
AbSciCon
2017
MESA, ARIZONA

1
00:00:06,160 --> 00:00:12,250
you

2
00:00:15,520 --> 00:00:13,560
[Music]

3
00:00:18,340 --> 00:00:15,530
what I'd like to talk to you guys today

4
00:00:20,320 --> 00:00:18,350
about is some of the work we did in 2015

5
00:00:22,150 --> 00:00:20,330
looking at some of these small stars

6
00:00:23,679 --> 00:00:22,160
that may potentially build up a biotic

7
00:00:25,240 --> 00:00:23,689
oxygen in their atmospheres and I want

8
00:00:26,290 --> 00:00:25,250
to take a particular I want to take a

9
00:00:29,920 --> 00:00:26,300
couple of slides and actually talk about

10
00:00:32,290 --> 00:00:29,930
Proxima Centauri B so just to orient

11
00:00:36,430 --> 00:00:32,300
everyone with the big picture I'm going

12
00:00:38,650 --> 00:00:36,440
to bash on M dwarves for a while so not

13
00:00:42,310 --> 00:00:38,660

an exhaustive list of the pros and cons

14
00:00:43,869 --> 00:00:42,320
but potentially M dwarfs have very long

15
00:00:46,060 --> 00:00:43,879
main sequence lifetimes they have very

16
00:00:48,900 --> 00:00:46,070
stable habitable zones over long periods

17
00:00:51,310 --> 00:00:48,910
of time which is great for evolving life

18
00:00:52,930 --> 00:00:51,320
they are also the most abundant star

19
00:00:55,119 --> 00:00:52,940
type and they are more likely to have

20
00:00:56,740 --> 00:00:55,129
rocky planets as some of Robbie's work

21
00:01:00,880 --> 00:00:56,750
pointed out looking at occurrence rates

22
00:01:03,010 --> 00:01:00,890
for M dwarves on the con side they have

23
00:01:04,180 --> 00:01:03,020
very long super luminous pre main

24
00:01:05,980 --> 00:01:04,190
sequence lifetimes which could

25
00:01:07,779 --> 00:01:05,990
potentially dehydrate planets or turn

26
00:01:09,999 --> 00:01:07,789
gas giants into terrestrial planets as

27
00:01:12,999 --> 00:01:10,009
some of those Roderigo Lugar's work

28
00:01:14,980 --> 00:01:13,009
showed they may start out dry initially

29
00:01:18,130 --> 00:01:14,990
to start with just no water at all

30
00:01:19,330 --> 00:01:18,140
depending on where they form the planets

31
00:01:20,920 --> 00:01:19,340
in their habitable zones could be

32
00:01:22,510 --> 00:01:20,930
tidally locked which has a number of

33
00:01:25,390 --> 00:01:22,520
effects and I'm certainly not going to

34
00:01:27,580 --> 00:01:25,400
touch on that and flares as we've heard

35
00:01:29,649 --> 00:01:27,590
several times today could have a very

36
00:01:32,170 --> 00:01:29,659
detrimental effect on a planet even if

37
00:01:34,420 --> 00:01:32,180
it does have an ozone shield but one of

38
00:01:37,480 --> 00:01:34,430

the things that funk Ann and myself

39
00:01:39,370 --> 00:01:37,490
pointed out in 2014-2015 is that some of

40
00:01:41,649 --> 00:01:39,380
these planets could potentially build up

41
00:01:43,060 --> 00:01:41,659
oxygen in their atmospheres to the level

42
00:01:45,819 --> 00:01:43,070
where we might be able to see it and

43
00:01:48,399 --> 00:01:45,829
detect it as a false positive so what do

44
00:01:52,149 --> 00:01:48,409
I mean by a false positive if we look at

45
00:01:54,280 --> 00:01:52,159
the Earth's history and particularly the

46
00:01:56,950 --> 00:01:54,290
evolution of the atmospheric oxygen

47
00:01:58,960 --> 00:01:56,960
budget on the earth the Archaean is

48
00:01:59,620 --> 00:01:58,970
noted to have very low oxygen and then

49
00:02:02,139 --> 00:01:59,630
at the goe

50
00:02:04,780 --> 00:02:02,149
you see a rise of oxygen to between one

51
00:02:07,030 --> 00:02:04,790
and 10 percent classically this estimate

52
00:02:09,310 --> 00:02:07,040
has been revised downward from some NOAA

53
00:02:12,160 --> 00:02:09,320
plan Topsy's work so at most it might be

54
00:02:15,720 --> 00:02:12,170
0.1% of the present atmospheric level of

55
00:02:18,039 --> 00:02:15,730
oxygen which is not a lot of oxygen and

56
00:02:20,020 --> 00:02:18,049
if you think about this from a detection

57
00:02:21,160 --> 00:02:20,030
perspective and I misses again broad

58
00:02:22,800 --> 00:02:21,170
brushstrokes I'm sure we're going to

59
00:02:25,650 --> 00:02:22,810
hear more about this likely

60
00:02:27,540 --> 00:02:25,660
Sarab Homer if you look at this from

61
00:02:30,150 --> 00:02:27,550
broad brushstrokes you can detect oxygen

62
00:02:34,020 --> 00:02:30,160
if it's greater than about 1% of modern

63
00:02:37,290 --> 00:02:34,030

oxygen you can detect ozone for about

64
00:02:39,920 --> 00:02:37,300
0.1% of modern oxygen levels and that's

65
00:02:42,870 --> 00:02:39,930
from a 2003 paper from Antigonus agora

66
00:02:45,390 --> 00:02:42,880
now that means that there could

67
00:02:47,550 --> 00:02:45,400
potentially be vast portions of our

68
00:02:49,979 --> 00:02:47,560
geologic history where we might not see

69
00:02:51,059 --> 00:02:49,989
life but there could be life happening

70
00:02:55,259 --> 00:02:51,069
on the surface of that planet as

71
00:02:57,600 --> 00:02:55,269
mentioned earlier by Nikki and the

72
00:02:59,550 --> 00:02:57,610
corollary here is that a false-positive

73
00:03:01,890 --> 00:02:59,560
could be any amount of oxygen that

74
00:03:04,080 --> 00:03:01,900
exceeds the amount of oxygen we expected

75
00:03:09,210 --> 00:03:04,090
for Earth's history where oxygen was a

76
00:03:17,370 --> 00:03:09,220
factor so how are we applying this to

77
00:03:20,520 --> 00:03:17,380
Proxima Centauri P I want to point out

78
00:03:23,160 --> 00:03:20,530
first that with any modeling effort it

79
00:03:25,020 --> 00:03:23,170
is important to state explicitly what

80
00:03:28,319 --> 00:03:25,030
your underlying assumptions are for that

81
00:03:31,259 --> 00:03:28,329
model now for our model we're

82
00:03:33,180 --> 00:03:31,269
considering global redox balances one of

83
00:03:35,210 --> 00:03:33,190
the the gold standards for the

84
00:03:38,400 --> 00:03:35,220
self-consistent steady-state of

85
00:03:39,750 --> 00:03:38,410
atmospheric composition and global redox

86
00:03:42,420 --> 00:03:39,760
balance is essentially the balance

87
00:03:45,330 --> 00:03:42,430
between reducing power coming into the

88
00:03:46,620 --> 00:03:45,340

atmosphere either through volcanic gases

89
00:03:49,050 --> 00:03:46,630
being introduced in the atmosphere or

90
00:03:51,930 --> 00:03:49,060
oxidative weathering so that's a sink

91
00:03:54,240 --> 00:03:51,940
fraction or a net source for hydrogen

92
00:03:55,979 --> 00:03:54,250
essentially balanced by the escape of

93
00:03:58,319 --> 00:03:55,989
hydrogen into space and the burial of

94
00:04:00,270 --> 00:03:58,329
reducing constituents now because my

95
00:04:02,610 --> 00:04:00,280
planet is lifeless a lot of these things

96
00:04:05,400 --> 00:04:02,620
go away which makes global redox balance

97
00:04:08,129 --> 00:04:05,410
a much easier equation to solve and for

98
00:04:10,530 --> 00:04:08,139
us global reacts balance is satisfied

99
00:04:14,340 --> 00:04:10,540
when we balance volcanic outgassing by

100
00:04:16,020 --> 00:04:14,350
the escape of hydrogen to space you can

101
00:04:17,940 --> 00:04:16,030
certainly make very different

102
00:04:19,500 --> 00:04:17,950
assumptions about your planet for

103
00:04:21,750 --> 00:04:19,510
example you can choose not to satisfy

104
00:04:23,670 --> 00:04:21,760
global reax valve but you must state

105
00:04:26,370 --> 00:04:23,680
explicitly that you are doing so and has

106
00:04:28,650 --> 00:04:26,380
a debt it has a very different effect on

107
00:04:31,830 --> 00:04:28,660
your model results so sitting in

108
00:04:33,270 --> 00:04:31,840
explicitly as an important

109
00:04:35,279 --> 00:04:33,280
and what this looks like from a

110
00:04:37,679 --> 00:04:35,289
schematic level at least for M star

111
00:04:39,179 --> 00:04:37,689
planets well let me back up it looks

112
00:04:40,469 --> 00:04:39,189
like this for most terrestrial planets

113
00:04:42,809 --> 00:04:40,479

but it looks very different in

114
00:04:43,800 --> 00:04:42,819
application for M star plants is in the

115
00:04:46,830 --> 00:04:43,810
upper part of the atmosphere you can

116
00:04:49,499 --> 00:04:46,840
photolyze co2 and you can make CO and O

117
00:04:51,330 --> 00:04:49,509
2 and stoichiometric quantities and then

118
00:04:53,309 --> 00:04:51,340
that Co no.2 can flow into the lower

119
00:04:55,740 --> 00:04:53,319
atmosphere where water vapor photolysis

120
00:04:58,770 --> 00:04:55,750
catalyzes the recombination of co no

121
00:05:01,350 --> 00:04:58,780
back into CO 2 and part of the 2015

122
00:05:03,779 --> 00:05:01,360
paper we outlined that this process is

123
00:05:06,149 --> 00:05:03,789
fairly slower around M dwarfs and so one

124
00:05:09,209 --> 00:05:06,159
of the big questions is what happens to

125
00:05:11,610 --> 00:05:09,219
the ce o-- and the O 2 in the solution

126
00:05:13,290 --> 00:05:11,620
in the ocean global ocean and they could

127
00:05:15,629 --> 00:05:13,300
potentially recombine but those aqueous

128
00:05:16,709 --> 00:05:15,639
reaction rates are relatively unknown so

129
00:05:20,429 --> 00:05:16,719
that's why there's a big question mark

130
00:05:23,459 --> 00:05:20,439
down here and so I mentioned before that

131
00:05:27,689 --> 00:05:23,469
this catalysis is relatively slow in M

132
00:05:29,550 --> 00:05:27,699
dwarf planets and that's a relic of the

133
00:05:30,719 --> 00:05:29,560
fact that the spectra that you're seeing

134
00:05:32,969 --> 00:05:30,729
at the top of the atmosphere is very

135
00:05:36,809 --> 00:05:32,979
different for solar-type stars as

136
00:05:39,570 --> 00:05:36,819
compared to M dwarf stars here you can

137
00:05:42,659 --> 00:05:39,580
see that a sun-like star has very bright

138
00:05:44,999 --> 00:05:42,669

in the near UV and it's fairly dim in

139
00:05:47,579 --> 00:05:45,009
the fuv but for M stars particularly

140
00:05:50,550 --> 00:05:47,589
Proxima Centauri it's essentially flat

141
00:05:53,850 --> 00:05:50,560
across the UV which gives it a very high

142
00:05:55,260 --> 00:05:53,860
f UV to n UV ratio and I zoomed in here

143
00:05:57,839 --> 00:05:55,270
just a little bit so that you can see

144
00:06:00,600 --> 00:05:57,849
and these are 1 au equivalent so these

145
00:06:01,760 --> 00:06:00,610
are integrated to be 1360 Watts premier

146
00:06:04,829 --> 00:06:01,770
squared at the top of the atmosphere

147
00:06:06,899 --> 00:06:04,839
that's why you're seeing relatively low

148
00:06:08,939 --> 00:06:06,909
contributions of UV and visible

149
00:06:10,559 --> 00:06:08,949
radiation from process and it's mostly

150
00:06:12,629 --> 00:06:10,569
in the infrared where you're getting

151
00:06:14,700 --> 00:06:12,639
most of the radiation but you can see

152
00:06:16,829 --> 00:06:14,710
that because it's relatively flatted

153
00:06:19,679 --> 00:06:16,839
it's a very different character f UV to

154
00:06:21,689 --> 00:06:19,689
n UV ratio which affects the chemistry

155
00:06:23,490 --> 00:06:21,699
because a lot of the fatalis is of

156
00:06:26,730 --> 00:06:23,500
important constituents in the atmosphere

157
00:06:30,340 --> 00:06:26,740
like co2 and o2 and water vapor happen

158
00:06:34,280 --> 00:06:30,350
in a relatively narrow UV region

159
00:06:39,860 --> 00:06:37,280
the 2015 paper pointed out that the fuv

160
00:06:42,680 --> 00:06:39,870
to nuv ratio was the dominant control

161
00:06:44,900 --> 00:06:42,690
for the abiotic production of oxygen in

162
00:06:48,170 --> 00:06:44,910
a terrestrial planetary atmosphere so

163
00:06:51,020 --> 00:06:48,180

these are 5% co2 cases located at about

164
00:06:53,390 --> 00:06:51,030
1.3 au equivalent so they're relatively

165
00:06:56,530 --> 00:06:53,400
far out in the habitable zone relatively

166
00:06:59,360 --> 00:06:56,540
colder and that decrease in radiation

167
00:07:00,740 --> 00:06:59,370
allows essentially the buildup of co2

168
00:07:03,620 --> 00:07:00,750
because we assume that there's a

169
00:07:05,930 --> 00:07:03,630
carbonate silicate feedback cycle but as

170
00:07:09,050 --> 00:07:05,940
you see for a sun-like star you get

171
00:07:11,680 --> 00:07:09,060
relatively low levels of abiotic oxygen

172
00:07:14,230 --> 00:07:11,690
vanishingly small what we think is can

173
00:07:15,950 --> 00:07:14,240
contend

174
00:07:19,010 --> 00:07:15,960
commensurate with what we see in the

175
00:07:21,140 --> 00:07:19,020
Archaean but as you change the fuv to

176
00:07:24,230 --> 00:07:21,150
any view ratio it's especially 4k

177
00:07:25,790 --> 00:07:24,240
dwarves and M dwarves you see that the

178
00:07:28,580 --> 00:07:25,800
amount of oxygen you produce from co2

179
00:07:30,350 --> 00:07:28,590
photolysis is actually on the order of a

180
00:07:31,670 --> 00:07:30,360
few percent in some cases and the new

181
00:07:34,580 --> 00:07:31,680
result here is that Proxima Centauri

182
00:07:37,970 --> 00:07:34,590
plots off the plot which is never

183
00:07:40,760 --> 00:07:37,980
encouraging and so you get up to about

184
00:07:43,130 --> 00:07:40,770
15% oxygen from a co2 dominated

185
00:07:45,680 --> 00:07:43,140
atmosphere in this case and this is a

186
00:07:49,670 --> 00:07:45,690
very limited part of parameter space if

187
00:07:51,740 --> 00:07:49,680
you include more co2 you get more oxygen

188
00:07:53,810 --> 00:07:51,750

it's just a consequence of the fact that

189
00:07:56,390 --> 00:07:53,820
your photo lysing co2 but if you have

190
00:07:59,060 --> 00:07:56,400
less co2 you will see less oxygen that's

191
00:08:01,190 --> 00:07:59,070
this bottom panel here where we varied

192
00:08:03,710 --> 00:08:01,200
the amount of co2 in the atmosphere and

193
00:08:05,780 --> 00:08:03,720
watched as the oxygen scaled with it and

194
00:08:07,700 --> 00:08:05,790
so I've put this dashed line here which

195
00:08:10,160 --> 00:08:07,710
is my threshold for a false positive

196
00:08:12,110 --> 00:08:10,170
oxygen signal and you can see that for

197
00:08:14,090 --> 00:08:12,120
large amounts of co2 which is

198
00:08:15,860 --> 00:08:14,100
commensurate with being located in the

199
00:08:17,360 --> 00:08:15,870
outer regions of the habitable zone it's

200
00:08:19,790 --> 00:08:17,370
entirely possible that you could build

201
00:08:22,640 --> 00:08:19,800
up some oxygen above that threshold but

202
00:08:25,370 --> 00:08:22,650
for relatively small amounts of co2 that

203
00:08:26,780 --> 00:08:25,380
oxygen false-positive does go away and

204
00:08:28,520 --> 00:08:26,790
you can include the effect of other

205
00:08:31,340 --> 00:08:28,530
reducing gases like more hydrogen

206
00:08:33,140 --> 00:08:31,350
methane ammonia outgassing for example

207
00:08:35,060 --> 00:08:33,150
which is not really a thing on earth but

208
00:08:38,300 --> 00:08:35,070
could be on other planets composition is

209
00:08:40,280 --> 00:08:38,310
a thing it actually decreases the amount

210
00:08:42,820 --> 00:08:40,290
of oxygen you can accumulate in the

211
00:08:47,320 --> 00:08:42,830
atmosphere but because these planets are

212
00:08:49,180 --> 00:08:47,330
and it's never easy the likelihood of Co

213
00:08:50,829 --> 00:08:49,190

runaway which is a consequence of some

214
00:08:52,500 --> 00:08:50,839
of the modeling we've done has been

215
00:08:55,769 --> 00:08:52,510
outlined by Kevin Donnelly in the past

216
00:08:58,960 --> 00:08:55,779
the Co runaway becomes a more

217
00:09:01,000 --> 00:08:58,970
problematic issue it occurs more often

218
00:09:05,530 --> 00:09:01,010
especially when you introduce more

219
00:09:07,180 --> 00:09:05,540
complex chemistry in these cases and so

220
00:09:10,030 --> 00:09:07,190
what I want you to take away from this

221
00:09:11,769 --> 00:09:10,040
talk is that with the same volcanic al

222
00:09:15,160 --> 00:09:11,779
casting and boundary conditions Proxima

223
00:09:17,860 --> 00:09:15,170
Centauri B behaves much like the other M

224
00:09:20,500 --> 00:09:17,870
star planets in that it can accumulate

225
00:09:23,110 --> 00:09:20,510
oxygen potentially above this threshold

226
00:09:26,860 --> 00:09:23,120
that we've assumed for a false positive

227
00:09:29,710 --> 00:09:26,870
from Earth's history but what you should

228
00:09:32,829 --> 00:09:29,720
note is that it also is dependent on the

229
00:09:35,650 --> 00:09:32,839
the UV spectrum of the hosts are for so

230
00:09:38,050 --> 00:09:35,660
for F and G and K stars they don't

231
00:09:40,600 --> 00:09:38,060
really show the same sort of behavior so

232
00:09:42,760 --> 00:09:40,610
for much of the planets that we may

233
00:09:44,829 --> 00:09:42,770
observe in the far future it's entirely

234
00:09:47,230 --> 00:09:44,839
likely that this mechanism is not going

235
00:09:49,750 --> 00:09:47,240
to be a large source of uncertainty in

236
00:09:52,900 --> 00:09:49,760
the amount of oxygen we might detect and

237
00:09:56,410 --> 00:09:52,910
this result also is a fairly dependent

238
00:09:58,389 --> 00:09:56,420

on which modelling group has contributed

239
00:10:00,150 --> 00:09:58,399
these results and so we are currently

240
00:10:02,350 --> 00:10:00,160
well underway in a model enter

241
00:10:03,819 --> 00:10:02,360
comparison to try to route out exactly

242
00:10:05,829 --> 00:10:03,829
what's driving the differences between

243
00:10:08,620 --> 00:10:05,839
whether or not you generate abiotic

244
00:10:14,240 --> 00:10:08,630
oxygen and so with that I'd like to take

245
00:10:18,900 --> 00:10:16,889
we have we have time for two to three

246
00:10:22,800 --> 00:10:18,910
questions here we are on time our

247
00:10:26,670 --> 00:10:22,810
speakers are awesome go to micron I was

248
00:10:27,840 --> 00:10:26,680
precisely on time thank you yeah let me

249
00:10:31,410 --> 00:10:27,850
repeat on NASA Goddard Space Flight

250
00:10:33,780 --> 00:10:31,420
Center yeah so the here you discussed

251
00:10:37,850 --> 00:10:33,790
the effect of the far UV and the near UV

252
00:10:42,449 --> 00:10:37,860
of photochemistry and - atmospheres but

253
00:10:44,759 --> 00:10:42,459
the we find that deflect of XUV EUV an

254
00:10:46,819 --> 00:10:44,769
x-ray are much more important especially

255
00:10:49,470 --> 00:10:46,829
when it comes to photo ionization

256
00:10:52,530 --> 00:10:49,480
because the process that you discover

257
00:10:54,360 --> 00:10:52,540
that they described is only works when

258
00:10:57,329 --> 00:10:54,370
everything is neutral and nice however

259
00:10:59,130 --> 00:10:57,339
it's not the case and we found and I

260
00:11:01,829 --> 00:10:59,140
don't know you didn't mention our paper

261
00:11:04,350 --> 00:11:01,839
when we will discuss the approxima be

262
00:11:07,740 --> 00:11:04,360
there atmospheric was escape due to the

263
00:11:09,269 --> 00:11:07,750

iron escape mechanism which we find very

264
00:11:17,280 --> 00:11:09,279
very important especially when you have

265
00:11:20,340 --> 00:11:17,290
a high high fluxes the energy fluxes and

266
00:11:21,530 --> 00:11:20,350
in EU V which is basically the case for

267
00:11:23,850 --> 00:11:21,540
a lot of Emsworth

268
00:11:25,470 --> 00:11:23,860
we're breaking a with exception of

269
00:11:27,720 --> 00:11:25,480
probably couple of very very weakly

270
00:11:29,880 --> 00:11:27,730
that's one thing the second is magnetic

271
00:11:31,889 --> 00:11:29,890
field we know that the Proxima Centauri

272
00:11:34,710 --> 00:11:31,899
has a magnetic field three hundred times

273
00:11:37,560 --> 00:11:34,720
stronger than our Sun so that means that

274
00:11:39,630 --> 00:11:37,570
at the distance of 0.05 the magnetic

275
00:11:41,400 --> 00:11:39,640
field the BZ component will be

276
00:11:43,620 --> 00:11:41,410
comparable to the magnetic field of

277
00:11:44,610 --> 00:11:43,630
Earth which will destroy the magnetic

278
00:11:47,220 --> 00:11:44,620
field so you

279
00:11:49,079 --> 00:11:47,230
so the megiddo steric effect come there

280
00:11:52,530 --> 00:11:49,089
become extremely important if not

281
00:11:54,480 --> 00:11:52,540
defining in the the whole climate models

282
00:11:57,150 --> 00:11:54,490
were on the assumption that everything

283
00:11:59,639 --> 00:11:57,160
is nice and soft so that will change the

284
00:12:01,620 --> 00:11:59,649
whole dynamics I totally agree with your

285
00:12:03,090 --> 00:12:01,630
opinion about the x-ray being a large

286
00:12:04,710 --> 00:12:03,100
component that and magnetic fields are

287
00:12:07,380 --> 00:12:04,720
very important but we do have some

288
00:12:08,490 --> 00:12:07,390

evidence that there are M star planets

289
00:12:10,620 --> 00:12:08,500
like the trampa system that are

290
00:12:12,590 --> 00:12:10,630
compatible with being a few percent

291
00:12:15,480 --> 00:12:12,600
water and if you've completely destroyed

292
00:12:17,670 --> 00:12:15,490
your atmosphere by drag offs and where's

293
00:12:19,500 --> 00:12:17,680
the water component so it seems like

294
00:12:21,329 --> 00:12:19,510
there's a disconnect there between what

295
00:12:23,400 --> 00:12:21,339
we're just seeing in nature and what

296
00:12:25,350 --> 00:12:23,410
we're modeling which is I agree a big

297
00:12:28,139 --> 00:12:25,360
issue we will have

298
00:12:29,609 --> 00:12:28,149
to go back to the next question if maybe

299
00:12:31,169 --> 00:12:29,619
we can continue it right there again the

300
00:12:34,439 --> 00:12:31,179
show some of the results of simulations

301
00:12:37,590 --> 00:12:34,449
for trapeze yeah after much shorter

302
00:12:40,079 --> 00:12:37,600
question your fuv is it is it dominated

303
00:12:41,309 --> 00:12:40,089
by Diamond alpha absolutely and then in

304
00:12:43,199 --> 00:12:41,319
that case the cross-sections of

305
00:12:43,710 --> 00:12:43,209
different molecules will be different

306
00:12:47,220 --> 00:12:43,720
right

307
00:12:48,449 --> 00:12:47,230
so yes the that also disconnect is

308
00:12:50,489 --> 00:12:48,459
because we're assuming that it's an

309
00:12:53,400 --> 00:12:50,499
average absorption across a wave band so

310
00:12:54,809 --> 00:12:53,410
that that is something that we can do

311
00:12:58,259 --> 00:12:54,819
better in the future and it is also

312
00:13:02,069 --> 00:12:58,269
pressured a payment yes yeah yeah okay

313
00:13:03,569 --> 00:13:02,079

we have noble questions all right so

314
00:13:04,710 --> 00:13:03,579
we'll go to the next speaker