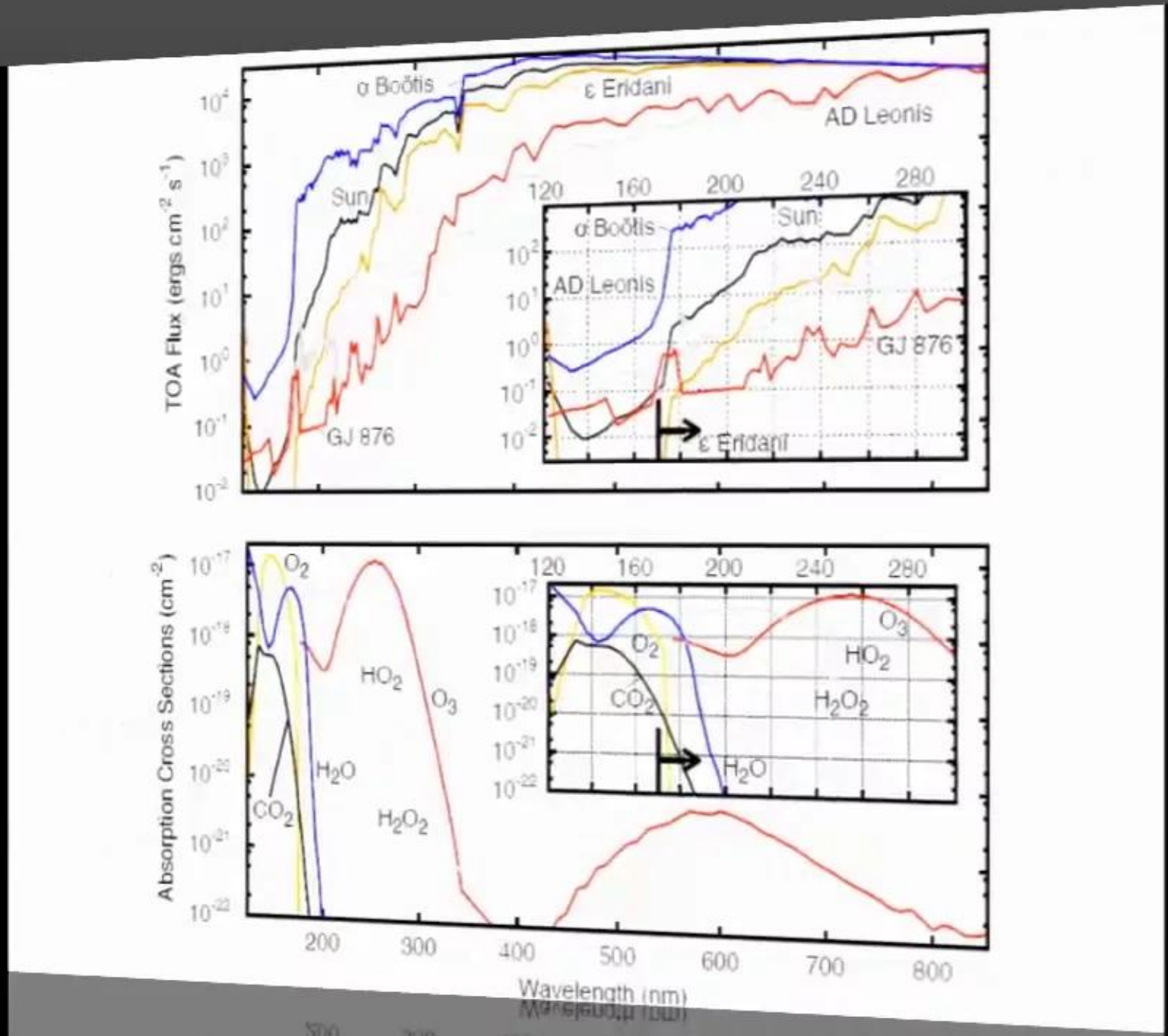
α Boötis
ε Eridani
AD Leonis
Sun
GJ 876
TOA Flux (ergs cm^{-2} s^{-1})
120 160 200 240 280
α Boötis
Sun
AD Leonis
GJ 876
ε Eridani
Absorption Cross Sections (cm^{-2})
O_2
HO_2
O_3
H_2O
CO_2
H_2O_2
200 300 400 500 600 700 800
Wavelength (nm)

1
00:00:14,539 --> 00:00:10,820
alright so as I mentioned this is the

2
00:00:16,460 --> 00:00:14,549
last of our two talks for planetary

3
00:00:18,470 --> 00:00:16,470
atmospheres I expect to see more next

4
00:00:20,600 --> 00:00:18,480
year guys seriously planetary

5
00:00:23,509 --> 00:00:20,610
atmospheres are awesome what I want to

6
00:00:26,859 --> 00:00:23,519
talk to you today about is mostly

7
00:00:29,689 --> 00:00:26,869
looking for life around other stars and

8
00:00:32,990 --> 00:00:29,699
one of the best ways that we can do that

9
00:00:36,619 --> 00:00:33,000
is by using the earth as an analog and

10
00:00:38,900 --> 00:00:36,629
so the big picture here is that we have

11
00:00:41,030 --> 00:00:38,910
this big blue ball and we know that

12
00:00:42,680 --> 00:00:41,040
there's life on it conveniently

13
00:00:45,590 --> 00:00:42,690

otherwise there would be no one here to

14
00:00:48,020 --> 00:00:45,600
listen to me talk now we can use the

15
00:00:50,720 --> 00:00:48,030
earth as a proxy by saying that life is

16
00:00:53,389 --> 00:00:50,730
here and we can see the signs for Life

17
00:00:54,760 --> 00:00:53,399
all around us and we want to do is we

18
00:00:57,200 --> 00:00:54,770
want to take those signs for life and

19
00:01:01,340 --> 00:00:57,210
extrapolate them to other places in the

20
00:01:04,310 --> 00:01:01,350
universe especially when what we're

21
00:01:06,680 --> 00:01:04,320
looking at is just the size of a pixel

22
00:01:08,870 --> 00:01:06,690
so looking for terrestrial planets

23
00:01:10,550 --> 00:01:08,880
around other stars this is about as much

24
00:01:12,620 --> 00:01:10,560
information as we're going to have any

25
00:01:15,380 --> 00:01:12,630
time in the next hundred years until we

26
00:01:19,100 --> 00:01:15,390
build some solar system size telescope

27
00:01:22,010 --> 00:01:19,110
to resolve these terrestrial planets now

28
00:01:24,529 --> 00:01:22,020
one of the biggest bio signatures in the

29
00:01:26,600 --> 00:01:24,539
terrestrial system is the oxygen that we

30
00:01:29,089 --> 00:01:26,610
are breathing now it is predominantly

31
00:01:32,449 --> 00:01:29,099
formed by biology on the present earth

32
00:01:36,020 --> 00:01:32,459
and oxygen has been suggested as a bio

33
00:01:38,600 --> 00:01:36,030
signature for basically 50 years at this

34
00:01:39,949 --> 00:01:38,610
point and attendance Upton's ups and

35
00:01:42,680 --> 00:01:39,959
downs there have been some suggestion

36
00:01:48,320 --> 00:01:42,690
that oxygen could have other abiotic

37
00:01:51,589 --> 00:01:48,330
sources but oxygen is wonderful because

38
00:01:54,380 --> 00:01:51,599

it has this big feature here at point

39
00:01:56,960 --> 00:01:54,390
seven six microns that is a pretty deep

40
00:01:59,570 --> 00:01:56,970
and we could see that so oxygen is

41
00:02:01,999 --> 00:01:59,580
visible at about greater than 1% the

42
00:02:05,600 --> 00:02:02,009
present atmospheric level so you can see

43
00:02:07,249 --> 00:02:05,610
this is 21% oxygen 1pl and as you

44
00:02:09,859 --> 00:02:07,259
decrease oxygen that feature kind of

45
00:02:12,290 --> 00:02:09,869
goes away now the nice thing is at low

46
00:02:14,600 --> 00:02:12,300
oxygen concentrations ozone which is a

47
00:02:17,030 --> 00:02:14,610
photo chemical byproduct of oxygen still

48
00:02:19,490 --> 00:02:17,040
stays visible so about point one percent

49
00:02:22,250 --> 00:02:19,500
PL o to you have a pretty

50
00:02:24,620 --> 00:02:22,260
a substantial ozone feature out in the

51
00:02:27,940 --> 00:02:24,630
infrared and so this is how we might

52
00:02:31,100 --> 00:02:27,950
detect oxygen in a planetary atmosphere

53
00:02:34,280 --> 00:02:31,110
now like I mentioned for some of the

54
00:02:35,990 --> 00:02:34,290
sources for oxygen we have transient

55
00:02:38,180 --> 00:02:36,000
sources in the present Earth's

56
00:02:41,210 --> 00:02:38,190
atmosphere including lightning so if you

57
00:02:44,270 --> 00:02:41,220
take some water and co2 nitrogen add a

58
00:02:47,360 --> 00:02:44,280
bunch of electricity you get n 0 and 0 2

59
00:02:48,830 --> 00:02:47,370
and some hydrogen or co this is

60
00:02:51,170 --> 00:02:48,840
remarkably short lived because that

61
00:02:54,110 --> 00:02:51,180
oxygen goes back to recombine with n 0

62
00:02:56,870 --> 00:02:54,120
or with h2 so it goes away fairly

63
00:02:58,910 --> 00:02:56,880

quickly another transient source is

64
00:03:00,860 --> 00:02:58,920
through co2 fatalis is for example in

65
00:03:03,410 --> 00:03:00,870
the upper atmosphere of the earth you

66
00:03:04,940 --> 00:03:03,420
can break apart co2 that loan oxygen

67
00:03:08,060 --> 00:03:04,950
goes off and finds itself a dance

68
00:03:10,580 --> 00:03:08,070
partner and makes 02 which could linger

69
00:03:15,500 --> 00:03:10,590
in the upper atmosphere more

70
00:03:17,930 --> 00:03:15,510
persistently however we have life which

71
00:03:19,930 --> 00:03:17,940
takes water in co2 and makes organic

72
00:03:22,280 --> 00:03:19,940
carbon which is buried in sediments and

73
00:03:25,400 --> 00:03:22,290
gaseous co2 which is allowed to

74
00:03:28,039 --> 00:03:25,410
accumulate in the atmosphere or through

75
00:03:30,440 --> 00:03:28,049
hydrogen loss so for example early Venus

76
00:03:33,080 --> 00:03:30,450
it probably lost most of its oceans

77
00:03:35,600 --> 00:03:33,090
through the Potala seas and subsequent

78
00:03:37,820 --> 00:03:35,610
loss of hydrogen to space leaving behind

79
00:03:39,680 --> 00:03:37,830
large amounts of oxygen which

80
00:03:41,900 --> 00:03:39,690
subsequently reacted saw planet it's

81
00:03:43,670 --> 00:03:41,910
gone today although there is a little

82
00:03:47,300 --> 00:03:43,680
photo chemical oxygen left over in the

83
00:03:49,520 --> 00:03:47,310
newsie naps here so if we're going to

84
00:03:51,530 --> 00:03:49,530
talk about oxygen as a bio signature we

85
00:03:53,449 --> 00:03:51,540
need again understand how it operates on

86
00:03:55,699 --> 00:03:53,459
the present earth and to do that we need

87
00:03:59,150 --> 00:03:55,709
to look at oxygen through time I showed

88
00:04:02,900 --> 00:03:59,160

this earlier in the intro mostly as a

89
00:04:05,509 --> 00:04:02,910
self-serving motion but if you look at

90
00:04:08,620 --> 00:04:05,519
oxygen before the gioi before the great

91
00:04:11,270 --> 00:04:08,630
oxidation event it is essentially zero

92
00:04:14,569 --> 00:04:11,280
the only sources of oxygen are going to

93
00:04:16,940 --> 00:04:14,579
be those transient or sources i

94
00:04:19,330 --> 00:04:16,950
mentioned before so co2 photolysis or

95
00:04:22,130 --> 00:04:19,340
lightning so there's very little here

96
00:04:24,260 --> 00:04:22,140
life however had different plans for the

97
00:04:26,780 --> 00:04:24,270
earth's atmosphere and so after the gioi

98
00:04:29,740 --> 00:04:26,790
oxygen is suggested to have jumped to

99
00:04:32,540 --> 00:04:29,750
between one and fifty percent of modern

100
00:04:34,340 --> 00:04:32,550
now there have been

101
00:04:36,410 --> 00:04:34,350
a number of recent suggestions that

102
00:04:39,140 --> 00:04:36,420
oxygen may have been lower so if you

103
00:04:41,060 --> 00:04:39,150
have read the 2014 klonoski at all paper

104
00:04:43,970 --> 00:04:41,070
in science they suggest that the

105
00:04:45,920 --> 00:04:43,980
proterozoic 02 so the oxygen level in

106
00:04:49,460 --> 00:04:45,930
here may have been in an order of

107
00:04:51,650 --> 00:04:49,470
magnitude or lower than an order of

108
00:04:54,290 --> 00:04:51,660
magnitude or more lower than the

109
00:05:00,380 --> 00:04:54,300
previous estimates for proterozoic

110
00:05:01,580 --> 00:05:00,390
oxygen and so what this means is that we

111
00:05:04,370 --> 00:05:01,590
could with a first generation

112
00:05:06,920 --> 00:05:04,380
terrestrial planet finder type telescope

113
00:05:09,470 --> 00:05:06,930

look for oxygen and may have detected it

114
00:05:12,530 --> 00:05:09,480
at the canonical values for proterozoic

115
00:05:16,400 --> 00:05:12,540
action or looked in the infrared for the

116
00:05:18,620 --> 00:05:16,410
ozone feature but really the earth could

117
00:05:20,990 --> 00:05:18,630
potentially be a planet without a

118
00:05:23,360 --> 00:05:21,000
significant bio signature for much of

119
00:05:29,000 --> 00:05:23,370
its history so this is bad news if we

120
00:05:31,310 --> 00:05:29,010
want to look for life elsewhere so this

121
00:05:33,560 --> 00:05:31,320
brings me to the crux of my question

122
00:05:36,140 --> 00:05:33,570
what is a false positive now as I

123
00:05:38,570 --> 00:05:36,150
mentioned before the proterozoic oxygen

124
00:05:41,600 --> 00:05:38,580
right after the first jump up was fairly

125
00:05:44,720 --> 00:05:41,610
low so it could be that in some

126
00:05:47,180 --> 00:05:44,730
situations the abiotic sources of oxygen

127
00:05:49,070 --> 00:05:47,190
actually produce more oxygen than the

128
00:05:52,520 --> 00:05:49,080
biotic sources did on the early Earth

129
00:05:57,190 --> 00:05:52,530
and so any abiotic oxygen in excess of

130
00:06:00,920 --> 00:05:59,600
and now I have to back away from this

131
00:06:03,260 --> 00:06:00,930
for a second and talk about some nuts

132
00:06:05,090 --> 00:06:03,270
and bolts just to give you guys a

133
00:06:06,850 --> 00:06:05,100
context for some of the things I will

134
00:06:09,860 --> 00:06:06,860
talk about towards the end of the talk

135
00:06:11,600 --> 00:06:09,870
when we talk about chemistry and a

136
00:06:13,460 --> 00:06:11,610
terrestrial planetary atmosphere what we

137
00:06:15,430 --> 00:06:13,470
really mean is that there's a whole slew

138
00:06:19,100 --> 00:06:15,440

of chemicals that are doing their own

139
00:06:21,320 --> 00:06:19,110
business in the atmosphere and in the

140
00:06:24,320 --> 00:06:21,330
case of co2 which I mentioned would be a

141
00:06:28,550 --> 00:06:24,330
big source of oxygen if these single

142
00:06:31,670 --> 00:06:28,560
oxygens could escape c 0 + 0 + m

143
00:06:34,370 --> 00:06:31,680
recombines those back into co2 or it

144
00:06:36,680 --> 00:06:34,380
would if that reaction wasn't spin

145
00:06:39,380 --> 00:06:36,690
forbidden and so what happens is you

146
00:06:41,840 --> 00:06:39,390
could build up CO and oh those o's could

147
00:06:43,640 --> 00:06:41,850
go off to make oxygen and we might see

148
00:06:44,770 --> 00:06:43,650
it that way however in the monitors

149
00:06:47,470 --> 00:06:44,780
atmosphere

150
00:06:50,379 --> 00:06:47,480
actually have these catalytic cycles

151
00:06:52,390 --> 00:06:50,389
that are fueled by the products of water

152
00:06:54,430 --> 00:06:52,400
vapor photolysis and so you can take CEO

153
00:06:56,080 --> 00:06:54,440
and the hydroxyl radical and through a

154
00:06:58,480 --> 00:06:56,090
bunch of other intermediate reactions

155
00:07:01,150 --> 00:06:58,490
you basically get a net result that is

156
00:07:03,220 --> 00:07:01,160
recombining CO and oh and this is very

157
00:07:06,129 --> 00:07:03,230
efficient in the prisoner its atmosphere

158
00:07:10,570 --> 00:07:06,139
that's why we get very little abiotic 02

159
00:07:12,340 --> 00:07:10,580
in the present atmosphere now this is

160
00:07:14,170 --> 00:07:12,350
particularly important if we start

161
00:07:16,800 --> 00:07:14,180
talking about other stars I know there's

162
00:07:20,860 --> 00:07:16,810
a lot of lines up here don't be scared

163
00:07:22,990 --> 00:07:20,870

the present Sun the solar spectrum is

164
00:07:26,530 --> 00:07:23,000
here in the black and you can see in

165
00:07:28,480 --> 00:07:26,540
this blow up that the the near you the

166
00:07:32,800 --> 00:07:28,490
far-uv which is these are in nanometers

167
00:07:35,140 --> 00:07:32,810
are is here and the far-uv is here the

168
00:07:38,080 --> 00:07:35,150
near-uv is here and there's actually a

169
00:07:40,510 --> 00:07:38,090
very different radiation environment for

170
00:07:43,960 --> 00:07:40,520
lower mass stars so you can see here GJ

171
00:07:45,850 --> 00:07:43,970
876 is an MSR middle M star and this is

172
00:07:48,190 --> 00:07:45,860
a dealio and gray which is another

173
00:07:49,540 --> 00:07:48,200
middle M star and those have very

174
00:07:52,030 --> 00:07:49,550
different radiation environments

175
00:07:53,680 --> 00:07:52,040
spanning this essentially a fairly

176
00:07:55,300 --> 00:07:53,690
arbitrary cutoff here so you can see

177
00:07:58,420 --> 00:07:55,310
that they have comparable amounts of

178
00:08:01,900 --> 00:07:58,430
what I'm going to call far UV and very

179
00:08:04,360 --> 00:08:01,910
different amounts of nuv up to two

180
00:08:06,370 --> 00:08:04,370
orders of magnitude less near-uv and

181
00:08:08,500 --> 00:08:06,380
this is particularly important when we

182
00:08:10,060 --> 00:08:08,510
look at the Potala sis cross-sections

183
00:08:11,170 --> 00:08:10,070
the absorption cross sections for some

184
00:08:13,719 --> 00:08:11,180
of the relevant species in the

185
00:08:16,630 --> 00:08:13,729
atmosphere so short word here we are

186
00:08:20,770 --> 00:08:16,640
getting still some fatalis asst of water

187
00:08:23,290 --> 00:08:20,780
vapor and co2 but long word than this so

188
00:08:25,120 --> 00:08:23,300

into the near-uv it's predominantly

189
00:08:27,520 --> 00:08:25,130
water vapor photolysis so that's that

190
00:08:32,409 --> 00:08:27,530
source of hydroxyl radical in an

191
00:08:35,100 --> 00:08:32,419
atmosphere now what that means is that

192
00:08:40,149 --> 00:08:35,110
i'm going to transition to a slide and

193
00:08:42,820 --> 00:08:40,159
wow sorry about that so the model in

194
00:08:44,260 --> 00:08:42,830
particular worries about the atmosphere

195
00:08:46,329 --> 00:08:44,270
as a whole and so we have to maintain

196
00:08:47,680 --> 00:08:46,339
global redox balance and I'm not going

197
00:08:49,450 --> 00:08:47,690
to get into the details because they're

198
00:08:51,700 --> 00:08:49,460
gory and kind of boring so I'm going to

199
00:08:53,560 --> 00:08:51,710
skip over them and say that if we assume

200
00:08:55,980 --> 00:08:53,570
that there are no geologic sinks for

201
00:08:57,150 --> 00:08:55,990
example on 100 million year time scales

202
00:09:00,030 --> 00:08:57,160
we

203
00:09:02,100 --> 00:09:00,040
can enforce atmospheric redox balance by

204
00:09:03,540 --> 00:09:02,110
assuming a return of reducing

205
00:09:06,030 --> 00:09:03,550
constituents to the atmosphere to

206
00:09:08,100 --> 00:09:06,040
balance the rain out of reducing and

207
00:09:09,840 --> 00:09:08,110
oxidizing species at the lower boundary

208
00:09:11,040 --> 00:09:09,850
that's a bunch of jumbled you don't have

209
00:09:14,790 --> 00:09:11,050
to worry about it if you have questions

210
00:09:18,900 --> 00:09:14,800
come see me the boundary conditions that

211
00:09:21,449 --> 00:09:18,910
are imposed are not tunable parameters

212
00:09:24,960 --> 00:09:21,459
they depend entirely on what you assume

213
00:09:27,360 --> 00:09:24,970

about the solid planet so these cases

214
00:09:30,019 --> 00:09:27,370
here where we're enforcing atmospheric

215
00:09:34,920 --> 00:09:30,029
redox balance that is in the context of

216
00:09:36,119 --> 00:09:34,930
global assumptions so I'm going to show

217
00:09:39,329 --> 00:09:36,129
you some results because that was kind

218
00:09:41,129 --> 00:09:39,339
of boring what we have here is I've

219
00:09:43,949 --> 00:09:41,139
taken the earth and I've plunked it

220
00:09:47,730 --> 00:09:43,959
around different types of stars and so

221
00:09:50,069 --> 00:09:47,740
for the Sun in the absence of life the

222
00:09:53,189 --> 00:09:50,079
oxygen mixing ratio at the surface is

223
00:09:55,319 --> 00:09:53,199
incredibly low it's our abiotic levels

224
00:09:58,829 --> 00:09:55,329
so like you saw before the gioi the

225
00:10:00,809 --> 00:09:58,839
oxygen was essentially zero for the f

226
00:10:02,999 --> 00:10:00,819
star which is slightly brighter than the

227
00:10:04,439 --> 00:10:03,009
Sun so the habitable zone moves out this

228
00:10:06,809 --> 00:10:04,449
terrestrial planet is nearly twice as

229
00:10:10,110 --> 00:10:06,819
far away from the Sun as the earth would

230
00:10:11,519 --> 00:10:10,120
be around the Sun the terrestrial planet

231
00:10:14,100 --> 00:10:11,529
on the f star is nearly twice as far

232
00:10:15,660 --> 00:10:14,110
away as it would be around the Sun but

233
00:10:17,490 --> 00:10:15,670
you can see that there's only slightly

234
00:10:19,499 --> 00:10:17,500
more oxygen in the upper atmosphere

235
00:10:22,559 --> 00:10:19,509
again that's from that Fatah lysis of

236
00:10:25,519 --> 00:10:22,569
co2 but again at the surface there's not

237
00:10:27,749 --> 00:10:25,529
so much what happens really is that

238
00:10:29,790 --> 00:10:27,759

around smaller stars where that

239
00:10:33,210 --> 00:10:29,800
radiation balance search the change is

240
00:10:34,679 --> 00:10:33,220
that we see we start to get for example

241
00:10:37,319 --> 00:10:34,689
with the K star which is slightly

242
00:10:38,990 --> 00:10:37,329
smaller than the Sun you start to see

243
00:10:41,490 --> 00:10:39,000
that the oxygen of the lower boundary

244
00:10:44,519 --> 00:10:41,500
irrespective of what you assume about

245
00:10:46,590 --> 00:10:44,529
the oxygen sinks the oxygen starts to

246
00:10:49,530 --> 00:10:46,600
build up and in the case of the M stars

247
00:10:51,749 --> 00:10:49,540
you get a range of values for oxygen

248
00:10:53,429 --> 00:10:51,759
based on your assumptions about the

249
00:10:55,710 --> 00:10:53,439
solid surface so in the worst-case

250
00:10:58,290 --> 00:10:55,720
scenario where we assume that there are

251
00:11:01,769 --> 00:10:58,300
no oxygen sinks which is likely

252
00:11:03,480 --> 00:11:01,779
unrealistic we get a few percent oxygen

253
00:11:06,629 --> 00:11:03,490
at the lower boundary which would be a

254
00:11:08,309 --> 00:11:06,639
detectable amount of oxygen in the cases

255
00:11:10,530 --> 00:11:08,319
where we assume that there is a large

256
00:11:12,480 --> 00:11:10,540
sink for oxidants

257
00:11:15,540 --> 00:11:12,490
for example the modern earth there's

258
00:11:17,760 --> 00:11:15,550
organic matter there's ferric iron

259
00:11:19,380 --> 00:11:17,770
deposition and banded iron formations so

260
00:11:21,690 --> 00:11:19,390
you could absorb a lot of that oxygen

261
00:11:23,790 --> 00:11:21,700
and actually draw it down to below that

262
00:11:27,600 --> 00:11:23,800
pollen offski at all false positive

263
00:11:30,060 --> 00:11:27,610

threshold I had suggested before and so

264
00:11:33,570 --> 00:11:30,070
to get back to this balance between the

265
00:11:38,460 --> 00:11:33,580
near you the far you the far-uv and the

266
00:11:41,340 --> 00:11:38,470
near-uv what we can say about what's

267
00:11:44,310 --> 00:11:41,350
driving the amount of oxygen is really

268
00:11:47,010 --> 00:11:44,320
this far UV to near-uv ratio and so if

269
00:11:49,980 --> 00:11:47,020
you plot these values for the stars

270
00:11:54,000 --> 00:11:49,990
based on their integrated fuv and

271
00:11:56,520 --> 00:11:54,010
near-uv fluxes you can see that the M

272
00:11:58,410 --> 00:11:56,530
stars plot way up here with the amount

273
00:12:02,520 --> 00:11:58,420
of oxygen being controlled by the amount

274
00:12:04,530 --> 00:12:02,530
of the ratio of f u v 2 nu V and the the

275
00:12:06,120 --> 00:12:04,540
g and the f star is down here and the K

276
00:12:08,610 --> 00:12:06,130
star sort of in the middle because it

277
00:12:11,510 --> 00:12:08,620
had a middling amount of oxygen but if

278
00:12:14,820 --> 00:12:11,520
you take the solar flux and you actually

279
00:12:16,920 --> 00:12:14,830
decrease the nu V so if you decrease the

280
00:12:18,960 --> 00:12:16,930
nu V we're coming over this way you can

281
00:12:22,740 --> 00:12:18,970
see that the oxygen actually builds up

282
00:12:26,400 --> 00:12:22,750
and and falls quite nicely along the

283
00:12:28,560 --> 00:12:26,410
other values for these stars and so in

284
00:12:32,580 --> 00:12:28,570
conclusion I'd like to suggest that

285
00:12:35,670 --> 00:12:32,590
there is little 02 or ozone around F and

286
00:12:37,080 --> 00:12:35,680
G type stars that there's a modest and

287
00:12:39,450 --> 00:12:37,090
potentially detectable amount of 02

288
00:12:43,500 --> 00:12:39,460

around k type stars and detectable 02

289
00:12:46,170 --> 00:12:43,510
around M stars in some cases EG if there

290
00:12:49,830 --> 00:12:46,180
are no surface sinks fro to and this is

291
00:12:51,980 --> 00:12:49,840
a lovely suite of spectra that Eddie

292
00:12:54,950 --> 00:12:51,990
schwieterman has put together from u-dub

293
00:12:58,080 --> 00:12:54,960
so not this you dub the other you dub

294
00:13:01,620 --> 00:12:58,090
and you can see that that for example

295
00:13:05,220 --> 00:13:01,630
that ozone feature in the UV is pretty

296
00:13:06,900 --> 00:13:05,230
strong for the M star and that oxygen

297
00:13:09,570 --> 00:13:06,910
feature at point seven and six microns

298
00:13:10,770 --> 00:13:09,580
is pretty strong too and so I'm going to

299
00:13:17,060 --> 00:13:10,780
leave that up I'm going to take

300
00:13:24,090 --> 00:13:22,050
questions for Sonny excellent i'm going

301
00:13:26,160 --> 00:13:24,100
to ask a naive question then so are you

302
00:13:28,530 --> 00:13:26,170
suggesting just that the takeaway is

303
00:13:30,660 --> 00:13:28,540
that if we have a detection around an

304
00:13:33,480 --> 00:13:30,670
effort a g-type star then that's

305
00:13:35,460 --> 00:13:33,490
probably fairly secure that it's biotic

306
00:13:37,200 --> 00:13:35,470
and not a biotic i would argue that if

307
00:13:39,810 --> 00:13:37,210
you do detect oxygen around an effort

308
00:13:42,750 --> 00:13:39,820
g-type star that it would likely be from

309
00:13:45,300 --> 00:13:42,760
a biological source okay of course the

310
00:13:46,860 --> 00:13:45,310
the gold standard biasing sure is oxygen

311
00:13:50,060 --> 00:13:46,870
in combination with some other reducing

312
00:13:54,030 --> 00:13:50,070
gas for example nitrous oxide there are

313
00:13:57,510 --> 00:13:54,040

very few and very small sources abiotic

314
00:14:02,100 --> 00:13:57,520
sources of n2o so those two together

315
00:14:03,570 --> 00:14:02,110
would be a good bio signature any other

316
00:14:07,110 --> 00:14:03,580
questions otherwise we're right on time