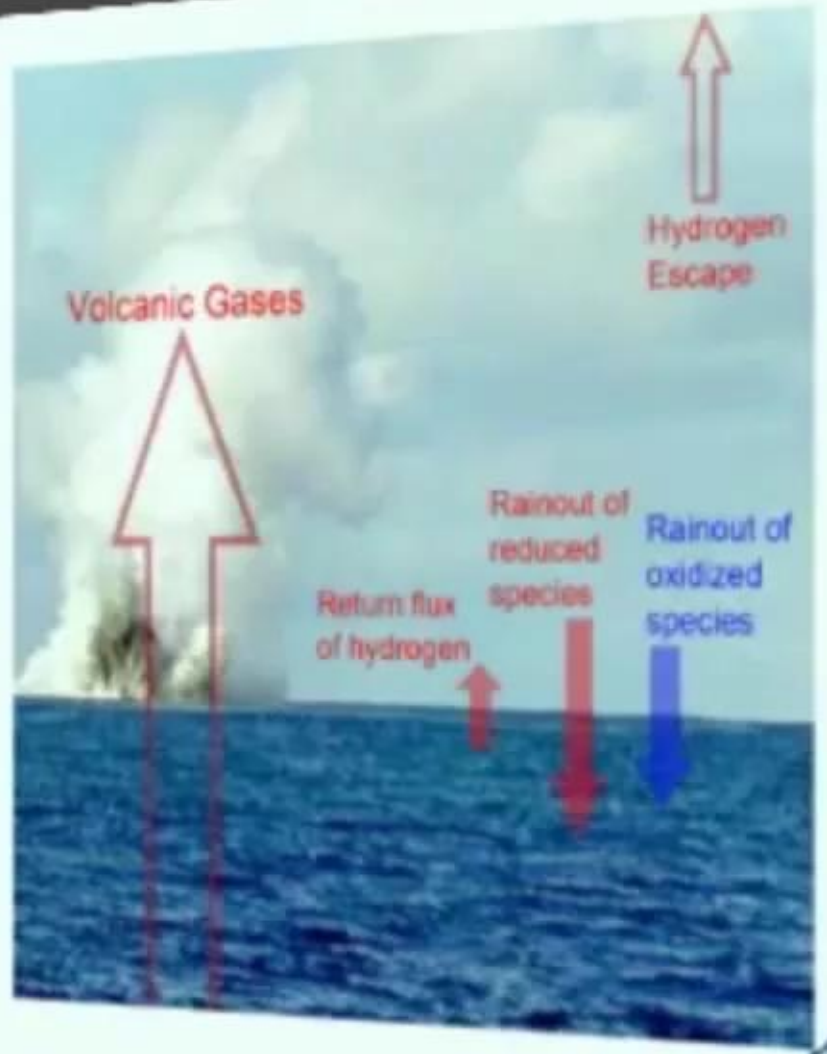

Modified from photo by Dr. Brent McInnes, CSIRO

DEPARTMENT OF
GEOSCIENCES

1
00:00:12,150 --> 00:00:10,260
okay so thanks everybody who's here for

2
00:00:13,020 --> 00:00:12,160
this afternoon talk I know lunch was

3
00:00:14,759 --> 00:00:13,030
delicious and you're all probably

4
00:00:18,089 --> 00:00:14,769
looking forward to a nap at some point I

5
00:00:19,740 --> 00:00:18,099
want to point out that most of the heavy

6
00:00:21,690 --> 00:00:19,750
lifting for this project has been done

7
00:00:25,109 --> 00:00:21,700
by an undergrad in our lab James

8
00:00:30,990 --> 00:00:25,119
seancody he does fantastic work and a

9
00:00:33,240 --> 00:00:31,000
lot of this is thanks to him so on the

10
00:00:36,360 --> 00:00:33,250
present earth we have about twenty one

11
00:00:38,729 --> 00:00:36,370
percent oxygen and about one part per

12
00:00:46,500 --> 00:00:38,739
million methane and this is a direct

13
00:00:51,690 --> 00:00:46,510

result of life on Earth oxygen as a bio

14
00:00:55,200 --> 00:00:51,700
signature then is this grand idea that

15
00:00:58,680 --> 00:00:55,210
the microbial community can dramatically

16
00:01:01,770 --> 00:00:58,690
alter the atmosphere of a planet just

17
00:01:04,950 --> 00:01:01,780
over fairly short time scales in Earth's

18
00:01:07,740 --> 00:01:04,960
history and this idea traces back to

19
00:01:10,830 --> 00:01:07,750
love lock in the 60s as eugenio

20
00:01:13,020 --> 00:01:10,840
mentioned where he first posited that we

21
00:01:15,179 --> 00:01:13,030
could look for oxygen in combination

22
00:01:17,039 --> 00:01:15,189
with hydrocarbons so for example in the

23
00:01:21,480 --> 00:01:17,049
modern atmosphere we have oxygen and

24
00:01:23,490 --> 00:01:21,490
methane as a bio signature for life on

25
00:01:25,770 --> 00:01:23,500
another planet and not to poke fun at

26
00:01:27,630 --> 00:01:25,780
Daniel but the habitable zone is a

27
00:01:30,149 --> 00:01:27,640
really great place to look for life

28
00:01:33,420 --> 00:01:30,159
because it's on the surface and it's

29
00:01:35,249 --> 00:01:33,430
modifying the atmosphere if and in

30
00:01:38,580 --> 00:01:35,259
conjunction with that it's also much

31
00:01:40,649 --> 00:01:38,590
easier to get photons from habitable

32
00:01:44,730 --> 00:01:40,659
zone planet than it is from a moon

33
00:01:46,770 --> 00:01:44,740
around a Jupiter so terrestrial planets

34
00:01:49,590 --> 00:01:46,780
in the habitable zone are great place to

35
00:01:52,560 --> 00:01:49,600
look for life as I said Lovelock

36
00:01:55,380 --> 00:01:52,570
pioneered this in the 60s and it's been

37
00:01:57,719 --> 00:01:55,390
modified and updated throughout time we

38
00:02:00,690 --> 00:01:57,729

figured out that while oxygen is a great

39
00:02:02,249 --> 00:02:00,700
tracer for life ozone is a tracer for

40
00:02:03,990 --> 00:02:02,259
oxygen and we can use that in place of

41
00:02:06,209 --> 00:02:04,000
that there's a much larger spectral

42
00:02:08,789 --> 00:02:06,219
fingerprint for ozone and so it's

43
00:02:10,319 --> 00:02:08,799
evolved from oxygen the ozone and the

44
00:02:12,000 --> 00:02:10,329
ozone and combination with those

45
00:02:17,220 --> 00:02:12,010
reducing compounds that we talked about

46
00:02:19,290 --> 00:02:17,230
before now another reason why we're

47
00:02:21,360 --> 00:02:19,300
looking for bio signatures

48
00:02:25,430 --> 00:02:21,370
terrestrial planets in the habitable

49
00:02:29,100 --> 00:02:25,440
zone is because of our neighbors so

50
00:02:32,580 --> 00:02:29,110
early in the solar system history when

51
00:02:35,040 --> 00:02:32,590
Venus was getting pummeled by radiation

52
00:02:36,750 --> 00:02:35,050
from the Sun it underwent a runaway

53
00:02:38,760 --> 00:02:36,760
greenhouse and most of its water vapor

54
00:02:40,050 --> 00:02:38,770
got into the upper atmosphere was

55
00:02:42,930 --> 00:02:40,060
dissociated and the hydrogen

56
00:02:46,320 --> 00:02:42,940
subsequently lost to space that hydrogen

57
00:02:48,450 --> 00:02:46,330
loss is Daniel mentioned can trigger the

58
00:02:51,900 --> 00:02:48,460
build-up of oxygen in an atmosphere

59
00:02:54,180 --> 00:02:51,910
that's not related to life if you lose

60
00:02:58,020 --> 00:02:54,190
an ocean of water from Venus you can get

61
00:02:59,790 --> 00:02:58,030
up to 240 bars of molecular oxygen just

62
00:03:03,120 --> 00:02:59,800
from that ocean by losing all the

63
00:03:05,460 --> 00:03:03,130

hydrogen so on the interior of the

64
00:03:08,640 --> 00:03:05,470
habitable zone towards a sun-like star

65
00:03:11,630 --> 00:03:08,650
you could destroy a planet but still get

66
00:03:13,770 --> 00:03:11,640
a transient oxygen signal on the

67
00:03:16,350 --> 00:03:13,780
exterior of the habitable zone our

68
00:03:18,390 --> 00:03:16,360
smaller cousin Mars currently has two

69
00:03:21,420 --> 00:03:18,400
tenths of a percent of molecular oxygen

70
00:03:24,870 --> 00:03:21,430
in its atmosphere this is a big deal

71
00:03:27,030 --> 00:03:24,880
this is if Mars was slightly larger it

72
00:03:31,410 --> 00:03:27,040
would have held on to more of its oxygen

73
00:03:34,350 --> 00:03:31,420
and subsequently Mars would look like a

74
00:03:36,180 --> 00:03:34,360
biological planet in terms of oxygen so

75
00:03:38,430 --> 00:03:36,190
that we would have to look for these

76
00:03:40,940 --> 00:03:38,440
secondary signposts these reducing

77
00:03:44,970 --> 00:03:40,950
compounds in conjunction with these

78
00:03:46,229 --> 00:03:44,980
oxidizing compounds to disentangle what

79
00:03:50,130 --> 00:03:46,239
processes are happening in that

80
00:03:52,380 --> 00:03:50,140
atmosphere and so the habitable zone for

81
00:03:54,180 --> 00:03:52,390
terrestrial mass planets is the place to

82
00:03:56,850 --> 00:03:54,190
look for bio signatures and that's why

83
00:03:59,880 --> 00:03:56,860
using oxygen as a bio signature for

84
00:04:02,400 --> 00:03:59,890
terrestrial mass planets is such a big

85
00:04:06,180 --> 00:04:02,410
deal it's it's here where we find that

86
00:04:08,040 --> 00:04:06,190
life is the cause of oxygen build up in

87
00:04:12,810 --> 00:04:08,050
the atmosphere not anything else or

88
00:04:14,850 --> 00:04:12,820

that's what we hope anyway in this study

89
00:04:16,590 --> 00:04:14,860
we're employing a one-dimensional

90
00:04:18,990 --> 00:04:16,600
horizontally averaged photochemical

91
00:04:21,360 --> 00:04:19,000
model like Eugenio mentioned the casting

92
00:04:25,010 --> 00:04:21,370
group has had numerous versions of this

93
00:04:28,050 --> 00:04:25,020
code but it essentially boils down to

94
00:04:30,450 --> 00:04:28,060
tens of kilometers tall test tube where

95
00:04:33,809 --> 00:04:30,460
photons come in the top and we have

96
00:04:35,610 --> 00:04:33,819
and gases and ran out moving chemicals

97
00:04:38,120 --> 00:04:35,620
at the bottom of the atmosphere and in

98
00:04:41,850 --> 00:04:38,130
the middle we have a steady-state

99
00:04:43,499 --> 00:04:41,860
chemical disequilibrium that's caused by

100
00:04:45,420 --> 00:04:43,509
the fluxes in an amount in and out of

101
00:04:47,040 --> 00:04:45,430
our atmosphere and so for the runs I'm

102
00:04:49,499 --> 00:04:47,050
going to talk about today we're in a

103
00:04:51,210 --> 00:04:49,509
ninety percent co2 atmosphere so it's

104
00:04:52,770 --> 00:04:51,220
going to be moved towards the outer edge

105
00:04:54,150 --> 00:04:52,780
of the habitable zone otherwise it's

106
00:04:57,300 --> 00:04:54,160
going to be a little too warm and go

107
00:04:59,070 --> 00:04:57,310
into a runaway you know one bar

108
00:05:01,559 --> 00:04:59,080
atmosphere and our base-case volcanism

109
00:05:04,040 --> 00:05:01,569
we're putting out sort of the upper end

110
00:05:06,510 --> 00:05:04,050
of what we think of a terrestrial mass

111
00:05:08,089 --> 00:05:06,520
planets volcanism so we're putting out

112
00:05:12,120 --> 00:05:08,099
hydrogen and methane and hydrogen

113
00:05:15,570 --> 00:05:12,130

sulfide and then when we reduce volcanic

114
00:05:18,779 --> 00:05:15,580
outgassing we're just leaving in h2 us

115
00:05:21,480 --> 00:05:18,789
which is commensurate with what some of

116
00:05:24,060 --> 00:05:21,490
the more recent results for oxygen false

117
00:05:28,700 --> 00:05:24,070
positives have pointed out as being an

118
00:05:31,140 --> 00:05:28,710
initiator for their runaway oxygenation

119
00:05:32,640 --> 00:05:31,150
so just to give you guys a little

120
00:05:37,050 --> 00:05:32,650
background I'm going to talk about redox

121
00:05:39,990 --> 00:05:37,060
because that's what I do so we define a

122
00:05:42,450 --> 00:05:40,000
system of redox with these neutral

123
00:05:43,980 --> 00:05:42,460
species that things are moving towards

124
00:05:46,439 --> 00:05:43,990
the chemical other chemical species are

125
00:05:49,320 --> 00:05:46,449
being pushed towards the redox neutral

126
00:05:52,800 --> 00:05:49,330
species so in our case we define neutral

127
00:05:55,439 --> 00:05:52,810
as water co2 and so2 and so for example

128
00:05:57,899 --> 00:05:55,449
a reduced chemical species like methane

129
00:06:00,600 --> 00:05:57,909
when combined with water vapor gets you

130
00:06:02,730 --> 00:06:00,610
back to co2 which is one of our other

131
00:06:05,550 --> 00:06:02,740
neutral species but gets you an excess

132
00:06:08,390 --> 00:06:05,560
of hydrogen and so the reducing species

133
00:06:11,310 --> 00:06:08,400
give you hydrogen in the redox budget on

134
00:06:13,980 --> 00:06:11,320
the other end of things the oxidized

135
00:06:15,990 --> 00:06:13,990
species like hydrogen peroxide you have

136
00:06:20,339 --> 00:06:16,000
to add hydrogen to get them back to that

137
00:06:22,589 --> 00:06:20,349
base redox neutral species and so in

138
00:06:26,850 --> 00:06:22,599

this case hydrogen peroxide has a net

139
00:06:28,320 --> 00:06:26,860
minus 1 h2 molecule so just for some

140
00:06:31,379 --> 00:06:28,330
audience participation who knows what

141
00:06:37,370 --> 00:06:31,389
the redox number for h2so4 is can you do

142
00:06:39,860 --> 00:06:37,380
the math in your head anybody was that

143
00:06:43,110 --> 00:06:39,870
h2so4

144
00:06:44,640 --> 00:06:43,120
well you say you're I guess I should

145
00:06:46,260 --> 00:06:44,650
explain this a little better so you're

146
00:06:48,719 --> 00:06:46,270
going to take h2so4 and you're going to

147
00:06:50,010 --> 00:06:48,729
add either hydrogen or one of the redox

148
00:06:51,960 --> 00:06:50,020
neutral species and either you're going

149
00:06:55,409 --> 00:06:51,970
to evolve hydrogen or give back to the

150
00:06:57,749 --> 00:06:55,419
neutral species so just to skip to the

151
00:07:00,719 --> 00:06:57,759
punchline h2so4 is a net minus one

152
00:07:04,589 --> 00:07:00,729
hydrogen and then CEO is a net plus a

153
00:07:08,520 --> 00:07:04,599
half hydrogen or plus 100 n see even I

154
00:07:10,170 --> 00:07:08,530
can't keep it straight so this is our

155
00:07:13,020 --> 00:07:10,180
model like I said we have a big test

156
00:07:14,310 --> 00:07:13,030
tube where we're putting volcanic gases

157
00:07:15,960 --> 00:07:14,320
into the bottom of the model and we

158
00:07:18,330 --> 00:07:15,970
assume that there's an ocean covering

159
00:07:21,270 --> 00:07:18,340
this planet that's only really in one

160
00:07:22,920 --> 00:07:21,280
dimension we're working on that so you

161
00:07:26,850 --> 00:07:22,930
have volcanic gases that are being

162
00:07:29,700 --> 00:07:26,860
evolved out of the subsurface

163
00:07:32,310 --> 00:07:29,710

essentially through the ocean layer and

164
00:07:34,260 --> 00:07:32,320
into the atmosphere you have rain out of

165
00:07:36,450 --> 00:07:34,270
reducing species and oxidizing species

166
00:07:39,029 --> 00:07:36,460
that accounts for redox at the ocean

167
00:07:41,399 --> 00:07:39,039
atmosphere boundary and then you have

168
00:07:44,219 --> 00:07:41,409
the escape of reducing species at the

169
00:07:47,850 --> 00:07:44,229
top of the atmosphere now on long time

170
00:07:50,820 --> 00:07:47,860
scales the influx of volcanic gases

171
00:07:54,060 --> 00:07:50,830
which are consistently reducing so we

172
00:07:55,350 --> 00:07:54,070
have methane and hydrogen sulfide and h2

173
00:07:59,480 --> 00:07:55,360
that are being evolved into the

174
00:08:02,550 --> 00:07:59,490
atmosphere on long time scales the

175
00:08:04,200 --> 00:08:02,560
volcanic gases are balanced by hydrogen

176
00:08:06,839 --> 00:08:04,210
escape and so what's happening in the

177
00:08:09,810 --> 00:08:06,849
atmosphere ocean boundary is important

178
00:08:12,149 --> 00:08:09,820
but it's not the principal control on

179
00:08:14,430 --> 00:08:12,159
atmospheric redox on long time scales

180
00:08:16,050 --> 00:08:14,440
and so what I'm going to do now is I'm

181
00:08:19,920 --> 00:08:16,060
going to show you a really scary table

182
00:08:24,120 --> 00:08:19,930
and I'm going to point out that here

183
00:08:26,879 --> 00:08:24,130
where who would all have no hydrogen

184
00:08:28,740 --> 00:08:26,889
emission where they have a prodigious

185
00:08:31,379 --> 00:08:28,750
amount of oxygen it's about a tenth of a

186
00:08:34,709 --> 00:08:31,389
percent of the lower boundary they have

187
00:08:37,550 --> 00:08:34,719
an imbalance in the fluxes of reducing

188
00:08:41,219 --> 00:08:37,560

components and oxidizing components at

189
00:08:46,550 --> 00:08:41,229
the atmosphere ocean boundary but if you

190
00:08:51,890 --> 00:08:46,560
were to look at the fluxes of hydrogen

191
00:08:53,190 --> 00:08:51,900
here hydrogen h2 + H to the fluxes of

192
00:08:55,890 --> 00:08:53,200
h2s what

193
00:08:58,470 --> 00:08:55,900
is there volcanic constituent the

194
00:09:00,900 --> 00:08:58,480
volcanic component is much larger than

195
00:09:03,090 --> 00:09:00,910
the escape of hydrogen to space so they

196
00:09:04,470 --> 00:09:03,100
should be gaining hydrogen in their

197
00:09:07,650 --> 00:09:04,480
atmosphere the atmosphere should be

198
00:09:10,410 --> 00:09:07,660
coming beep excuse me should be becoming

199
00:09:12,450 --> 00:09:10,420
more reducing with time not more

200
00:09:14,840 --> 00:09:12,460
oxidizing and so the fact that this

201
00:09:18,420 --> 00:09:14,850
lower boundary is not balanced is a

202
00:09:20,460 --> 00:09:18,430
problem and a problem that we can fix by

203
00:09:22,860 --> 00:09:20,470
returning that hydrogen returning that

204
00:09:26,820 --> 00:09:22,870
imbalance to the atmosphere and so

205
00:09:29,190 --> 00:09:26,830
balancing the atmosphere ocean redox

206
00:09:32,580 --> 00:09:29,200
budget is a key component of

207
00:09:37,310 --> 00:09:32,590
understanding the integrated redox state

208
00:09:39,720 --> 00:09:37,320
of these atmospheres so I mentioned

209
00:09:43,380 --> 00:09:39,730
solar-type stars and how we have false

210
00:09:46,350 --> 00:09:43,390
positives around the habitable zone but

211
00:09:48,990 --> 00:09:46,360
not in it we haven't seen a conclusive

212
00:09:51,090 --> 00:09:49,000
case of a total atmosphere ocean redox

213
00:09:53,490 --> 00:09:51,100

system that's been balanced that

214
00:09:56,570 --> 00:09:53,500
generates an oxygen false positive the

215
00:09:59,910 --> 00:09:56,580
2012 results from Rena hue and all are

216
00:10:03,780 --> 00:09:59,920
indicative of an imbalance at the ocean

217
00:10:06,630 --> 00:10:03,790
atmosphere boundary but not indicative

218
00:10:08,730 --> 00:10:06,640
of a false positive in the context of an

219
00:10:12,330 --> 00:10:08,740
atmosphere ocean system that's totally

220
00:10:14,190 --> 00:10:12,340
balanced but we have to look at other

221
00:10:15,240 --> 00:10:14,200
stars as well we're not going to fund

222
00:10:17,100 --> 00:10:15,250
we're not just going to look at

223
00:10:18,990 --> 00:10:17,110
terrestrial mass planets and have little

224
00:10:21,090 --> 00:10:19,000
zone of solar type starts we're going to

225
00:10:23,310 --> 00:10:21,100
look around M stars and K stars because

226
00:10:27,540 --> 00:10:23,320
they're just easier to observe habitable

227
00:10:30,210 --> 00:10:27,550
zone planets around and so here for my

228
00:10:31,740 --> 00:10:30,220
model results I have the Sun and green I

229
00:10:33,210 --> 00:10:31,750
apologize for those of you who are

230
00:10:36,240 --> 00:10:33,220
red-green colorblind I did try to make

231
00:10:38,850 --> 00:10:36,250
this as friendly as possible but the Sun

232
00:10:41,310 --> 00:10:38,860
is in green we have HD 2204 9 which is

233
00:10:43,500 --> 00:10:41,320
AK 2 star so that's slightly less

234
00:10:46,590 --> 00:10:43,510
massive than the Sun and then we have

235
00:10:50,370 --> 00:10:46,600
two M Dwarfs we have a dealio which is a

236
00:10:53,070 --> 00:10:50,380
classic very active M star that flares

237
00:10:54,690 --> 00:10:53,080
occasionally it's a pretty exciting for

238
00:10:57,690 --> 00:10:54,700

any planets that might be around it and

239
00:11:00,570 --> 00:10:57,700
then we have g GJ 876 which is a

240
00:11:01,600 --> 00:11:00,580
slightly less massive slightly cooler m

241
00:11:05,590 --> 00:11:01,610
star

242
00:11:08,290 --> 00:11:05,600
in red here and so if we were to take

243
00:11:11,170 --> 00:11:08,300
these stars with the same atmospheric

244
00:11:13,690 --> 00:11:11,180
parameters the same fluxes of gases the

245
00:11:16,660 --> 00:11:13,700
same parameterization of rain out and do

246
00:11:18,790 --> 00:11:16,670
model runs I'm going to show you a

247
00:11:21,490 --> 00:11:18,800
really scary figure with lots of lines

248
00:11:24,850 --> 00:11:21,500
would just stick with me so we see that

249
00:11:31,480 --> 00:11:24,860
four major constituents like water vapor

250
00:11:32,980 --> 00:11:31,490
and co in the base case which is the

251
00:11:34,690 --> 00:11:32,990
left-hand side so remember we're getting

252
00:11:38,769 --> 00:11:34,700
more volcanic outgassing in the

253
00:11:41,230 --> 00:11:38,779
left-hand cases your left on line you

254
00:11:45,449 --> 00:11:41,240
get pretty consistent atmospheric

255
00:11:49,079 --> 00:11:45,459
profiles across different stellar types

256
00:11:51,340 --> 00:11:49,089
but it's really when you get down here

257
00:11:53,650 --> 00:11:51,350
to where we're looking at the oxygen

258
00:11:58,810 --> 00:11:53,660
bearing species that something stands

259
00:12:02,019 --> 00:11:58,820
out and so here around GJ 876 we get

260
00:12:03,639 --> 00:12:02,029
about 10 to the minus 7 oxygen at the

261
00:12:06,340 --> 00:12:03,649
lower boundary which is somewhere

262
00:12:08,790 --> 00:12:06,350
between 6 and 10 x 10 orders of

263
00:12:14,470 --> 00:12:08,800

magnitude more oxygen than every other

264
00:12:16,900 --> 00:12:14,480
star in our model excuse me so this is

265
00:12:18,939 --> 00:12:16,910
just the base case where we have lots of

266
00:12:20,860 --> 00:12:18,949
volcanic out casting lots of reducing

267
00:12:23,110 --> 00:12:20,870
power going into the atmosphere if we

268
00:12:25,000 --> 00:12:23,120
turn down the volcanism not turn it all

269
00:12:26,860 --> 00:12:25,010
the way off just turn it down to a

270
00:12:28,240 --> 00:12:26,870
minimal level we're still putting

271
00:12:31,269 --> 00:12:28,250
reducing compounds into the atmosphere

272
00:12:33,100 --> 00:12:31,279
you get something like we see on Mars

273
00:12:35,530 --> 00:12:33,110
where we're nearly at a tenth of a

274
00:12:37,660 --> 00:12:35,540
percent oxygen at the lower boundary and

275
00:12:39,910 --> 00:12:37,670
this is a big deal if you were to

276
00:12:41,980 --> 00:12:39,920
continue to turn down volcanism on a

277
00:12:45,100 --> 00:12:41,990
terrestrial mass planet in the habitable

278
00:12:47,740 --> 00:12:45,110
zone you would get a runaway oxygenation

279
00:12:51,430 --> 00:12:47,750
you would get this false positive around

280
00:12:52,990 --> 00:12:51,440
an m-dwarf which is probably where we

281
00:12:54,370 --> 00:12:53,000
are going to find our first to rest room

282
00:12:56,769 --> 00:12:54,380
last planet where we're going to do our

283
00:12:59,800 --> 00:12:56,779
first spectroscopy where we're going to

284
00:13:03,240 --> 00:12:59,810
find this signpost that we think is

285
00:13:05,800 --> 00:13:03,250
infallible and so this result here is

286
00:13:09,340 --> 00:13:05,810
preliminary I won't say it's conclusive

287
00:13:11,710 --> 00:13:09,350
but it is indicative that there's a lot

288
00:13:14,710 --> 00:13:11,720

of work to be done on understanding how

289
00:13:19,400 --> 00:13:14,720
M Dwarfs how the spectral

290
00:13:23,270 --> 00:13:19,410
fluxes effect atmospheres especially in

291
00:13:25,190 --> 00:13:23,280
the context of bio signatures so we find

292
00:13:28,520 --> 00:13:25,200
this false positive lurking for high CO

293
00:13:30,790 --> 00:13:28,530
2 atmospheres future work we're going to

294
00:13:33,260 --> 00:13:30,800
look into actually keeping track of

295
00:13:34,520 --> 00:13:33,270
aqueous chemistry currently we're just

296
00:13:37,040 --> 00:13:34,530
returning reducing power to the

297
00:13:39,440 --> 00:13:37,050
atmospheres hydrogen it's not the best

298
00:13:40,670 --> 00:13:39,450
but we don't have a firm grasp on what

299
00:13:45,380 --> 00:13:40,680
aqueous chemistry is going to look like

300
00:13:48,470 --> 00:13:45,390
on an alien world so future work also

301
00:13:50,690 --> 00:13:48,480
will include exploring what parts of the

302
00:13:52,550 --> 00:13:50,700
stellar radiation are influencing this

303
00:13:55,610 --> 00:13:52,560
oxygen false positive so if we turn down

304
00:13:57,440 --> 00:13:55,620
for example the far UV radiation or the

305
00:14:00,620 --> 00:13:57,450
near UV radiation what's going to cause

306
00:14:02,780 --> 00:14:00,630
us to build up oxygen because every star

307
00:14:05,150 --> 00:14:02,790
is not alike and so we need to

308
00:14:07,130 --> 00:14:05,160
understand where in the stellar

309
00:14:09,020 --> 00:14:07,140
parameter space we're going to find

310
00:14:11,750 --> 00:14:09,030
these planets that look like they have

311
00:14:18,210 --> 00:14:11,760
life but probably don't and so with that

312
00:14:34,230 --> 00:14:23,700
yeah Thank Chester so no one cares about

313
00:14:35,670 --> 00:14:34,240

you Eric thanks honey yeah if you go

314
00:14:38,610 --> 00:14:35,680
back to your figures your four figures

315
00:14:41,550 --> 00:14:38,620
slide what's the main constituent of

316
00:14:43,680 --> 00:14:41,560
your atmosphere is it n to know these

317
00:14:45,930 --> 00:14:43,690
are ninety percent co2 atmosphere so n 2

318
00:14:48,570 --> 00:14:45,940
is a very minor component of these ok I

319
00:14:51,030 --> 00:14:48,580
see any don't blood co2 here ok well I

320
00:14:54,420 --> 00:14:51,040
mean so we set co2 is a fixed mixing

321
00:14:57,270 --> 00:14:54,430
ratio and I mean there have been studies

322
00:14:59,790 --> 00:14:57,280
that have used it as a as an actual

323
00:15:00,960 --> 00:14:59,800
variable chemical constituent but

324
00:15:02,760 --> 00:15:00,970
there's not really much of a difference

325
00:15:06,480 --> 00:15:02,770
between at these levels whether it's a

326
00:15:10,950 --> 00:15:06,490
fixed mixing ratio or variable chemical

327
00:15:13,710 --> 00:15:10,960
constituent thanks I do have a quick

328
00:15:15,750 --> 00:15:13,720
question so from from the observation

329
00:15:17,310 --> 00:15:15,760
decide what kind of telescopes do we

330
00:15:18,870 --> 00:15:17,320
need to observe stuff like that is that

331
00:15:21,360 --> 00:15:18,880
possible with James Webb or more with

332
00:15:22,680 --> 00:15:21,370
like next-generation telescopes that's

333
00:15:24,960 --> 00:15:22,690
actually a really good question for

334
00:15:27,180 --> 00:15:24,970
Natasha I think that the standard

335
00:15:29,010 --> 00:15:27,190
understanding is that a tenth of a

336
00:15:31,410 --> 00:15:29,020
percent oxygen is detectable with the

337
00:15:33,120 --> 00:15:31,420
next generation of telescopes so the

338
00:15:36,150 --> 00:15:33,130

oxygen false positives we see for

339
00:15:40,200 --> 00:15:36,160
reduced volcanic outgassing could be a