
THE HUNT FOR ISOTOP(OLOGU)ES
IN EXOPLANET ATMOSPHERES
PAUL MOLLIERE

1
00:00:08,970 --> 00:00:06,679
[Music]

2
00:00:11,580 --> 00:00:08,980
thank you very much else to the

3
00:00:14,640 --> 00:00:11,590
organizers to now give me time to speak

4
00:00:16,289 --> 00:00:14,650
here today yeah I said I will talk about

5
00:00:18,269 --> 00:00:16,299
how to find I stopped Locke's

6
00:00:20,520 --> 00:00:18,279
explanatory atmospheres using

7
00:00:23,580 --> 00:00:20,530
high-resolution cross circulation

8
00:00:27,090 --> 00:00:23,590
yeah spectroscopy this is work that I do

9
00:00:29,880 --> 00:00:27,100
together with Ignace nella in enlighten

10
00:00:32,400 --> 00:00:29,890
but because I got more time when I was

11
00:00:35,069 --> 00:00:32,410
hoping for you get two topics for the

12
00:00:36,660 --> 00:00:35,079
price of one so something else that I'll

13
00:00:39,030 --> 00:00:36,670

be talking about here you see that being

14
00:00:41,210 --> 00:00:39,040
alluded to here on the right is how to

15
00:00:44,880 --> 00:00:41,220
retrieve the atmospheres of

16
00:00:46,620 --> 00:00:44,890
self-luminous cloudy planets and yeah

17
00:00:48,959 --> 00:00:46,630
this is work I do together with people

18
00:00:51,270 --> 00:00:48,969
from the gravity collaboration so in

19
00:00:53,280 --> 00:00:51,280
this case Matthias Nowak Weslaco and

20
00:00:56,900 --> 00:00:53,290
Benjamin Shani from the observatory of

21
00:00:59,850 --> 00:00:56,910
Paris but to start the first topic

22
00:01:01,830 --> 00:00:59,860
isotopes yeah I thought maybe it's good

23
00:01:03,810 --> 00:01:01,840
to start actually with where these

24
00:01:06,060 --> 00:01:03,820
isotopes that you want to see in finance

25
00:01:07,889 --> 00:01:06,070
are coming from so then we can start by

26
00:01:09,960 --> 00:01:07,899
the isotopes that make up the molecules

27
00:01:14,490 --> 00:01:09,970
which are then called isotopes stem from

28
00:01:16,350 --> 00:01:14,500
so if if you look for carbon oxygen

29
00:01:19,320 --> 00:01:16,360
isotopes these are thought to come from

30
00:01:22,859 --> 00:01:19,330
the phases of evolved AGB stars

31
00:01:24,899 --> 00:01:22,869
and yeah 13 carbon for example which one

32
00:01:26,550 --> 00:01:24,909
instant species is a reaction

33
00:01:29,670 --> 00:01:26,560
intermediate of the siena of one branch

34
00:01:31,590 --> 00:01:29,680
of the CNO cycle for the theorem we

35
00:01:33,990 --> 00:01:31,600
basically would work with whatever the

36
00:01:36,899 --> 00:01:34,000
Stars have left falls from the Big Bang

37
00:01:38,880 --> 00:01:36,909
nucleosynthesis so this is where the

38
00:01:40,740 --> 00:01:38,890

isotopes in space are but want to bring

39
00:01:42,690 --> 00:01:40,750
them into planets so we have to look at

40
00:01:45,870 --> 00:01:42,700
the planetary building blocks and I'm

41
00:01:49,950 --> 00:01:45,880
focusing on the solid component and this

42
00:01:52,230 --> 00:01:49,960
is quite a nice thought from from the

43
00:01:55,200 --> 00:01:52,240
colossal Minko to you know analysis I'll

44
00:01:58,620 --> 00:01:55,210
take it out 2015 where they show the D

45
00:02:01,260 --> 00:01:58,630
to H number ratios in solid bodies in

46
00:02:03,660 --> 00:02:01,270
the solar system but yeah before I just

47
00:02:05,940 --> 00:02:03,670
talk about this also solid bodies this

48
00:02:08,190 --> 00:02:05,950
here's the book so a nebula value a 2

49
00:02:10,259 --> 00:02:08,200
times 10 to the minus 5 that's important

50
00:02:12,209 --> 00:02:10,269
there but you also see that some other

51
00:02:13,860 --> 00:02:12,219
planets are consistent with this but if

52
00:02:17,519 --> 00:02:13,870
you look at the solid building blocks

53
00:02:18,050 --> 00:02:17,529
the odd and the family comments the

54
00:02:20,600 --> 00:02:18,060
iron-rich

55
00:02:23,480 --> 00:02:20,610
factor of 10 or 20 even compared the pop

56
00:02:24,800 --> 00:02:23,490
solar nebula value icy moons could be

57
00:02:28,100 --> 00:02:24,810
thought of as a building block maybe as

58
00:02:29,690 --> 00:02:28,110
well so Enceladus is enriched chondrites

59
00:02:32,390 --> 00:02:29,700
enriched and also the earth finally is

60
00:02:34,580 --> 00:02:32,400
imaged so this is what we yeah working

61
00:02:36,290 --> 00:02:34,590
with when building planets and now

62
00:02:37,070 --> 00:02:36,300
looking actually now at the planets in

63
00:02:39,740 --> 00:02:37,080

the solar system

64
00:02:42,979 --> 00:02:39,750
I'm putting the DTH ratio that 1/2 as a

65
00:02:46,070 --> 00:02:42,989
function of mass yeah as I maybe already

66
00:02:48,020 --> 00:02:46,080
said a bit just just before Saturn and

67
00:02:50,750 --> 00:02:48,030
Jupiter are consistent with the solar

68
00:02:53,000 --> 00:02:50,760
nebula value yeah but if you look at

69
00:02:55,580 --> 00:02:53,010
Uranus and Neptune already they aren't

70
00:02:57,470 --> 00:02:55,590
rich about factor of 2 and if you look

71
00:02:59,630 --> 00:02:57,480
at the earth that is enriched by a

72
00:03:01,460 --> 00:02:59,640
factor of maybe 10 and this whole

73
00:03:03,140 --> 00:03:01,470
already kind of indicative of that of

74
00:03:05,960 --> 00:03:03,150
their being maybe a trend and as neither

75
00:03:08,360 --> 00:03:05,970
people think that maybe yeah he actually

76
00:03:09,949 --> 00:03:08,370
see a sign of relative importance of

77
00:03:11,930 --> 00:03:09,959
solid-body accretion during the

78
00:03:13,820 --> 00:03:11,940
formation of these planets are basically

79
00:03:15,920 --> 00:03:13,830
in Jupiter and Saturn just diluted with

80
00:03:18,860 --> 00:03:15,930
lots of gas from the from the from the

81
00:03:21,229 --> 00:03:18,870
disk then we get below eth ratios and

82
00:03:24,289 --> 00:03:21,239
yeah you have to be careful though so if

83
00:03:28,120 --> 00:03:24,299
you look at Venus Venus sitting at 1,000

84
00:03:30,110 --> 00:03:28,130
here and Mars is sitting at 50 and yeah

85
00:03:32,390 --> 00:03:30,120
the community thinks that's coming from

86
00:03:36,259 --> 00:03:32,400
a creation that basically retains the

87
00:03:37,789 --> 00:03:36,269
more massive yes species in this case

88
00:03:40,670 --> 00:03:37,799

deuterium is more massive than hydrogen

89
00:03:42,229 --> 00:03:40,680
if a body is more massive than 13

90
00:03:44,780 --> 00:03:42,239
Jupiter masses it will start burning

91
00:03:45,830 --> 00:03:44,790
deuterium we don't have a round off in

92
00:03:47,780 --> 00:03:45,840
the solar system

93
00:03:49,580 --> 00:03:47,790
yes they put it on here so that we

94
00:03:53,240 --> 00:03:49,590
wouldn't expect to see any deuterium in

95
00:03:55,580 --> 00:03:53,250
the atmospheres so how we find these

96
00:03:57,710 --> 00:03:55,590
isotope locks yeah

97
00:03:59,660 --> 00:03:57,720
one way is to go for high resolution

98
00:04:01,750 --> 00:03:59,670
spectroscopy because if you look at the

99
00:04:04,640 --> 00:04:01,760
lines in this case of carbon monoxide

100
00:04:07,039 --> 00:04:04,650
shown and the first overtone band at 2.4

101
00:04:08,810 --> 00:04:07,049
micron you see for the main isotope log

102
00:04:10,759 --> 00:04:08,820
and whites you see yeah well all the

103
00:04:12,140 --> 00:04:10,769
lines in high resolution and all the

104
00:04:14,720 --> 00:04:12,150
secondary I stopped logs

105
00:04:16,699 --> 00:04:14,730
searching see 1600 for example they give

106
00:04:18,800 --> 00:04:16,709
rise to these these blue lines that you

107
00:04:20,930 --> 00:04:18,810
see in between and the reason for that

108
00:04:22,670 --> 00:04:20,940
is just coming from quantum mechanics if

109
00:04:24,950 --> 00:04:22,680
you look at the rotation of the patient

110
00:04:26,390 --> 00:04:24,960
energy levels they depend for example on

111
00:04:28,040 --> 00:04:26,400
the reduced mass if you have a diatomic

112
00:04:29,779 --> 00:04:28,050
molecule if you start playing on the

113
00:04:31,360 --> 00:04:29,789

masses of one of these atomic partners

114
00:04:33,250 --> 00:04:31,370
your shifts and

115
00:04:36,430 --> 00:04:33,260
scale distances between of levels and

116
00:04:38,590 --> 00:04:36,440
you can just ripped around the lines the

117
00:04:40,689 --> 00:04:38,600
technique for them now finding us has

118
00:04:43,689 --> 00:04:40,699
been very nicely explained yes theory by

119
00:04:44,950 --> 00:04:43,699
Jane yeah but what we wanted to go for

120
00:04:46,540 --> 00:04:44,960
was the cross collation technique the

121
00:04:49,150 --> 00:04:46,550
problem is these planets have single two

122
00:04:50,860 --> 00:04:49,160
noises of one or below one on a single

123
00:04:53,110 --> 00:04:50,870
pixel and how will you be able to see a

124
00:04:54,790 --> 00:04:53,120
single line then this one possible for

125
00:04:57,400 --> 00:04:54,800
the single line but you use cross

126
00:04:59,409 --> 00:04:57,410
collation that's math math definition

127
00:05:01,570 --> 00:04:59,419
basically cost equation is just serve

128
00:05:03,219 --> 00:05:01,580
two functions you multiply them you

129
00:05:04,779 --> 00:05:03,229
calculate the integral and one of these

130
00:05:06,640 --> 00:05:04,789
functions has been shifted by certain

131
00:05:09,490 --> 00:05:06,650
amount and now one of these functions

132
00:05:10,930 --> 00:05:09,500
you can take to be the spectrum as a

133
00:05:13,029 --> 00:05:10,940
function of wavelength the observation

134
00:05:15,310 --> 00:05:13,039
and one could be a model for that

135
00:05:17,620 --> 00:05:15,320
observation and if you have the perfect

136
00:05:20,260 --> 00:05:17,630
model for the observation but the shift

137
00:05:22,180 --> 00:05:20,270
that you apply here so if you busy over

138
00:05:24,040 --> 00:05:22,190

for these two functions you multiply

139
00:05:27,159 --> 00:05:24,050
them you get the integral basically get

140
00:05:28,960 --> 00:05:27,169
just noise out but if you find the right

141
00:05:30,310 --> 00:05:28,970
shift and lines and the model fall on

142
00:05:32,500 --> 00:05:30,320
two lines in the spectrum and then

143
00:05:36,100 --> 00:05:32,510
that's good that basically boosts the

144
00:05:38,020 --> 00:05:36,110
line signal and then if you plot this

145
00:05:39,250 --> 00:05:38,030
integral thicken as a function of shift

146
00:05:42,520 --> 00:05:39,260
and the right side should be at zero you

147
00:05:44,500 --> 00:05:42,530
get a peak in the synthetic calculation

148
00:05:46,690 --> 00:05:44,510
here and if something is not in the

149
00:05:48,940 --> 00:05:46,700
spectrum you don't get a peak yeah and

150
00:05:50,860 --> 00:05:48,950
the really powerful thing about this is

151
00:05:53,200 --> 00:05:50,870
to first order you can say well the

152
00:05:54,760 --> 00:05:53,210
signal of this peak is roughly equal to

153
00:05:56,520 --> 00:05:54,770
the single pixel single line signal

154
00:05:58,600 --> 00:05:56,530
times the square root of number of lines

155
00:06:01,089 --> 00:05:58,610
yeah and this has been used extensively

156
00:06:03,550 --> 00:06:01,099
there was already more complete list yes

157
00:06:06,700 --> 00:06:03,560
they already into in stock yeah to find

158
00:06:09,430 --> 00:06:06,710
different molecules in emission in

159
00:06:11,950 --> 00:06:09,440
transmission you can also use as was

160
00:06:14,439 --> 00:06:11,960
said already the the shape or the shift

161
00:06:16,390 --> 00:06:14,449
of this correlation function to learn

162
00:06:19,240 --> 00:06:16,400
something about winds or spin rate of

163
00:06:20,770 --> 00:06:19,250

planets right so this is the technique

164
00:06:22,600 --> 00:06:20,780
that we wanted to use now the problem is

165
00:06:24,790 --> 00:06:22,610
isotopologues haven't been found in

166
00:06:28,270 --> 00:06:24,800
planets yet so we had to kind of make

167
00:06:30,339 --> 00:06:28,280
make our own signal observations so this

168
00:06:32,469 --> 00:06:30,349
what we did so we started with a

169
00:06:34,420 --> 00:06:32,479
self-consistent atmospheric model in

170
00:06:36,820 --> 00:06:34,430
radiative convective in chemical

171
00:06:38,980 --> 00:06:36,830
equilibrium so that works in that case I

172
00:06:40,060 --> 00:06:38,990
use my code we viously start with the

173
00:06:42,040 --> 00:06:40,070
initial guess for the temperature

174
00:06:43,930 --> 00:06:42,050
calculate Akutan chemistry use these

175
00:06:44,420 --> 00:06:43,940
abundances calculate opacities and they

176
00:06:46,400 --> 00:06:44,430
do rate

177
00:06:47,719 --> 00:06:46,410
transfer and a conductive adjustment

178
00:06:49,189 --> 00:06:47,729
step and we get the new temperature that

179
00:06:50,270 --> 00:06:49,199
is inconsistent with the initial

180
00:06:52,969 --> 00:06:50,280
temperature and then we just loop around

181
00:06:55,189 --> 00:06:52,979
until we find convert solution and then

182
00:06:57,320 --> 00:06:55,199
basically you've tried to play telescope

183
00:06:59,510 --> 00:06:57,330
instrument so we top so we

184
00:07:01,640 --> 00:06:59,520
post-processing is high these structures

185
00:07:03,170 --> 00:07:01,650
get high resolution spectra and then we

186
00:07:05,779 --> 00:07:03,180
applied oppler shift for the motion of

187
00:07:07,100 --> 00:07:05,789
the planet and the stellar system waxing

188
00:07:08,689 --> 00:07:07,110

and waning of the planet was take into

189
00:07:10,909 --> 00:07:08,699
account put in some terrific absorption

190
00:07:13,969 --> 00:07:10,919
pin that down to the instrumental

191
00:07:16,240 --> 00:07:13,979
resolution involves it and admit that

192
00:07:20,689 --> 00:07:16,250
undetected pixels added noise of course

193
00:07:23,390 --> 00:07:20,699
and then yeah tried playing observer to

194
00:07:26,150 --> 00:07:23,400
take out the two lyrics again that we

195
00:07:28,520 --> 00:07:26,160
put in and also sometimes removing all

196
00:07:30,350 --> 00:07:28,530
the lines in the Planet X plant that we

197
00:07:32,360 --> 00:07:30,360
don't interested in be able to really

198
00:07:33,909 --> 00:07:32,370
just measure the signal of the secondary

199
00:07:36,379 --> 00:07:33,919
isotope block that we wanted to measure

200
00:07:37,400 --> 00:07:36,389
this is a really really highest thing

201
00:07:39,560 --> 00:07:37,410
that's nice

202
00:07:42,650 --> 00:07:39,570
run another normally you just look like

203
00:07:44,890 --> 00:07:42,660
static but sorry is Felicity already so

204
00:07:47,029 --> 00:07:44,900
this is the phase of the planets this is

205
00:07:48,650 --> 00:07:47,039
this is the way I think down here

206
00:07:49,790 --> 00:07:48,660
color-coded is the emission signal you

207
00:07:51,650 --> 00:07:49,800
see the waxing and waning and the

208
00:07:53,600 --> 00:07:51,660
Doppler motion of the planets in this

209
00:07:54,770 --> 00:07:53,610
year is if you take out all the lines of

210
00:07:57,050 --> 00:07:54,780
all species we're not interested in

211
00:07:59,060 --> 00:07:57,060
these are only 13 carbon 60 no lines and

212
00:08:00,830 --> 00:07:59,070
you cannot using the cross collation

213
00:08:04,189 --> 00:08:00,840

technique you can now start to measure

214
00:08:06,980 --> 00:08:04,199
the signal is imprinted this is an

215
00:08:09,439 --> 00:08:06,990
example for a hot Jupiter so this is

216
00:08:11,689 --> 00:08:09,449
select calculation for HD one seven nine

217
00:08:14,390 --> 00:08:11,699
nine four nine B in this case we were

218
00:08:15,890 --> 00:08:14,400
looking for a carbon monoxide I stopped

219
00:08:19,640 --> 00:08:15,900
locks because carbon dress is a really

220
00:08:21,080 --> 00:08:19,650
favorable isotope ratio and we see color

221
00:08:25,339 --> 00:08:21,090
coded here is the detection

222
00:08:28,189 --> 00:08:25,349
signal-to-noise for 13 C six no and

223
00:08:30,140 --> 00:08:28,199
orange the main 12 six no in red as a

224
00:08:32,630 --> 00:08:30,150
function of wavelength in the background

225
00:08:34,730 --> 00:08:32,640
this here is the transmission of the

226
00:08:37,130 --> 00:08:34,740
Earth's atmosphere and in purple is your

227
00:08:38,510 --> 00:08:37,140
paucity of carbon monoxide so only of

228
00:08:40,130 --> 00:08:38,520
course where the transmission is high

229
00:08:41,899 --> 00:08:40,140
and where the opacity is actually

230
00:08:44,029 --> 00:08:41,909
nonzero we expect to see something and

231
00:08:46,699 --> 00:08:44,039
this is also a find so in the first

232
00:08:49,670 --> 00:08:46,709
overtone bands we get the main isotope

233
00:08:51,230 --> 00:08:49,680
block in our simulations with quite a

234
00:08:52,640 --> 00:08:51,240
hyacinth noise actually comparable to

235
00:08:55,160 --> 00:08:52,650
what has been found for that planets

236
00:08:57,079 --> 00:08:55,170
with real data it predicts that for the

237
00:08:58,319 --> 00:08:57,089
sector as to block within a single night

238
00:09:01,169 --> 00:08:58,329

of so we should get a

239
00:09:02,910 --> 00:09:01,179
on Phi Sigma the fundamental band would

240
00:09:05,699 --> 00:09:02,920
be even better if there was no earth

241
00:09:06,929 --> 00:09:05,709
atmosphere emitting and yeah just

242
00:09:11,009 --> 00:09:06,939
putting noise basically in terms of

243
00:09:12,389 --> 00:09:11,019
photons yeah so I talked about h.o.t to

244
00:09:13,739 --> 00:09:12,399
H ratio being important but this is no

245
00:09:16,319 --> 00:09:13,749
carbon so let's talk about something

246
00:09:19,590 --> 00:09:16,329
more interesting as I made these pots

247
00:09:21,269 --> 00:09:19,600
here as well which basically help you

248
00:09:23,910 --> 00:09:21,279
understand how easy it is to see in this

249
00:09:25,799 --> 00:09:23,920
case H do so the deuterium carrying

250
00:09:27,509 --> 00:09:25,809
water at stop block and how you read

251
00:09:30,840 --> 00:09:27,519
these spots is if you have a planet of

252
00:09:32,639 --> 00:09:30,850
say 600 K equipment temperature and you

253
00:09:35,280 --> 00:09:32,649
assume well it's a gas giant maybe as a

254
00:09:37,889 --> 00:09:35,290
solar put a solar nebula value H ratio

255
00:09:39,840 --> 00:09:37,899
so you had one year then looking at the

256
00:09:41,669 --> 00:09:39,850
color here or the levels here tells you

257
00:09:43,590 --> 00:09:41,679
the signal-to-noise we have to have on

258
00:09:46,769 --> 00:09:43,600
your observation on a single pixel in

259
00:09:49,470 --> 00:09:46,779
order to detect H do so in that case for

260
00:09:51,059 --> 00:09:49,480
that 600 K one planet you would need to

261
00:09:53,160 --> 00:09:51,069
have a single pick sickness between one

262
00:09:55,439 --> 00:09:53,170
and three to CH you are the signals of

263
00:09:57,809 --> 00:09:55,449

five which is pretty bad in terms of

264
00:09:59,879 --> 00:09:57,819
boosting and signal problem is here

265
00:10:03,150 --> 00:09:59,889
that's a so sorry and I actually put

266
00:10:05,729 --> 00:10:03,160
some single nights predictions using BLT

267
00:10:07,530 --> 00:10:05,739
and ELT instruments to to actually see

268
00:10:09,539 --> 00:10:07,540
what we could get to in single night so

269
00:10:11,729 --> 00:10:09,549
this really looks really hard the

270
00:10:13,470 --> 00:10:11,739
problem is here that H 2 is actually

271
00:10:16,619 --> 00:10:13,480
strongly blanketed by methane in

272
00:10:18,449 --> 00:10:16,629
hydrogen tamara spears the way around

273
00:10:20,189 --> 00:10:18,459
this could be that if you go to cool

274
00:10:23,429 --> 00:10:20,199
kulish planets where non-acute in

275
00:10:26,189 --> 00:10:23,439
chemistry mixes methane poor material to

276
00:10:27,929 --> 00:10:26,199
the firts fears that you don't have this

277
00:10:30,239 --> 00:10:27,939
blanketing anymore so if you fully take

278
00:10:32,879 --> 00:10:30,249
out the methane opacity and methane's

279
00:10:35,189 --> 00:10:32,889
influence on these models it looks much

280
00:10:37,109 --> 00:10:35,199
much better very much easier with VLT

281
00:10:38,249 --> 00:10:37,119
the crowd's past comes back within a

282
00:10:41,159 --> 00:10:38,259
single night you should be able to see

283
00:10:42,179 --> 00:10:41,169
something but it is a very very extreme

284
00:10:45,239 --> 00:10:42,189
and optimistic

285
00:10:47,850 --> 00:10:45,249
okay so basic is saying the truth should

286
00:10:51,090 --> 00:10:47,860
be somewhere in between yeah don't don't

287
00:10:55,619 --> 00:10:51,100
take those at face value we also look

288
00:10:58,109 --> 00:10:55,629

it's yeah methane CH 3 D here it

289
00:11:00,629 --> 00:10:58,119
actually looks as difficult or more

290
00:11:04,379 --> 00:11:00,639
difficult as it does for the nominal HD

291
00:11:05,819 --> 00:11:04,389
okay's the problem here is that yeah

292
00:11:08,039 --> 00:11:05,829
just the sky background emission is

293
00:11:10,859 --> 00:11:08,049
really bad basically from space will be

294
00:11:11,790 --> 00:11:10,869
much better and this also was Helen

295
00:11:13,499 --> 00:11:11,800
Molly showed

296
00:11:16,379 --> 00:11:13,509
in the paper that she brought last at

297
00:11:18,660 --> 00:11:16,389
the same time as ours baby you see that

298
00:11:20,879 --> 00:11:18,670
if you go for coolish step lemma

299
00:11:23,189 --> 00:11:20,889
Skynet's within 10 parsecs within I

300
00:11:27,299 --> 00:11:23,199
think 10 hours 8 hours like a single

301
00:11:34,220 --> 00:11:27,309
night you can actually start seeing yeah

302
00:11:37,259 --> 00:11:34,230
CHP in these in these exciting one very

303
00:11:39,389 --> 00:11:37,269
fortunate case for this study if you

304
00:11:41,609 --> 00:11:39,399
make the right assumptions is the case

305
00:11:45,689 --> 00:11:41,619
of Proximus mb so this is proximal

306
00:11:47,519 --> 00:11:45,699
Center so yeah the the yeah planet in

307
00:11:49,499 --> 00:11:47,529
the habitable zone drawn the closest arc

308
00:11:51,509 --> 00:11:49,509
from the solar system they have been

309
00:11:53,579 --> 00:11:51,519
predictions on the climate stage when

310
00:11:55,559 --> 00:11:53,589
the paper the time it was announced I'm

311
00:11:58,799 --> 00:11:55,569
not going to be and for example for

312
00:12:00,720 --> 00:11:58,809
tightly locked that or a CT to spin

313
00:12:03,090 --> 00:12:00,730

orbit resonance planets but if saying

314
00:12:04,470 --> 00:12:03,100
temperature maps for the planets for

315
00:12:07,829 --> 00:12:04,480
different atmospheric abundances

316
00:12:09,960 --> 00:12:07,839
earth-like or co2 greenhouse atmosphere

317
00:12:12,449 --> 00:12:09,970
but everything which is blue here in

318
00:12:14,340 --> 00:12:12,459
these temperature maps allows for liquid

319
00:12:15,960 --> 00:12:14,350
water on the surface and then if you

320
00:12:16,949 --> 00:12:15,970
have like the water on the surface maybe

321
00:12:19,439 --> 00:12:16,959
you can also have steam in the

322
00:12:21,739 --> 00:12:19,449
atmosphere obviously so yeah maybe it

323
00:12:25,199 --> 00:12:21,749
makes sense to a creature on this planet

324
00:12:27,359 --> 00:12:25,209
young so we saw this paper and then is

325
00:12:30,539 --> 00:12:27,369
just assumed twin and put that around

326
00:12:32,939 --> 00:12:30,549
próximas then this is what we get so in

327
00:12:35,609 --> 00:12:32,949
in red this is the reflected light of

328
00:12:37,499 --> 00:12:35,619
Proxima 7 when you put the earth around

329
00:12:39,660 --> 00:12:37,509
focus mass in and serve it from the

330
00:12:42,869 --> 00:12:39,670
solar system and then white this is the

331
00:12:46,590 --> 00:12:42,879
emission that we calculate and actually

332
00:12:48,119 --> 00:12:46,600
these two vertical lines in between us

333
00:12:51,059 --> 00:12:48,129
the range that we interested in for HDL

334
00:12:52,829 --> 00:12:51,069
and you can already see making certain

335
00:12:55,350 --> 00:12:52,839
assumptions on the albedo which is took

336
00:12:57,210 --> 00:12:55,360
to be 30% the reflected light is

337
00:13:00,749 --> 00:12:57,220
actually better than the emitted light

338
00:13:02,669 --> 00:13:00,759

and if you zoom in all these lines here

339
00:13:05,189 --> 00:13:02,679
are coming from h2o there's no water

340
00:13:07,230 --> 00:13:05,199
because yeah at this wavelength range H

341
00:13:08,999 --> 00:13:07,240
you're strong water this week there's a

342
00:13:11,129 --> 00:13:09,009
little methane in the Earth's atmosphere

343
00:13:14,220 --> 00:13:11,139
so we predict making certain assumptions

344
00:13:16,439 --> 00:13:14,230
again on the flux suppression at 2

345
00:13:18,329 --> 00:13:16,449
lambda over D away from the star using

346
00:13:21,030 --> 00:13:18,339
the Eels he meters instrument when it

347
00:13:22,470 --> 00:13:21,040
comes online that within a single night

348
00:13:25,079 --> 00:13:22,480
if it's really an earth twin you should

349
00:13:30,030 --> 00:13:25,089
be able to see the H 0 it should be

350
00:13:32,850 --> 00:13:30,040
Marcus something else yeah that's also

351
00:13:35,189 --> 00:13:32,860
interesting yes there was a paper the

352
00:13:37,230 --> 00:13:35,199
CFL in coffee at all where they look at

353
00:13:39,720 --> 00:13:37,240
Travis one be if it was as enriched in

354
00:13:41,790 --> 00:13:39,730
the serum as Venus is then I think in

355
00:13:44,400 --> 00:13:41,800
within ten transits with James Webb

356
00:13:46,079 --> 00:13:44,410
those be able to see the h2o Sigma so

357
00:13:51,150 --> 00:13:46,089
this is an alternative interesting ruby

358
00:13:53,730 --> 00:13:51,160
thing right so that was about I stopped

359
00:13:56,819 --> 00:13:53,740
locks now the second topic they I won't

360
00:14:01,110 --> 00:13:56,829
talk about I already talked about a bit

361
00:14:02,460 --> 00:14:01,120
that I post processed these is structure

362
00:14:04,679 --> 00:14:02,470
calculations to get high-resolution

363
00:14:06,660 --> 00:14:04,689

spectrum and I did that with a tool that

364
00:14:09,090 --> 00:14:06,670
I put out a couple of months ago it's

365
00:14:11,009 --> 00:14:09,100
called pto Atkins this is the website

366
00:14:13,889 --> 00:14:11,019
where you can find it and this is open a

367
00:14:15,360 --> 00:14:13,899
publicly available tool and source can

368
00:14:17,460 --> 00:14:15,370
calculate low in high resolution spectra

369
00:14:19,199 --> 00:14:17,470
if you provide a atmospheric profile

370
00:14:20,189 --> 00:14:19,209
temperature in the band's profile you

371
00:14:22,739 --> 00:14:20,199
can do transmission emission

372
00:14:24,809 --> 00:14:22,749
spectroscopy clear and cloudy at models

373
00:14:27,689 --> 00:14:24,819
if you want you can use optical

374
00:14:31,350 --> 00:14:27,699
constants for the clouds I claim it's

375
00:14:33,840 --> 00:14:31,360
easy to use it's entitled so I'm so

376
00:14:36,210 --> 00:14:33,850
happy to be available and also claim

377
00:14:37,980 --> 00:14:36,220
that's fast accurate in benchmarked so

378
00:14:39,809 --> 00:14:37,990
if you want you can try it out but this

379
00:14:42,389 --> 00:14:39,819
was really what I used for the second

380
00:14:44,160 --> 00:14:42,399
part and the big problem is here in box

381
00:14:46,019 --> 00:14:44,170
are announced here and the public

382
00:14:47,549 --> 00:14:46,029
version there's no scattering included

383
00:14:49,530 --> 00:14:47,559
in the emission spectroscopy right now

384
00:14:50,790 --> 00:14:49,540
it's in the transit but transmission

385
00:14:53,220 --> 00:14:50,800
spectroscopy I'm not in the mission

386
00:14:55,139 --> 00:14:53,230
because it's hard to make it fast and to

387
00:14:56,309 --> 00:14:55,149
show you why this is a big problem if

388
00:14:58,169 --> 00:14:56,319

you look at self-luminous

389
00:15:01,169 --> 00:14:58,179
spectra which you think I supposed to be

390
00:15:03,480 --> 00:15:01,179
cloudy maybe this is a prediction of

391
00:15:06,660 --> 00:15:03,490
myself consistent codes putting clouds

392
00:15:10,230 --> 00:15:06,670
in self luminous object and if I just

393
00:15:12,239 --> 00:15:10,240
feed the structure in in pretty hot

394
00:15:14,699 --> 00:15:12,249
hands code but neglect scattering

395
00:15:16,769 --> 00:15:14,709
I get this the I think scattering you

396
00:15:18,360 --> 00:15:16,779
gets way too much flux out you can treat

397
00:15:19,650 --> 00:15:18,370
the scattering as absorption but then

398
00:15:22,499 --> 00:15:19,660
you get to way too little flanks hours

399
00:15:24,809 --> 00:15:22,509
and so it doesn't really work so I try

400
00:15:28,230 --> 00:15:24,819
to make scattering work in a fast ways

401
00:15:29,639 --> 00:15:28,240
with how it currently looks like so I

402
00:15:31,799 --> 00:15:29,649
see it's not yet perfect but if it's

403
00:15:33,929 --> 00:15:31,809
much much much better than before and

404
00:15:35,939 --> 00:15:33,939
the thing is so the accuracy here is a

405
00:15:37,289 --> 00:15:35,949
basically freely scalable parameter but

406
00:15:38,790 --> 00:15:37,299
now it's chosen such that it within a

407
00:15:40,769 --> 00:15:38,800
couple of seconds to get

408
00:15:44,610 --> 00:15:40,779
the spectrum out mission actually allows

409
00:15:46,290 --> 00:15:44,620
two to retrievals and this was the whole

410
00:15:49,410 --> 00:15:46,300
point why I started doing this because I

411
00:15:50,790 --> 00:15:49,420
saw was approach kind of by the gravis

412
00:15:53,310 --> 00:15:50,800
people and saw the really really nice

413
00:15:56,610 --> 00:15:53,320

spectrum but better pick B which is not

414
00:15:58,740 --> 00:15:56,620
yet published but you can see there in a

415
00:16:02,040 --> 00:15:58,750
second I talk about some more slide

416
00:16:03,990 --> 00:16:02,050
sorry right so with that code and

417
00:16:06,509 --> 00:16:04,000
scattering now in flowers I can actually

418
00:16:08,750 --> 00:16:06,519
retrieve more or less what I put in so

419
00:16:10,560 --> 00:16:08,760
this is the temperature profile of that

420
00:16:12,870 --> 00:16:10,570
self-consistent cloudy spectrum that I

421
00:16:15,990 --> 00:16:12,880
showed you and this is the insert the

422
00:16:17,970 --> 00:16:16,000
envelopes that I retrieve and yeah I

423
00:16:20,370 --> 00:16:17,980
cannot retrieve the parameters that I

424
00:16:22,889 --> 00:16:20,380
put in so these are CTO ratios in the

425
00:16:24,870 --> 00:16:22,899
atmosphere metallicity I can retrieve

426
00:16:27,300 --> 00:16:24,880
that I didn't put a quench pressure or

427
00:16:29,250 --> 00:16:27,310
didn't have frenching in my model yet

428
00:16:31,769 --> 00:16:29,260
cloud parameters I can retrieve log T

429
00:16:36,420 --> 00:16:31,779
radius so obvious tests seem to work for

430
00:16:39,870 --> 00:16:36,430
now right but now coming to a very nice

431
00:16:42,600 --> 00:16:39,880
gravity but I pick B spectrum that's in

432
00:16:43,819 --> 00:16:42,610
the K bound to see that here when I saw

433
00:16:46,440 --> 00:16:43,829
that for the first time was actually

434
00:16:48,389 --> 00:16:46,450
glowing awake you can say because I mean

435
00:16:50,220 --> 00:16:48,399
the resolution is very high the

436
00:16:52,920 --> 00:16:50,230
signal-to-noise is very high you can see

437
00:16:57,300 --> 00:16:52,930
really cool stuff like multiple carbon

438
00:17:00,060 --> 00:16:57,310

monoxide band hats there's some problems

439
00:17:02,250 --> 00:17:00,070
still going on here but just overall the

440
00:17:04,409 --> 00:17:02,260
spectrum is really really nice you see

441
00:17:06,780 --> 00:17:04,419
actually in purple is the fit that we

442
00:17:08,640 --> 00:17:06,790
get if you got tons now in the back so

443
00:17:09,449 --> 00:17:08,650
it feels very good there's a bit of a

444
00:17:13,140 --> 00:17:09,459
difference here

445
00:17:14,819 --> 00:17:13,150
in the red slope of the flux this

446
00:17:16,679 --> 00:17:14,829
actually comes from that we don't not

447
00:17:19,470 --> 00:17:16,689
only fit the gravity data we also feel

448
00:17:23,579 --> 00:17:19,480
cheap line the GPA at the same time so

449
00:17:25,829 --> 00:17:23,589
the combined fit looks like this yeah so

450
00:17:28,530 --> 00:17:25,839
it fits here it fits very well here if

451
00:17:30,210 --> 00:17:28,540
it's a bit less less well the problem

452
00:17:32,370 --> 00:17:30,220
actually is the signal-to-noise he is so

453
00:17:33,930 --> 00:17:32,380
high but the GPI data is never allowed

454
00:17:35,970 --> 00:17:33,940
to dominate too strongly

455
00:17:38,400 --> 00:17:35,980
if you blow up the arrow bars here the

456
00:17:41,790 --> 00:17:38,410
fit becomes better here yeah but we

457
00:17:45,960 --> 00:17:41,800
decided against doing this for now right

458
00:17:48,210 --> 00:17:45,970
and yeah so we can fit that now and you

459
00:17:50,190 --> 00:17:48,220
can also see what the rigidity profile

460
00:17:52,650 --> 00:17:50,200
is so you get like a typical

461
00:17:54,810 --> 00:17:52,660
wrong go of cloudy like the keep

462
00:17:57,360 --> 00:17:54,820
while in this case the fitfully clouds

463
00:17:59,670 --> 00:17:57,370

and iron cloud here to hide these deep

464
00:18:02,970 --> 00:17:59,680
regions from you not get too much flux

465
00:18:04,470 --> 00:18:02,980
out in the noon Fred and what I really

466
00:18:06,060 --> 00:18:04,480
liked about this brush like about this

467
00:18:07,830 --> 00:18:06,070
project so this is materials know I

468
00:18:09,480 --> 00:18:07,840
guess leading this and it's in prep and

469
00:18:11,100 --> 00:18:09,490
should be submitted soon what I really

470
00:18:12,540 --> 00:18:11,110
like about this project that it's also a

471
00:18:15,030 --> 00:18:12,550
banjo national name who is part of this

472
00:18:18,870 --> 00:18:15,040
team and he has the axiom code which is

473
00:18:22,010 --> 00:18:18,880
self-consistent cloudy cloud feedback

474
00:18:24,030 --> 00:18:22,020
couples non equilibrium chemistry code

475
00:18:25,290 --> 00:18:24,040
also for doing these kind of

476
00:18:27,180 --> 00:18:25,300
calculations but in a self-consistent

477
00:18:28,650 --> 00:18:27,190
not in the free retrieval way if you

478
00:18:30,530 --> 00:18:28,660
actually compare if what we get out

479
00:18:33,570 --> 00:18:30,540
makes sense or if it's at least the same

480
00:18:35,580 --> 00:18:33,580
so we get that as well so we both find a

481
00:18:37,980 --> 00:18:35,590
CTO ratio which is one point for you

482
00:18:40,980 --> 00:18:37,990
both find that the planet is enriched by

483
00:18:42,330 --> 00:18:40,990
a factor of three to five maybe my value

484
00:18:44,370 --> 00:18:42,340
is a bit higher but he actually the

485
00:18:47,850 --> 00:18:44,380
upper limit of the grid was hit that was

486
00:18:50,130 --> 00:18:47,860
used for the fit I find a bit over 200k

487
00:18:51,900 --> 00:18:50,140
hotter temperature polar planets but

488
00:18:54,510 --> 00:18:51,910

also find a smaller radius which

489
00:18:56,190 --> 00:18:54,520
basically yeah then just or for the

490
00:18:57,720 --> 00:18:56,200
temperature radius a difference here

491
00:18:59,760 --> 00:18:57,730
because you want to have the same flux

492
00:19:01,260 --> 00:18:59,770
coming out of the planet and I'll talk

493
00:19:03,870 --> 00:19:01,270
about that bit more in a second as well

494
00:19:06,360 --> 00:19:03,880
the rock G is also comparable mine's a

495
00:19:09,030 --> 00:19:06,370
bit higher again but potentially if a hi

496
00:19:10,170 --> 00:19:09,040
I'm Christy was allowed here potentially

497
00:19:12,060 --> 00:19:10,180
he also looked he could have been hired

498
00:19:13,950 --> 00:19:12,070
because there's a degeneracy between the

499
00:19:15,480 --> 00:19:13,960
two the city and look G and what is

500
00:19:18,240 --> 00:19:15,490
really cool but I like a lot about this

501
00:19:19,890 --> 00:19:18,250
is that the mass that I get only from

502
00:19:21,780 --> 00:19:19,900
the spectrum is actually consistent with

503
00:19:24,990 --> 00:19:21,790
the astrometric mass that comes from

504
00:19:26,490 --> 00:19:25,000
either the guy and Hipparcos coupling or

505
00:19:28,830 --> 00:19:26,500
from the extremity of the gravity

506
00:19:30,600 --> 00:19:28,840
measurement so that's just coming from

507
00:19:33,930 --> 00:19:30,610
the spectrum now and it's consistent

508
00:19:35,400 --> 00:19:33,940
with measurement for the xrm fit in this

509
00:19:38,150 --> 00:19:35,410
case there was a prior that to be

510
00:19:42,090 --> 00:19:38,160
applied to get a similar mass collection

511
00:19:43,980 --> 00:19:42,100
yeah so right one that one last also

512
00:19:46,320 --> 00:19:43,990
word on this on this temperature and

513
00:19:48,050 --> 00:19:46,330

radius differences these values here a

514
00:19:49,770 --> 00:19:48,060
bit more consistent also with

515
00:19:52,680 --> 00:19:49,780
oscillating at the mass with

516
00:19:55,170 --> 00:19:52,690
evolutionary models being that large at

517
00:19:57,630 --> 00:19:55,180
that mass actually would require a

518
00:20:00,210 --> 00:19:57,640
higher mass at that age of the system

519
00:20:02,670 --> 00:20:00,220
and a higher temperature yeah so one one

520
00:20:05,160 --> 00:20:02,680
that wasn't comment on that but in

521
00:20:06,010 --> 00:20:05,170
general it looks pretty consistent it

522
00:20:08,230 --> 00:20:06,020
makes

523
00:20:10,720 --> 00:20:08,240
no sense for now maybe that was also

524
00:20:13,570 --> 00:20:10,730
just luck but what I what I like about

525
00:20:15,730 --> 00:20:13,580
this is now maybe we can then trust

526
00:20:17,620 --> 00:20:15,740
these c2o ratios dimension C values

527
00:20:19,810 --> 00:20:17,630
somewhat more and they actually think

528
00:20:23,320 --> 00:20:19,820
about how can one find out which is that

529
00:20:24,700 --> 00:20:23,330
massive be quite strongly enraged it's a

530
00:20:25,780 --> 00:20:24,710
sub so that's it already was at

531
00:20:27,790 --> 00:20:25,790
substellar we don't know because you

532
00:20:29,560 --> 00:20:27,800
don't know the CTO ratio of the star but

533
00:20:32,680 --> 00:20:29,570
you can I think maybe start thinking

534
00:20:34,960 --> 00:20:32,690
about explaining information with a bit

535
00:20:47,890 --> 00:20:34,970
more trust on what has been derived for

536
00:20:51,310 --> 00:20:47,900
the spectrum thank you very much thank

537
00:20:55,900 --> 00:20:51,320
you very much well um I see a question

538
00:20:57,310 --> 00:20:55,910

over there Hika Hika Hika fine hailing

539
00:20:59,530 --> 00:20:57,320
from Santa Rosa thank you for this nice

540
00:21:02,830 --> 00:20:59,540
talk but I think we need to realize that

541
00:21:04,630 --> 00:21:02,840
your teacher or ratio and your element

542
00:21:06,250 --> 00:21:04,640
abundances are only for the optically

543
00:21:08,560 --> 00:21:06,260
thin part of the atmosphere

544
00:21:11,850 --> 00:21:08,570
so therefore very extremely hard to

545
00:21:15,010 --> 00:21:11,860
linked us to planetary evolution slash

546
00:21:19,480 --> 00:21:15,020
formation models right so it's a bit of

547
00:21:22,510 --> 00:21:19,490
yeah I mean go I mean thatís of course

548
00:21:24,100 --> 00:21:22,520
important point and yeah it's a bit of a

549
00:21:26,560 --> 00:21:24,110
difference so what is important here

550
00:21:28,510 --> 00:21:26,570
this is chemical equilibrium with a

551
00:21:30,640 --> 00:21:28,520
quench pressure so it's not that I'm

552
00:21:33,550 --> 00:21:30,650
kind of affected by condensation in a

553
00:21:35,230 --> 00:21:33,560
sense and then I assume I get a wrong

554
00:21:37,290 --> 00:21:35,240
CTO ratio out because the pronunciation

555
00:21:40,090 --> 00:21:37,300
is they put put into this as well and

556
00:21:41,620 --> 00:21:40,100
yes you're right there's a very

557
00:21:43,240 --> 00:21:41,630
important step which is connecting the

558
00:21:46,450 --> 00:21:43,250
atmosphere to the interior part this is

559
00:21:48,730 --> 00:21:46,460
crucial and I think getting you would

560
00:21:50,230 --> 00:21:48,740
not get an even you would not get a high

561
00:21:52,480 --> 00:21:50,240
metallicity in the atmosphere and a

562
00:21:55,240 --> 00:21:52,490
lower one envelope I think because of

563
00:21:56,800 --> 00:21:55,250

settling so if if you say you get a very

564
00:21:59,320 --> 00:21:56,810
high this year in the atmosphere already

565
00:22:00,070 --> 00:21:59,330
it can potentially only be higher in the

566
00:22:08,040 --> 00:22:00,080
in the envelope

567
00:22:15,520 --> 00:22:11,710
hey Jeremy reckons Gianaris

568
00:22:17,530 --> 00:22:15,530
I'm just wondering if you do find that

569
00:22:18,680 --> 00:22:17,540
you have clouds that are hiding your

570
00:22:21,349 --> 00:22:18,690
lower Atmos

571
00:22:23,330 --> 00:22:21,359
how come your uncertainties on the

572
00:22:25,580 --> 00:22:23,340
temperature in this floor atmosphere are

573
00:22:28,009 --> 00:22:25,590
not bigger okay that's a good very

574
00:22:30,139 --> 00:22:28,019
important question so when I did these

575
00:22:32,330 --> 00:22:30,149
retrieval tests where I tried to

576
00:22:33,889 --> 00:22:32,340
retrieve what I put in and I put in a

577
00:22:36,289 --> 00:22:33,899
brown wolf

578
00:22:39,259 --> 00:22:36,299
klaudia structure which had a clouds and

579
00:22:41,450 --> 00:22:39,269
there had a quite free PT proper

580
00:22:44,419 --> 00:22:41,460
parameters ation I basically got Pascal

581
00:22:45,289 --> 00:22:44,429
Tomlin's answer which even though I knew

582
00:22:48,049 --> 00:22:45,299
it was cloudy

583
00:22:52,249 --> 00:22:48,059
I got no clouds and quiet isothermal

584
00:22:54,979 --> 00:22:52,259
deep regions and so I had to think about

585
00:22:56,839 --> 00:22:54,989
this a bit how making the assumptions of

586
00:22:59,089 --> 00:22:56,849
that there are clouds I can retrieve

587
00:23:01,879 --> 00:22:59,099
what I put in and what I do is actually

588
00:23:03,979 --> 00:23:01,889

in the deep regions from my radiative

589
00:23:07,219 --> 00:23:03,989
transfer modeling I get an estimate of

590
00:23:08,690 --> 00:23:07,229
the Kappa rosseland mean opacity so then

591
00:23:11,149 --> 00:23:08,700
I know where the atmosphere should

592
00:23:14,899 --> 00:23:11,159
become up to be thick and there I give a

593
00:23:17,029 --> 00:23:14,909
quite a strong prior penalty if the

594
00:23:18,799 --> 00:23:17,039
atmosphere is not radiative variant if

595
00:23:21,710 --> 00:23:18,809
diffusive in the temperature people in

596
00:23:24,169 --> 00:23:21,720
the PT gradient and of course is some

597
00:23:26,119 --> 00:23:24,179
kind of physical prior if it's even keep

598
00:23:29,359 --> 00:23:26,129
I also force it onto a conductor a moist

599
00:23:31,609 --> 00:23:29,369
adiabat so that's why knowing what's

600
00:23:33,499 --> 00:23:31,619
going on up there and also yeah

601
00:23:39,080 --> 00:23:33,509
the propagates down into what you see

602
00:23:40,580 --> 00:23:39,090
down there in the beginning of your talk

603
00:23:42,769 --> 00:23:40,590
you mentioned that the earth has a high

604
00:23:44,359 --> 00:23:42,779
D to H ratio as compared to Saturn and

605
00:23:46,789 --> 00:23:44,369
Jupiter and you explained that it's

606
00:23:49,180 --> 00:23:46,799
because of because of accreted lot of

607
00:23:53,089 --> 00:23:49,190
gases I don't know

608
00:23:56,930 --> 00:23:53,099
yeah all right so no I think so the

609
00:23:58,999 --> 00:23:56,940
earth I think it created more solids in

610
00:24:00,789 --> 00:23:59,009
the rocket then it's in comparison to

611
00:24:03,469 --> 00:24:00,799
the triumph in its and that's why

612
00:24:05,869 --> 00:24:03,479
situation with Mike I think that one of

613
00:24:08,570 --> 00:24:05,879

other reason is the loss of hydrogen

614
00:24:12,249 --> 00:24:08,580
from the atmosphere of the earth early

615
00:24:16,460 --> 00:24:12,259
Earth that increased the d2s ratio okay

616
00:24:18,619 --> 00:24:16,470
there's a review by gender at all 2016

617
00:24:20,389 --> 00:24:18,629
that mentioned the the other factors