00:39:44,359

and that's again because we're truncated

1089
00:39:47,679 --> 00:39:46,219
by the cloud deck on Venus I can't get

1090
00:39:50,679 --> 00:39:47,689
down to see the full ninety three bars

1091
00:39:54,099 --> 00:39:50,689
of atmosphere there so brightness

1092
00:39:56,410 --> 00:39:54,109
temperatures for these again this is

1093
00:39:58,779 --> 00:39:56,420
interesting because this planet had

1094
00:40:00,219 --> 00:39:58,789
about a 317 Kelvin surface temperature

1095
00:40:02,349 --> 00:40:00,229
but you'll note that the inferred

1096
00:40:04,419 --> 00:40:02,359
brightness temperature is only about 288

1097
00:40:06,339 --> 00:40:04,429
so we really are not seeing to the

1098
00:40:08,559 --> 00:40:06,349
surface of the planet because the co2

1099
00:40:10,059 --> 00:40:08,569
atmosphere is so dense so this is one of

1100
00:40:11,829 --> 00:40:10,069
these warnings I like to put out that

1101
00:40:13,059 --> 00:40:11,839
just because you have an estate window

1102
00:40:16,449 --> 00:40:13,069
doesn't mean you got all the way to the

1103
00:40:17,620 --> 00:40:16,459
surface and sensing the atmosphere so I

1104
00:40:19,029 --> 00:40:17,630
will skip through these because it's

1105
00:40:21,789 --> 00:40:19,039
just a summary of what we've said

1106
00:40:23,380 --> 00:40:21,799
overall and move on to the final face

1107
00:40:25,150 --> 00:40:23,390
with which is the coevolution of

1108
00:40:27,009 --> 00:40:25,160
photosynthesis with the atmospheres of

1109
00:40:29,859 --> 00:40:27,019
extrasolar worlds and this is work this

1110
00:40:32,019 --> 00:40:29,869
make led by Nancy keying for the vpl and

1111
00:40:33,699 --> 00:40:32,029
it's actually involved a lot of our our

1112
00:40:37,329 --> 00:40:33,709
younger scientists here so this is this

1113
00:40:39,130 --> 00:40:37,339

is really great um great work and what

1114
00:40:40,449 --> 00:40:39,140
we're doing here is that before we were

1115
00:40:42,910 --> 00:40:40,459
we're modeling planet so that we could

1116
00:40:44,410 --> 00:40:42,920
look at them from above as an astronomer

1117
00:40:46,719 --> 00:40:44,420
and trying to tell what the planet was

1118
00:40:49,509 --> 00:40:46,729
like here we're looking at them from the

1119
00:40:52,179 --> 00:40:49,519
vegetation the Leafs I view and we're

1120
00:40:53,650 --> 00:40:52,189
looking up at our our star of a

1121
00:40:55,089 --> 00:40:53,660
different spectral type and we're

1122
00:40:56,679 --> 00:40:55,099
looking at how much of that radiation

1123
00:40:59,049 --> 00:40:56,689
makes it through atmospheres of

1124
00:41:00,599 --> 00:40:59,059
different compositions so if you take a

1125
00:41:02,829 --> 00:41:00,609
planet you put it around another star

1126
00:41:04,449 --> 00:41:02,839
what does the leaf see what does the

1127
00:41:06,249 --> 00:41:04,459
microbe see at the surface of the planet

1128
00:41:07,779 --> 00:41:06,259
and what does that tell you about where

1129
00:41:09,460 --> 00:41:07,789
it's likely to choose to put its

1130
00:41:11,510 --> 00:41:09,470
pigments for photosynthesis

1131
00:41:13,640 --> 00:41:11,520
so we use planetary atmosphere

1132
00:41:16,039 --> 00:41:13,650
compositions and a stellar spectra for

1133
00:41:18,079 --> 00:41:16,049
earth-like planets so those with the one

1134
00:41:20,390 --> 00:41:18,089
x of the present amp straight level of

1135
00:41:22,220 --> 00:41:20,400
oxygen and also for near anoxic planners

1136
00:41:23,539 --> 00:41:22,230
that only had one part in 10 to the 5 of

1137
00:41:25,789 --> 00:41:23,549
the current level of oxygen and their

1138
00:41:27,440 --> 00:41:25,799

atmospheres now we put them around FG k

1139
00:41:29,210 --> 00:41:27,450
and m stars so these are the spectra

1140
00:41:31,099 --> 00:41:29,220
I've just shown you which we use for a

1141
00:41:32,690 --> 00:41:31,109
different purpose when we run the

1142
00:41:34,280 --> 00:41:32,700
radiative transfer model we generate the

1143
00:41:36,289 --> 00:41:34,290
spectrum of the top and the spiracles

1144
00:41:38,690 --> 00:41:36,299
service so we just took that

1145
00:41:41,089 --> 00:41:38,700
product and that's what we use so we

1146
00:41:43,339 --> 00:41:41,099
derived the incident spectral photon

1147
00:41:44,809 --> 00:41:43,349
flux densities that's important not the

1148
00:41:46,700 --> 00:41:44,819
radiance but the actual number of

1149
00:41:48,020 --> 00:41:46,710
photons that are coming in because

1150
00:41:50,839 --> 00:41:48,030
that's what plants care about

1151
00:41:53,450 --> 00:41:50,849
photosynthesis is a photon numerical

1152
00:41:55,039 --> 00:41:53,460
process and so that's what we had a look

1153
00:41:57,589 --> 00:41:55,049
at we did that for planetary services

1154
00:41:59,599 --> 00:41:57,599
and underwater as well we identified for

1155
00:42:01,250 --> 00:41:59,609
a synthetically relevant radiation and

1156
00:42:03,319 --> 00:42:01,260
looked at the likely pigment peak

1157
00:42:05,000 --> 00:42:03,329
adsorbents and also made an attempt to

1158
00:42:07,160 --> 00:42:05,010
calculate planetary productivity and

1159
00:42:08,839 --> 00:42:07,170
that is going to be published in the m

1160
00:42:10,490 --> 00:42:08,849
star special edition of astrobiology

1161
00:42:11,900 --> 00:42:10,500
which is coming out in March and that

1162
00:42:13,520 --> 00:42:11,910
should be a really great addition by the

1163
00:42:17,030 --> 00:42:13,530

way it's got lots of really good papers

1164
00:42:20,180 --> 00:42:17,040
in it so here um does it for me have a

1165
00:42:22,130 --> 00:42:20,190
look at me this has the spectrum that's

1166
00:42:24,440 --> 00:42:22,140
insulin at the top of our atmosphere on

1167
00:42:26,210 --> 00:42:24,450
the Sun this is the average spectrum

1168
00:42:28,370 --> 00:42:26,220
that in fact makes its way through the

1169
00:42:31,940 --> 00:42:28,380
atmosphere and what we noticed is that

1170
00:42:34,220 --> 00:42:31,950
right ozone takes to absorb out here and

1171
00:42:36,770 --> 00:42:34,230
we'll the actual peak of the

1172
00:42:38,450 --> 00:42:36,780
radiation from what is he could incident

1173
00:42:39,980 --> 00:42:38,460
at the top of the atmosphere to what is

1174
00:42:43,549 --> 00:42:39,990
peak at the surface of the atmosphere

1175
00:42:45,829 --> 00:42:43,559
actually shifts towards the red and so

1176
00:42:47,780 --> 00:42:45,839
what Nancy did was was put together a

1177
00:42:50,809 --> 00:42:47,790
series of rules Nancy and collaborators

1178
00:42:52,880 --> 00:42:50,819
of where we might expect pigments for

1179
00:42:54,829 --> 00:42:52,890
photosynthesis to curve and the first

1180
00:42:56,329 --> 00:42:54,839
characteristic you look for is the

1181
00:43:00,200 --> 00:42:56,339
wavelength of peak incident photon flux

1182
00:43:01,400 --> 00:43:00,210
at the surface okay so so again we found

1183
00:43:04,460 --> 00:43:01,410
that the atmosphere actually multiply

1184
00:43:05,450 --> 00:43:04,470
that intended to shift it we also say

1185
00:43:07,150 --> 00:43:05,460
that you should look for the longest

1186
00:43:10,010 --> 00:43:07,160
wavelengths within the radiation window

1187
00:43:13,039 --> 00:43:10,020
also for these core antenna or or

1188
00:43:15,200 --> 00:43:13,049

pigments that are satellite pigments

1189
00:43:16,460 --> 00:43:15,210
that are used and these longest

1190
00:43:18,770 --> 00:43:16,470
wavelength is so that you can capture

1191
00:43:20,150 --> 00:43:18,780
the the photon fairly easily the

1192
00:43:21,319 --> 00:43:20,160
shortest wavelength is

1193
00:43:23,329 --> 00:43:21,329
there because it's high energy and

1194
00:43:25,430 --> 00:43:23,339
therefore valuable when you calf get it

1195
00:43:26,750 --> 00:43:25,440
down to the photon Center so there's the

1196
00:43:28,190 --> 00:43:26,760
peak because there's lots of stuff there

1197
00:43:29,960 --> 00:43:28,200
and then you also have accessory

1198
00:43:32,930 --> 00:43:29,970
pigments on either side satellites

1199
00:43:34,970 --> 00:43:32,940
essentially that also funnel photons

1200
00:43:38,120 --> 00:43:34,980
into this process to help actually do

1201
00:43:39,349 --> 00:43:38,130
photosynthesis so what we found then was

1202
00:43:41,180 --> 00:43:39,359
that says the ozone ship rebound

1203
00:43:42,789 --> 00:43:41,190
strongly affected the pig surface

1204
00:43:44,720 --> 00:43:42,799
radiation has shifted it over this way

1205
00:43:47,390 --> 00:43:44,730
that's actually pretty much where

1206
00:43:50,089 --> 00:43:47,400
chlorophyll-a operates at least on the

1207
00:43:51,799 --> 00:43:50,099
red end and Nancy and collaborators have

1208
00:43:54,109 --> 00:43:51,809
postulated that that made fun fact be

1209
00:43:55,609 --> 00:43:54,119
why plants are green they're smart they

1210
00:43:57,319 --> 00:43:55,619
actually know where the peak photon flux

1211
00:44:00,309 --> 00:43:57,329
is and they've gone over there to do

1212
00:44:02,450 --> 00:44:00,319
their photosynthesis towards the red

1213
00:44:04,069 --> 00:44:02,460

what we also looked at with surface

1214
00:44:06,579 --> 00:44:04,079
incident flux versus the atmospheric

1215
00:44:09,319 --> 00:44:06,589
composition see how it changed again

1216
00:44:11,210 --> 00:44:09,329
ozone was affecting the spectrum what

1217
00:44:13,309 --> 00:44:11,220
was reaching surface so here we kind of

1218
00:44:16,430 --> 00:44:13,319
had the average are incident and then

1219
00:44:18,020 --> 00:44:16,440
the average on the surface and again

1220
00:44:19,849 --> 00:44:18,030
there's a chick eating out of here in

1221
00:44:21,770 --> 00:44:19,859
the f star spectrum from the ozone very

1222
00:44:23,720 --> 00:44:21,780
strong ozone absorption and what that

1223
00:44:26,269 --> 00:44:23,730
did was actually ship keep photon flux

1224
00:44:28,460 --> 00:44:26,279
to the blue for the X star so depending

1225
00:44:29,809 --> 00:44:28,470
on where the ozone fell relative to the

1226
00:44:31,250 --> 00:44:29,819
stellar spectrum radiation it would

1227
00:44:33,170 --> 00:44:31,260
actually shift it over to the blue or

1228
00:44:35,240 --> 00:44:33,180
over to the red so in the X da case it

1229
00:44:36,890 --> 00:44:35,250
shifted it to the blue every other

1230
00:44:39,200 --> 00:44:36,900
planet is shipped a bit more towards the

1231
00:44:41,359 --> 00:44:39,210
red and at a case of the M star planets

1232
00:44:43,549 --> 00:44:41,369
they had so much absorption from species

1233
00:44:45,890 --> 00:44:43,559
their atmospheres including water and

1234
00:44:47,930 --> 00:44:45,900
methane that there were very quantized

1235
00:44:50,599 --> 00:44:47,940
windows available for the pigments to

1236
00:44:53,510 --> 00:44:50,609
work in and other areas where almost no

1237
00:44:55,400 --> 00:44:53,520
radiation go to the surface so this is a

1238
00:44:59,000 --> 00:44:55,410

little bit scary but what it's showing

1239
00:45:01,010 --> 00:44:59,010
overall is the peak surface photon flux

1240
00:45:03,079 --> 00:45:01,020
for Earth's around strands of different

1241
00:45:05,180 --> 00:45:03,089
spectral type and here we see that peak

1242
00:45:06,980 --> 00:45:05,190
photon flux the f star push over here to

1243
00:45:09,980 --> 00:45:06,990
the blue but for everything else the

1244
00:45:11,359 --> 00:45:09,990
peak photon flux is either in the red or

1245
00:45:14,440 --> 00:45:11,369
it's like even move over into the

1246
00:45:17,870 --> 00:45:14,450
infrared for some of the m star planets

1247
00:45:19,190 --> 00:45:17,880
the other thing we looked at is what you

1248
00:45:21,230 --> 00:45:19,200
would see if you are an organism

1249
00:45:23,030 --> 00:45:21,240
underwater on one of these planets

1250
00:45:24,980 --> 00:45:23,040
the main conclusion is that you probably

1251
00:45:26,570 --> 00:45:24,990
don't want to be operating doing your

1252
00:45:28,130 --> 00:45:26,580
photon catching anywhere longer with one

1253
00:45:30,380 --> 00:45:28,140
point one micron in these particular

1254
00:45:32,240 --> 00:45:30,390
cases but it also gave us an idea of

1255
00:45:34,040 --> 00:45:32,250
where the pigments might be especially

1256
00:45:35,930 --> 00:45:34,050
the M star planets if we could

1257
00:45:38,359 --> 00:45:35,940
potentially push them over to infrared

1258
00:45:45,530 --> 00:45:38,369
radiation infrared regions and that

1259
00:45:46,880 --> 00:45:45,540
would be particularly valuable ya know

1260
00:45:48,260 --> 00:45:46,890
we did we did also look at different

1261
00:45:50,330 --> 00:45:48,270
water depths I don't have the plots but

1262
00:45:52,690 --> 00:45:50,340
doing that them in the paper yeah so we

1263
00:45:55,760 --> 00:45:52,700

went down and in fact I'll show you um

1264
00:45:58,520 --> 00:45:55,770
safety levels in a minute okay for the

1265
00:45:59,960 --> 00:45:58,530
different ones and here we go so am i if

1266
00:46:02,660 --> 00:45:59,970
the water'd that's worth their safety

1267
00:46:04,970 --> 00:46:02,670
and what we did here was for the MCR

1268
00:46:06,950 --> 00:46:04,980
planets there around a star that's

1269
00:46:09,440 --> 00:46:06,960
potentially active and flaring so the

1270
00:46:11,000 --> 00:46:09,450
question is is it possible to evolve and

1271
00:46:12,680 --> 00:46:11,010
find a level within water where you're

1272
00:46:14,660 --> 00:46:12,690
safe from flaring even the worst of the

1273
00:46:17,300 --> 00:46:14,670
flaring but still have enough photons to

1274
00:46:19,400 --> 00:46:17,310
be able to do photosynthesis and what we

1275
00:46:21,560 --> 00:46:19,410
found was that essentially as long as

1276
00:46:24,290 --> 00:46:21,570
the flares don't exceed this energy here

1277
00:46:26,210 --> 00:46:24,300
just I think kind of mid-range this is

1278
00:46:28,190 --> 00:46:26,220
the extreme for a treo I believe the

1279
00:46:29,810 --> 00:46:28,200
extreme that's been seen but as long as

1280
00:46:31,849 --> 00:46:29,820
you don't exceed this range of flare

1281
00:46:33,140 --> 00:46:31,859
then you can survive okay on the surface

1282
00:46:34,640 --> 00:46:33,150
of an M star planet even in the

1283
00:46:36,980 --> 00:46:34,650
habitable zone you don't need water to

1284
00:46:38,630 --> 00:46:36,990
protect you beyond this energy you do

1285
00:46:40,520 --> 00:46:38,640
need water and this is the depth of

1286
00:46:43,400 --> 00:46:40,530
water that you need so the bottom line

1287
00:46:44,660 --> 00:46:43,410
was that it is long as you a 9.1 meters

1288
00:46:46,220 --> 00:46:44,670

under water and I'm sure that point one

1289
00:46:48,140 --> 00:46:46,230
is really important but if you remember

1290
00:46:49,580 --> 00:46:48,150
when leaders have ordered you would

1291
00:46:53,060 --> 00:46:49,590
still escape the worst of the flare

1292
00:46:55,400 --> 00:46:53,070
energy from an M star and still have

1293
00:46:57,710 --> 00:46:55,410
enough photons in facts to support

1294
00:46:59,599 --> 00:46:57,720
something like red algae by more than a

1295
00:47:01,070 --> 00:46:59,609
factor of 10 so that was really

1296
00:47:03,230 --> 00:47:01,080
interesting you could actually find a

1297
00:47:06,080 --> 00:47:03,240
safe zone but still be able to to make

1298
00:47:07,130 --> 00:47:06,090
your food and so that's the end of the

1299
00:47:09,920 --> 00:47:07,140
talk here and these are our major

1300
00:47:11,210 --> 00:47:09,930
conclusions planetary environmental

1301
00:47:13,010 --> 00:47:11,220
modeling has shown us that you know

1302
00:47:14,420 --> 00:47:13,020
different planetary compositions and

1303
00:47:16,820 --> 00:47:14,430
environmental characteristics can be

1304
00:47:19,880 --> 00:47:16,830
determined from discovery spectra larger

1305
00:47:21,590 --> 00:47:19,890
waveland coverage always are useful and

1306
00:47:22,940 --> 00:47:21,600
of course we as scientists are always

1307
00:47:23,750 --> 00:47:22,950
putting the engineers to give us more in

1308
00:47:26,690 --> 00:47:23,760
the way but

1309
00:47:28,640 --> 00:47:26,700
but certainly a very important for for

1310
00:47:30,680 --> 00:47:28,650
census of greenhouse gases finding

1311
00:47:31,970 --> 00:47:30,690
metabolites and being able to to be

1312
00:47:34,340 --> 00:47:31,980
certain that what you've seen at low

1313
00:47:36,380 --> 00:47:34,350

resolution is what you think it is also

1314
00:47:40,070 --> 00:47:36,390
the planets UV environment affected what

1315
00:47:41,780 --> 00:47:40,080
we saw in very non-intuitive ways but

1316
00:47:43,670 --> 00:47:41,790
also the fact that earth-like planets as

1317
00:47:46,010 --> 00:47:43,680
long as you had a oxygen ozone layers

1318
00:47:48,020 --> 00:47:46,020
would form in response to the spectrum

1319
00:47:50,830 --> 00:47:48,030
of the parent star in such a way that we

1320
00:47:52,820 --> 00:47:50,840
obtained habitability on the surface

1321
00:47:54,110 --> 00:47:52,830
also the fact that planets around M

1322
00:47:56,300 --> 00:47:54,120
stars can potentially build up these

1323
00:47:57,650 --> 00:47:56,310
other gases that are biomarkers because

1324
00:48:00,290 --> 00:47:57,660
they have longer lifetimes in those

1325
00:48:03,230 --> 00:48:00,300
atmospheres abiotic formation of o2 and

1326
00:48:04,490 --> 00:48:03,240
o3 in high CO 2 atmospheres is unlikely

1327
00:48:07,220 --> 00:48:04,500
as long as you have an act of

1328
00:48:09,740 --> 00:48:07,230
hydrological cycle and finally the

1329
00:48:11,960 --> 00:48:09,750
surface photon flux that you see is

1330
00:48:12,940 --> 00:48:11,970
planetary environment dependent depends

1331
00:48:15,110 --> 00:48:12,950
on what's actually in your atmosphere

1332
00:48:16,850 --> 00:48:15,120
strong dependence on ozone being there

1333
00:48:18,860 --> 00:48:16,860
as well and it will likely govern the

1334
00:48:20,420 --> 00:48:18,870
most advantageous pigments for

1335
00:48:22,790 --> 00:48:20,430
photosynthesis for planets around stars

1336
00:48:29,240 --> 00:48:22,800
a different spectral type so I will

1337
00:48:33,390 --> 00:48:31,200
well thank you very much for that

1338
00:48:45,950 --> 00:48:33,400

wide-ranging and fascinating talk I'm

1339
00:49:02,070 --> 00:48:48,300
narrowband just want to treat your

1340
00:49:03,900 --> 00:49:02,080
customers I didn't hear the left yeah so

1341
00:49:05,820 --> 00:49:03,910
what was the very last day it seems like

1342
00:49:09,510 --> 00:49:05,830
maybe you would do better signals and I

1343
00:49:11,940 --> 00:49:09,520
don't get you you would and and there

1344
00:49:13,410 --> 00:49:11,950
are people who have done that work and

1345
00:49:15,089 --> 00:49:13,420
West tribe is one of them and in the

1346
00:49:17,160 --> 00:49:15,099
demo al paper which is a classic browser

1347
00:49:18,960 --> 00:49:17,170
u21 they talk about matched filter bands

1348
00:49:20,190 --> 00:49:18,970
for these types of things I have a

1349
00:49:24,000 --> 00:49:20,200
different view I actually don't like

1350
00:49:26,400 --> 00:49:24,010
that and here's why because TPF is going

1351
00:49:28,109 --> 00:49:26,410
to be an instrument of discovery and as

1352
00:49:30,240 --> 00:49:28,119
I said these plants may be completely

1353
00:49:31,740 --> 00:49:30,250
unlike anything we've ever seen so I

1354
00:49:33,660 --> 00:49:31,750
think it's a little bit dangerous to

1355
00:49:36,359 --> 00:49:33,670
have nothing but mesh filter bands for

1356
00:49:37,620 --> 00:49:36,369
things we expect to see one thing I

1357
00:49:39,690 --> 00:49:37,630
didn't show you here as well is that

1358
00:49:41,609 --> 00:49:39,700
that even though you might know roughly

1359
00:49:43,710 --> 00:49:41,619
how wide the feature is going to be to

1360
00:49:45,690 --> 00:49:43,720
match the band you probably never know

1361
00:49:48,540 --> 00:49:45,700
how wide the continuum is going to be um

1362
00:49:50,370 --> 00:49:48,550
and and so the more species you have in

1363
00:49:52,020 --> 00:49:50,380

in the in the atmosphere and in the

1364
00:49:53,790 --> 00:49:52,030
spectrum the more your continuum tends

1365
00:49:55,109 --> 00:49:53,800
to narrow down in some cases that may be

1366
00:49:56,760 --> 00:49:55,119
the Narrows feature in the spectrum

1367
00:49:59,190 --> 00:49:56,770
those co2 planets the other continuum is

1368
00:50:00,870 --> 00:49:59,200
really tiny so I'm more of the

1369
00:50:03,359 --> 00:50:00,880
philosophy that that this thing really

1370
00:50:06,329 --> 00:50:03,369
should be a broad wavelength capability

1371
00:50:07,589 --> 00:50:06,339
and if binning is required which I agree

1372
00:50:09,540 --> 00:50:07,599
is definitely the better way to go for

1373
00:50:11,250 --> 00:50:09,550
signal-to-noise it would be better if we

1374
00:50:14,099 --> 00:50:11,260
had a wider wavelength capability that

1375
00:50:17,070 --> 00:50:14,109
could be bend to get signal to noise but

1376
00:50:19,349 --> 00:50:17,080
should we be deliriously lucky to get a

1377
00:50:21,060 --> 00:50:19,359
bright terrestrial planet nearby that we

1378
00:50:22,770 --> 00:50:21,070
at least had the spectral capability to

1379
00:50:24,839 --> 00:50:22,780
then go after that one target with as

1380
00:50:26,670 --> 00:50:24,849
much structural range as possible so

1381
00:50:28,859 --> 00:50:26,680
that's the way I'd rather go is there

1382
00:50:31,170 --> 00:50:28,869
some kind of after instrument binning of

1383
00:50:33,240 --> 00:50:31,180
the data but again that requires that we

1384
00:50:34,950 --> 00:50:33,250
have really low Reed noise and I'm not

1385
00:50:36,089 --> 00:50:34,960
sure those detectors are built yet but

1386
00:50:37,450 --> 00:50:36,099
I'm sure we have a lot of time to

1387
00:50:40,000 --> 00:50:37,460
develop things so

1388
00:50:42,790 --> 00:50:40,010

hopefully we'll work on that other

1389
00:50:47,890 --> 00:50:42,800
questions yes have a related question

1390
00:50:50,589 --> 00:50:47,900
how much of an issue is red shift uh

1391
00:50:51,730 --> 00:50:50,599
negligible as far as i know that's it's

1392
00:50:55,150 --> 00:50:51,740
not a big deal at all they're really

1393
00:50:57,190 --> 00:50:55,160
nearby yeah weird i mean the the most

1394
00:51:00,820 --> 00:50:57,200
distant things are going to be at you

1395
00:51:02,920 --> 00:51:00,830
know about 10-15 parsecs you know it may

1396
00:51:04,660 --> 00:51:02,930
be out to 45 at the very outer limit but

1397
00:51:06,490 --> 00:51:04,670
we really are extremely close in the

1398
00:51:10,839 --> 00:51:06,500
solar neighborhood firth for trying to

1399
00:51:15,579 --> 00:51:10,849
find these sorts of things no no it

1400
00:51:18,099 --> 00:51:15,589
doesn't other questions yes people where

1401
00:51:21,490 --> 00:51:18,109
you said the DNA dangers of uncle Timon

1402
00:51:23,770 --> 00:51:21,500
and see entries for the hen work um no

1403
00:51:25,420 --> 00:51:23,780
and I'm not sure I'd have to talk to

1404
00:51:26,740 --> 00:51:25,430
aunty I think we may have calculated

1405
00:51:28,150 --> 00:51:26,750
this but we didn't publish them so i

1406
00:51:29,440 --> 00:51:28,160
didn't i didn't take them out of video

1407
00:51:34,390 --> 00:51:29,450
but if you want them like that we can

1408
00:51:38,230 --> 00:51:34,400
get them remember uh I think it's pretty

1409
00:51:40,270 --> 00:51:38,240
negligible overall even at the surface

1410
00:51:42,010 --> 00:51:40,280
and even if we don't produce very much

1411
00:51:45,010 --> 00:51:42,020
ozone I think it really wasn't a major

1412
00:51:47,980 --> 00:51:45,020
concern some of the higher energy a uva

1413
00:51:49,359 --> 00:51:47,990

can get through but but for the rest of

1414
00:51:51,339 --> 00:51:49,369
it i think it was down by like a factor

1415
00:51:52,990 --> 00:51:51,349
of twenty or something versus earth for

1416
00:51:57,760 --> 00:51:53,000
the rest of the spectrum i believe that

1417
00:52:02,170 --> 00:51:57,770
was right ha open up the business DNA

1418
00:52:05,349 --> 00:52:02,180
damages what age of story that would

1419
00:52:09,970 --> 00:52:05,359
change certainly for an early she starts

1420
00:52:12,579 --> 00:52:09,980
early early history how did you I think

1421
00:52:14,849 --> 00:52:12,589
the f star was probably older and I mean

1422
00:52:19,570 --> 00:52:14,859
we plotted the UV that we had for those

1423
00:52:21,550 --> 00:52:19,580
the the mville the a dealio one was

1424
00:52:23,470 --> 00:52:21,560
actually you know outrageously active I

1425
00:52:25,180 --> 00:52:23,480
didn't I didn't show that one the case

1426
00:52:26,859 --> 00:52:25,190
how I can't remember what age it wants

1427
00:52:28,270 --> 00:52:26,869
but that's certainly true that you know

1428
00:52:30,790 --> 00:52:28,280
very early on you would have the higher

1429
00:52:32,170 --> 00:52:30,800
UV fluxes in the activity so Sofia

1430
00:52:33,880 --> 00:52:32,180
fluxes we calculate a word for the age

1431
00:52:35,200 --> 00:52:33,890
of the stars that we chose and I can't

1432
00:52:36,930 --> 00:52:35,210
remember exactly what they were but I

1433
00:52:39,490 --> 00:52:36,940
think their order of billions of years

1434
00:52:41,370 --> 00:52:39,500
can you looked into absorption spectra

1435
00:52:46,180 --> 00:52:41,380
that we might hope to get as we

1436
00:52:48,190 --> 00:52:46,190
with a chesty for transiting planets I

1437
00:52:49,690 --> 00:52:48,200
haven't looked into that but Giovanna

1438
00:52:51,730 --> 00:52:49,700

tinetti who is one of our former

1439
00:52:53,680 --> 00:52:51,740
postdocs and I was working EFA in Paris

1440
00:52:56,650 --> 00:52:53,690
she's specifically using these types of

1441
00:52:59,080 --> 00:52:56,660
models to look at trends spectra through

1442
00:53:01,420 --> 00:52:59,090
terrestrial planet atmosphere for these

1443
00:53:03,940 --> 00:53:01,430
types of transits as well and also for

1444
00:53:06,610 --> 00:53:03,950
Jovians so she's working on that we are

1445
00:53:08,320 --> 00:53:06,620
not what do you suggest it to me that

1446
00:53:10,840 --> 00:53:08,330
these spectral searches should include

1447
00:53:15,490 --> 00:53:10,850
designer molecules of advanced life like

1448
00:53:16,990 --> 00:53:15,500
free on 06 um yeah um okay I'm

1449
00:53:18,940 --> 00:53:17,000
interesting respond to that he's are

1450
00:53:20,560 --> 00:53:18,950
your doober that up um yes that's

1451
00:53:21,910 --> 00:53:20,570
conceivable as some of these have very

1452
00:53:23,800 --> 00:53:21,920
narrow features of Khmer only really

1453
00:53:24,910 --> 00:53:23,810
seen it at relatively high resolution so

1454
00:53:26,290 --> 00:53:24,920
some of them are difficult to detect

1455
00:53:27,610 --> 00:53:26,300
others are so diffuse they're also

1456
00:53:31,390 --> 00:53:27,620
difficult to detect on low

1457
00:53:33,220 --> 00:53:31,400
signal-to-noise my my maybe flip but but

1458
00:53:34,420 --> 00:53:33,230
this is the way I feel answer is first

1459
00:53:38,770 --> 00:53:34,430
of all we really want to find these

1460
00:53:40,750 --> 00:53:38,780
things and secondly I think that

1461
00:53:42,730 --> 00:53:40,760
astronomically speaking unless the

1462
00:53:45,100 --> 00:53:42,740
civilization is really dumb and kills

1463
00:53:46,780 --> 00:53:45,110

itself those signatures should only be

1464
00:53:49,180 --> 00:53:46,790
around for a very small period of time

1465
00:53:51,130 --> 00:53:49,190
until the civilization realizes what the

1466
00:53:53,020 --> 00:53:51,140
heck is doing and then scrubs them out

1467
00:53:54,190 --> 00:53:53,030
of the atmosphere and I think in the

1468
00:53:55,690 --> 00:53:54,200
case of the earth who would have seen

1469
00:53:58,210 --> 00:53:55,700
these build up and then we will see them

1470
00:53:59,920 --> 00:53:58,220
go down on a very short span compared

1471
00:54:01,330 --> 00:53:59,930
with the age of the star and so

1472
00:54:04,120 --> 00:54:01,340
astronomically when we go and look out

1473
00:54:05,050 --> 00:54:04,130
for TPF you know around other stars I

1474
00:54:06,760 --> 00:54:05,060
don't think there's a very high

1475
00:54:08,800 --> 00:54:06,770
statistical probability that will see it

1476
00:54:10,300 --> 00:54:08,810
unless they really do destroy their

1477
00:54:11,850 --> 00:54:10,310
peril and I would argue just bring the

1478
00:54:13,960 --> 00:54:11,860
equivalent of your narrow spectral

1479
00:54:16,270 --> 00:54:13,970
signature big you that you don't define

1480
00:54:17,380 --> 00:54:16,280
too much I'll chillin on earth yeah so

1481
00:54:18,640 --> 00:54:17,390
that's the other thing if we hadn't

1482
00:54:20,350 --> 00:54:18,650
filled matched filter bands you'd never

1483
00:54:31,719 --> 00:54:20,360
see those so again if he nice to have

1484
00:54:36,739 --> 00:54:34,459
right we do have some without an oxygen

1485
00:54:39,170 --> 00:54:36,749
carbonyl sulfide can be measured in

1486
00:54:40,849 --> 00:54:39,180
those particular wavelength ranges they

1487
00:54:44,120 --> 00:54:40,859
are in the same regime there was water

1488
00:54:45,229 --> 00:54:44,130

in methane so if water a methane at

1489
00:54:47,420 --> 00:54:45,239
present and if you want a habitable

1490
00:54:50,390 --> 00:54:47,430
planet water will be that does make it

1491
00:54:52,339 --> 00:54:50,400
quite difficult to pull out so so they

1492
00:54:53,959 --> 00:54:52,349
are there that there theoretically we

1493
00:54:55,819 --> 00:54:53,969
could observe them but it may be

1494
00:54:57,920 --> 00:54:55,829
difficult on actual habitable planets

1495
00:54:59,599 --> 00:54:57,930
ironically on an uninhabited planet they

1496
00:55:00,799 --> 00:54:59,609
stick out like a sore thumb one on Venus

1497
00:55:03,559 --> 00:55:00,809
you know they're much much easier to

1498
00:55:05,329 --> 00:55:03,569
detect overall but certainly something

1499
00:55:07,160 --> 00:55:05,339
we could look for and I know Carl has

1500
00:55:08,959 --> 00:55:07,170
also been looking at dimethyl sulfide

1501
00:55:10,839 --> 00:55:08,969
for example as an output and it has a

1502
00:55:14,509 --> 00:55:10,849
very strong feature also in that range

1503
00:55:31,820 --> 00:55:14,519
I'm actually asking she was it let's

1504
00:55:41,640 --> 00:55:39,630
go with you I assume you're gonna see a

1505
00:55:43,020 --> 00:55:41,650
lot of methane right so they'll be

1506
00:55:45,360 --> 00:55:43,030
methane and water which would actually

1507
00:55:46,800 --> 00:55:45,370
serve to mask a lot of that we could

1508
00:55:47,940 --> 00:55:46,810
certainly try modeling it and see if

1509
00:55:49,230 --> 00:55:47,950
there's anything there that that makes

1510
00:55:50,790 --> 00:55:49,240
its way out i'm trying to think of this

1511
00:55:54,900 --> 00:55:50,800
anything up in that way it would be I

1512
00:55:57,210 --> 00:55:54,910
think extremely all of it okay and well

1513
00:56:05,250 --> 00:55:57,220

you see my goal to biomass and you had

1514
00:56:06,300 --> 00:56:05,260
working at any happens a lot right well

1515
00:56:08,070 --> 00:56:06,310
you saw what happened when we had a

1516
00:56:09,840 --> 00:56:08,080
dense co2 atmosphere mean pretty much

1517
00:56:13,470 --> 00:56:09,850
most of that vision the men afraid with

1518
00:56:15,150 --> 00:56:13,480
eaten away by co2 absorption but I mean

1519
00:56:16,710 --> 00:56:15,160
I think I can't answer that without

1520
00:56:18,600 --> 00:56:16,720
doing a model to see if something could

1521
00:56:20,250 --> 00:56:18,610
slip between the gaps between co2 and

1522
00:56:22,530 --> 00:56:20,260
methane that might be detectable like

1523
00:56:24,900 --> 00:56:22,540
so2 or the other thing too is the

1524
00:56:26,640 --> 00:56:24,910
arguments Jim casting also is pointed

1525
00:56:28,980 --> 00:56:26,650
this out if that the sulfur gas is tend

1526
00:56:30,420 --> 00:56:28,990
to be very soluble in water and so if

1527
00:56:31,440 --> 00:56:30,430
you had an ocean you might end up

1528
00:56:34,020 --> 00:56:31,450
scrubbing them out of the atmosphere

1529
00:56:36,330 --> 00:56:34,030
pretty fast but as in the case of oxygen

1530
00:56:37,710 --> 00:56:36,340
sinks can be overwhelmed and so you know

1531
00:56:39,750 --> 00:56:37,720
you might argue that potentially you

1532
00:56:41,070 --> 00:56:39,760
could build up sulfur dioxide the other

1533
00:56:43,530 --> 00:56:41,080
thing is discriminating that from

1534
00:56:45,480 --> 00:56:43,540
volcanism at that time because the

1535
00:56:47,490 --> 00:56:45,490
location also put a lot of sulfur gases

1536
00:56:48,540 --> 00:56:47,500
into the atmosphere other thing is life

1537
00:56:50,130 --> 00:56:48,550
to himself against this in the

1538
00:56:52,470 --> 00:56:50,140

atmosphere can be fairly short against

1539
00:56:55,170 --> 00:56:52,480
catalysis so depending on what haze we

1540
00:56:56,550 --> 00:56:55,180
have available so it's a toughy but I

1541
00:57:04,590 --> 00:56:56,560
mean we could we could try modeling it

1542
00:57:10,420 --> 00:57:07,660
that we can get you so we have a

1543
00:57:12,610 --> 00:57:10,430
question from outside Seattle are are

1544
00:57:19,830 --> 00:57:12,620
there any questions from Ames or any

1545
00:57:22,620 --> 00:57:19,840
other we don't have any questions here

1546
00:57:26,890 --> 00:57:22,630
so we have time for one or two more here

1547
00:57:29,650 --> 00:57:26,900
yeah well if students and I your

1548
00:57:38,080 --> 00:57:29,660
region/sector compared to observe

1549
00:57:39,970 --> 00:57:38,090
specter of the earth the Sun right well

1550
00:57:41,590 --> 00:57:39,980
we have all of the Earth's spectra that

1551
00:57:44,290 --> 00:57:41,600
I should have been validated against

1552
00:57:46,330 --> 00:57:44,300
discount observations from the test

1553
00:57:48,580 --> 00:57:46,340
instrument whereas it was going to Mars

1554
00:57:50,710 --> 00:57:48,590
it looks back and took a spectra and

1555
00:57:52,630 --> 00:57:50,720
then in the optical invalidated against

1556
00:57:54,460 --> 00:57:52,640
earth science retro Louise party at a

1557
00:57:56,440 --> 00:57:54,470
restaurant your conference contained

1558
00:57:59,200 --> 00:57:56,450
left and three participants at this time

1559
00:58:01,270 --> 00:57:59,210
if you would like to continue that's our

1560
00:58:06,460 --> 00:58:01,280
one yeah for the conference will be

1561
00:58:08,050 --> 00:58:06,470
terminated spacecraft observations of

1562
00:58:09,100 --> 00:58:08,060
discouraged data coming back so that's

1563
00:58:12,340 --> 00:58:09,110

the first thing we do before we do

1564
00:58:16,330 --> 00:58:12,350
anything else and you know all those any

1565
00:58:18,460 --> 00:58:16,340
hacking yeah you do have to get the

1566
00:58:20,590 --> 00:58:18,470
right cloud balance which is variable on

1567
00:58:22,300 --> 00:58:20,600
the day and so what we try to do is go

1568
00:58:24,490 --> 00:58:22,310
and get the motor stator for the cloud

1569
00:58:26,050 --> 00:58:24,500
on the day so that we have you know at

1570
00:58:28,330 --> 00:58:26,060
least some good approximation of what's

1571
00:58:30,070 --> 00:58:28,340
going on and that's that's what we try

1572
00:58:31,660 --> 00:58:30,080
to use but certainly if you were doing

1573
00:58:33,460 --> 00:58:31,670
it just cold not knowing what the cloud

1574
00:58:36,310 --> 00:58:33,470
distribution and type was on the day

1575
00:58:38,380 --> 00:58:36,320
then you would have to tweak cloud types

1576
00:58:40,060 --> 00:58:38,390
and abundances to try and get a match to

1577
00:58:41,579 --> 00:58:40,070
the discouraged entrance but that's the

1578
00:58:46,510 --> 00:58:41,589
main variable is a cloud