Thea Kozakis

Dying to Live:
Post-Main Sequence Habitability

1
00:00:00,240 --> 00:00:10,810
[Music]

2
00:00:19,010 --> 00:00:13,610
all right so I'm just signal if it's not

3
00:00:22,070 --> 00:00:19,020
or this stops working so I am SIA and

4
00:00:24,920 --> 00:00:22,080
I'm a graduate student at Cornell at the

5
00:00:27,590 --> 00:00:24,930
Carl Sagan Institute I work with Lisa

6
00:00:29,600 --> 00:00:27,600
Colton Egger I also work with Jack the

7
00:00:31,460 --> 00:00:29,610
color got from his few talks ago and he

8
00:00:33,650 --> 00:00:31,470
actually made me this image for my

9
00:00:34,970 --> 00:00:33,660
research so if you become friends with

10
00:00:37,189 --> 00:00:34,980
him sometimes he makes artists

11
00:00:38,840 --> 00:00:37,199
conception of your research so today I'm

12
00:00:40,099 --> 00:00:38,850
gonna talk to you about my most recent

13
00:00:42,380 --> 00:00:40,109

oh my god

14
00:00:44,060 --> 00:00:42,390
project which is a post main-sequence

15
00:00:45,349 --> 00:00:44,070
habitability and I'm gonna tell you what

16
00:00:48,349 --> 00:00:45,359
the post main sequence is because I'm

17
00:00:51,520 --> 00:00:48,359
aware that you're not all astronomers so

18
00:00:54,410 --> 00:00:51,530
my thesis is basically about how

19
00:00:56,090 --> 00:00:54,420
habitability and planetary atmospheres

20
00:00:58,219 --> 00:00:56,100
would change throughout stellar

21
00:00:59,630 --> 00:00:58,229
evolution so if we want to put earth

22
00:01:02,029 --> 00:00:59,640
around another star

23
00:01:03,619 --> 00:01:02,039
it wouldn't be earth anymore because

24
00:01:05,060 --> 00:01:03,629
that star is different it has a

25
00:01:07,190 --> 00:01:05,070
different brightness and it's giving off

26
00:01:08,840 --> 00:01:07,200
different types of light and the light

27
00:01:10,690 --> 00:01:08,850
the star is giving off it affects

28
00:01:13,070 --> 00:01:10,700
everything in the planet if tribes the

29
00:01:16,550 --> 00:01:13,080
chemistry of the atmosphere surface

30
00:01:18,680 --> 00:01:16,560
temperature everything so you really

31
00:01:21,320 --> 00:01:18,690
have to think about what star your

32
00:01:23,090 --> 00:01:21,330
planet is around and I don't just do

33
00:01:27,370 --> 00:01:23,100
that I also think about where is that

34
00:01:35,360 --> 00:01:32,060
where is the star in evolution so amber

35
00:01:38,390 --> 00:01:35,370
briefly talked about how stars evolved

36
00:01:40,490 --> 00:01:38,400
so here's the life cycle of our Sun so

37
00:01:43,310 --> 00:01:40,500
right now it's on what we call the main

38
00:01:46,280 --> 00:01:43,320

sequence so the core is fusing hydrogen

39
00:01:49,820 --> 00:01:46,290
into helium and the main sequence takes

40
00:01:50,930 --> 00:01:49,830
up most of the life of most stars but

41
00:01:53,480 --> 00:01:50,940
there's all this other stuff that

42
00:01:55,160 --> 00:01:53,490
happens too so you might have all heard

43
00:01:57,530 --> 00:01:55,170
that one day the Sun is going to become

44
00:01:59,630 --> 00:01:57,540
huge and come out and destroy earth so

45
00:02:02,840 --> 00:01:59,640
that is true and that's what I'm going

46
00:02:06,950 --> 00:02:02,850
to be talking about today so it's gonna

47
00:02:09,319 --> 00:02:06,960
get really big and you could see here I

48
00:02:12,440 --> 00:02:09,329
actually have plotted out this is what's

49
00:02:13,280 --> 00:02:12,450
going to happen to our own Sun so here

50
00:02:16,429 --> 00:02:13,290
we have

51
00:02:19,100 --> 00:02:16,439
with time this orange line is the radius

52
00:02:20,690 --> 00:02:19,110
of the Sun this green region here is the

53
00:02:22,729 --> 00:02:20,700
habitable zone where liquid water could

54
00:02:25,610 --> 00:02:22,739
exist and then we have the orbits of

55
00:02:27,740 --> 00:02:25,620
Earth Jupiter and Saturn and this red

56
00:02:29,809 --> 00:02:27,750
shaded in region is the red giant branch

57
00:02:31,610 --> 00:02:29,819
so that's when the star is getting

58
00:02:34,430 --> 00:02:31,620
really big and expanding what you could

59
00:02:36,940 --> 00:02:34,440
see with the radius and also here the

60
00:02:40,550 --> 00:02:36,950
Sun will come out and touch earth so

61
00:02:42,199 --> 00:02:40,560
that's not good for us but what I'm

62
00:02:44,869 --> 00:02:42,209
gonna focus on is look at right here

63
00:02:48,349 --> 00:02:44,879

Jupiter and Saturn are going to be in

64
00:02:50,089 --> 00:02:48,359
the habitable zone of our Sun so what's

65
00:02:52,759 --> 00:02:50,099
exciting about that is that means that

66
00:02:55,160 --> 00:02:52,769
object like Europa are going to thaw out

67
00:02:58,610 --> 00:02:55,170
and those oceans are going to be exposed

68
00:03:00,440 --> 00:02:58,620
for everyone to see the atmosphere so we

69
00:03:03,080 --> 00:03:00,450
could maybe detect life there so right

70
00:03:05,599 --> 00:03:03,090
now we can't but if it were well we

71
00:03:07,280 --> 00:03:05,609
would be dead but in the future we might

72
00:03:10,490 --> 00:03:07,290
be able to remotely detect life on

73
00:03:12,559 --> 00:03:10,500
objects like Europa so for this talk the

74
00:03:15,229 --> 00:03:12,569
questions I want to answer are how long

75
00:03:17,420 --> 00:03:15,239
could a planet or a moon remain in the

76
00:03:19,520 --> 00:03:17,430
habitable zone of a post main sequence

77
00:03:21,710 --> 00:03:19,530
star and then what were the atmospheres

78
00:03:23,930 --> 00:03:21,720
and the UV environments of those stars

79
00:03:28,009 --> 00:03:23,940
look like because very important for

80
00:03:29,539 --> 00:03:28,019
habitability so to briefly go over the

81
00:03:32,390 --> 00:03:29,549
post main sequence here we have the

82
00:03:34,819 --> 00:03:32,400
luminosity evolution of stars of

83
00:03:37,729 --> 00:03:34,829
different masses so first there's the

84
00:03:40,640 --> 00:03:37,739
red giant branch so the core has run out

85
00:03:43,220 --> 00:03:40,650
of hydrogen diffuse so it starts fusing

86
00:03:45,050 --> 00:03:43,230
hydrogen in a shell around the core and

87
00:03:47,390 --> 00:03:45,060
when this happens the star becomes very

88
00:03:49,220 --> 00:03:47,400

big so it expands it cools and becomes

89
00:03:50,629 --> 00:03:49,230
very luminous so with all these

90
00:03:53,599 --> 00:03:50,639
different luminosity tracks the red

91
00:03:56,210 --> 00:03:53,609
giant branch is this first peak so

92
00:03:57,229 --> 00:03:56,220
finally the core will reach the high

93
00:03:59,000 --> 00:03:57,239
enough temperature and pressure

94
00:04:01,460 --> 00:03:59,010
conditions and it will finally be able

95
00:04:03,229 --> 00:04:01,470
to start to fuse helium in the core so

96
00:04:05,509 --> 00:04:03,239
this is the horizontal branch so this is

97
00:04:06,920 --> 00:04:05,519
the area between the peaks and you'll

98
00:04:08,119 --> 00:04:06,930
see it's different for stars of

99
00:04:10,729 --> 00:04:08,129
different masses which I'll get into

100
00:04:12,949 --> 00:04:10,739
more so a horizontal branch and then

101
00:04:15,379 --> 00:04:12,959
just like before with hydrogen the star

102
00:04:16,550 --> 00:04:15,389
is gonna run out of core helium and it's

103
00:04:18,710 --> 00:04:16,560
gonna freak out again and it's gonna

104
00:04:20,750 --> 00:04:18,720
start fusing helium the shell on the

105
00:04:22,490 --> 00:04:20,760
asymptotic giant branch which is sort of

106
00:04:24,709 --> 00:04:22,500
similar to the red giant branch and

107
00:04:26,379 --> 00:04:24,719
that's the second peak here so what I

108
00:04:29,170 --> 00:04:26,389
want you to take away from this is

109
00:04:31,629 --> 00:04:29,180
even though these three phases happen to

110
00:04:33,459 --> 00:04:31,639
all these stars it's very different the

111
00:04:36,219 --> 00:04:33,469
time skills are very different and the

112
00:04:38,350 --> 00:04:36,229
luminosity change is very dependent on

113
00:04:39,760 --> 00:04:38,360

the mass of the star so obviously the

114
00:04:41,679 --> 00:04:39,770
habitable zone during the post main

115
00:04:45,189 --> 00:04:41,689
sequence is really going to depend on

116
00:04:47,649 --> 00:04:45,199
the mass of the star so when I was

117
00:04:49,839 --> 00:04:47,659
looking what I did is I looked at all

118
00:04:51,459 --> 00:04:49,849
these different star masses and I found

119
00:04:53,409 --> 00:04:51,469
if I want something to stay in the

120
00:04:55,959 --> 00:04:53,419
habitable zone for like the longest

121
00:04:59,860 --> 00:04:55,969
continuous time the horizontal branch is

122
00:05:02,439 --> 00:04:59,870
the best bet so it's pretty stable if

123
00:05:06,159 --> 00:05:02,449
you look here here is the evolution of a

124
00:05:08,140 --> 00:05:06,169
1.5 solar mass star so again we have the

125
00:05:10,269 --> 00:05:08,150
radius of the star we have the habitable

126
00:05:12,369 --> 00:05:10,279
zone the red shaded region is the red

127
00:05:13,990 --> 00:05:12,379
giant branch blue is asymptotic giant

128
00:05:15,999 --> 00:05:14,000
branch and in between is the horizontal

129
00:05:18,040 --> 00:05:16,009
branch so look it's pretty stable there

130
00:05:19,689 --> 00:05:18,050
that's pretty nice and on the red timer

131
00:05:22,600 --> 00:05:19,699
and it's moving it's changing really

132
00:05:24,939 --> 00:05:22,610
quickly so a planet would not enjoy that

133
00:05:26,860 --> 00:05:24,949
and this blue line is the orbit I

134
00:05:28,480 --> 00:05:26,870
calculated so if a planet was there

135
00:05:30,369 --> 00:05:28,490
that's the maximum amount of time could

136
00:05:31,990 --> 00:05:30,379
stay in the habitable zone so

137
00:05:34,059 --> 00:05:32,000
unsurprisingly when I look at these

138
00:05:35,860 --> 00:05:34,069

different stars the habitable zone time

139
00:05:37,869 --> 00:05:35,870
scales the longest possible one is

140
00:05:40,119 --> 00:05:37,879
basically the length of the horizontal

141
00:05:42,579 --> 00:05:40,129
branch but what's interesting here is

142
00:05:45,159 --> 00:05:42,589
the length of the horizontal branch does

143
00:05:47,350 --> 00:05:45,169
not linearly scale with the lifetime of

144
00:05:48,939 --> 00:05:47,360
the star so a star like the Sun the

145
00:05:52,360 --> 00:05:48,949
horizontal branch is actually only about

146
00:05:53,230 --> 00:05:52,370
1% of the Suns total lifetime but for

147
00:05:55,200 --> 00:05:53,240
more massive stars

148
00:05:58,059 --> 00:05:55,210
it's almost 30 percent of its lifetime

149
00:05:59,980 --> 00:05:58,069
so if you look here here we have the

150
00:06:02,409 --> 00:05:59,990
absolute values of the horizontal the

151
00:06:04,209 --> 00:06:02,419
time on the horizontal branch so for

152
00:06:06,519 --> 00:06:04,219
higher math stars is actually much

153
00:06:08,709 --> 00:06:06,529
longer and this is a bit

154
00:06:10,450 --> 00:06:08,719
counterintuitive because the more

155
00:06:11,079 --> 00:06:10,460
massive a star is the shorter its

156
00:06:13,659 --> 00:06:11,089
lifetime

157
00:06:16,119 --> 00:06:13,669
but the more massive a star is the

158
00:06:19,119 --> 00:06:16,129
easier it is for the core to become hot

159
00:06:21,839 --> 00:06:19,129
enough to fuse helium in the core so

160
00:06:24,969 --> 00:06:21,849
it's really around higher mass stars

161
00:06:26,800 --> 00:06:24,979
particular like 22.3 solar masses but

162
00:06:29,409 --> 00:06:26,810
they have the longest habitable zone

163
00:06:31,329 --> 00:06:29,419

lifetimes four-post main sequence which

164
00:06:33,999 --> 00:06:31,339
usually these stars are left out of

165
00:06:36,879 --> 00:06:34,009
habitability searches so this is their

166
00:06:39,030 --> 00:06:36,889
chance post main sequence so I

167
00:06:41,910 --> 00:06:39,040
calculated the habitable zones

168
00:06:44,280 --> 00:06:41,920
for hosts between 1.3 and 3.5 solar

169
00:06:46,530 --> 00:06:44,290
masses and the reason for this isn't

170
00:06:49,430 --> 00:06:46,540
just because the horizontal branch is

171
00:06:52,890 --> 00:06:49,440
longer but also because these stars

172
00:06:55,620 --> 00:06:52,900
exist so for a star like our Sun it

173
00:06:57,930 --> 00:06:55,630
takes about 11 billion years to reach

174
00:06:59,280 --> 00:06:57,940
the post main sequence and if you know

175
00:07:03,240 --> 00:06:59,290
anything about the galaxy the oldest

176
00:07:05,820 --> 00:07:03,250
stars are 11 billion years old so I only

177
00:07:08,730 --> 00:07:05,830
I made the decision to only study stars

178
00:07:11,000 --> 00:07:08,740
that exists so can't say I'm not

179
00:07:14,580 --> 00:07:11,010
realistic

180
00:07:16,680 --> 00:07:14,590
so what I did after I calculated these

181
00:07:18,810 --> 00:07:16,690
orbits of maximum probability is I also

182
00:07:21,810 --> 00:07:18,820
look at the atmospheres of these planets

183
00:07:23,670 --> 00:07:21,820
and I did this using XO prime which is a

184
00:07:26,040 --> 00:07:23,680
1d couple of climate photochemistry

185
00:07:28,260 --> 00:07:26,050
model it's sort of like a cousin of

186
00:07:31,590 --> 00:07:28,270
Atmos which I know a lot of people use

187
00:07:33,270 --> 00:07:31,600
and what it does is it as a climate code

188
00:07:36,300 --> 00:07:33,280

in a photochemistry code and they sort

189
00:07:38,820 --> 00:07:36,310
of talk to each other so what I do is I

190
00:07:41,070 --> 00:07:38,830
put in put a star spectrum I specify

191
00:07:42,510 --> 00:07:41,080
things like the distance the initial

192
00:07:44,580 --> 00:07:42,520
conditions of the atmosphere which I

193
00:07:46,170 --> 00:07:44,590
look at earth-like planets because earth

194
00:07:49,110 --> 00:07:46,180
is the only planet we know about light

195
00:07:50,760 --> 00:07:49,120
so start there and the climate code will

196
00:07:52,350 --> 00:07:50,770
use the chemistry in the atmosphere to

197
00:07:53,880 --> 00:07:52,360
calculate a temperature throughout the

198
00:07:55,170 --> 00:07:53,890
atmosphere then it goes over to the

199
00:07:57,210 --> 00:07:55,180
photochemistry code and it will

200
00:07:59,580 --> 00:07:57,220
calculate the chemistry based on the

201
00:08:01,410 --> 00:07:59,590
incoming stellar radiation but also the

202
00:08:04,230 --> 00:08:01,420
temperature and the two of them go back

203
00:08:06,660 --> 00:08:04,240
and forth until it agrees with a planet

204
00:08:08,250 --> 00:08:06,670
at this distance from this star is what

205
00:08:10,800 --> 00:08:08,260
the temperature and the chemistry would

206
00:08:12,750 --> 00:08:10,810
look like for it to be in equilibrium so

207
00:08:15,150 --> 00:08:12,760
I did this and I modeled atmospheres of

208
00:08:17,550 --> 00:08:15,160
planets at the 180 equivalent and also

209
00:08:19,920 --> 00:08:17,560
several points along these orbits of

210
00:08:21,960 --> 00:08:19,930
maximum habitability and when I say why

211
00:08:23,700 --> 00:08:21,970
don't you equivalent here all I mean is

212
00:08:26,250 --> 00:08:23,710
just a distance where the planet would

213
00:08:29,220 --> 00:08:26,260

receive the same total amount of flux

214
00:08:32,850 --> 00:08:29,230
that Earth does so basically I'm just

215
00:08:35,760 --> 00:08:32,860
like earth for the purposes of this talk

216
00:08:37,260 --> 00:08:35,770
so this code outputs a lot of stuff but

217
00:08:39,409 --> 00:08:37,270
for the purposes of this talk I'm just

218
00:08:42,960 --> 00:08:39,419
gonna focus on you be to the ground so

219
00:08:45,660 --> 00:08:42,970
UV is really important because it's what

220
00:08:49,200 --> 00:08:45,670
we need to live but too much UV would

221
00:08:51,420 --> 00:08:49,210
kill everything so it's important we

222
00:08:54,930 --> 00:08:51,430
usually it divided up into three

223
00:08:57,240 --> 00:08:54,940
regime's UVA UVB and UVC so we have here

224
00:08:59,790 --> 00:08:57,250
demonstrating how much of these three

225
00:09:02,820 --> 00:08:59,800
regimes reach the ground on earth so UVA

226
00:09:07,019 --> 00:09:02,830
is actually good for us it's what causes

227
00:09:09,150 --> 00:09:07,029
vitamin D to be produced in our skin and

228
00:09:10,980 --> 00:09:09,160
if not variational do by ozone but

229
00:09:14,460 --> 00:09:10,990
that's okay it's good for us life

230
00:09:16,170 --> 00:09:14,470
probably need to UVA UVB if you've ever

231
00:09:20,699 --> 00:09:16,180
had sunburn

232
00:09:24,960 --> 00:09:20,709
thanks CTV be also tanning so UVB in

233
00:09:26,910 --> 00:09:24,970
small doses is okay but too much will

234
00:09:29,910 --> 00:09:26,920
probably cause things like skin cancer

235
00:09:33,030 --> 00:09:29,920
so most of UVB is shielded by our ozone

236
00:09:35,190 --> 00:09:33,040
layer and then there's UVC which ruins

237
00:09:37,740 --> 00:09:35,200
everything so it can literally break up

238
00:09:40,920 --> 00:09:37,750

heart DNA so luckily with our

239
00:09:43,650 --> 00:09:40,930
atmospheric shielding of ozone almost no

240
00:09:45,780 --> 00:09:43,660
UVC you reaches the ground here but if

241
00:09:47,550 --> 00:09:45,790
we were on a different planet from a

242
00:09:48,990 --> 00:09:47,560
different star the chemistry would be

243
00:09:50,269 --> 00:09:49,000
different so we don't know if you guys

244
00:09:52,769 --> 00:09:50,279
aren't shielding would be enough and

245
00:09:55,860 --> 00:09:52,779
what's interesting here is that ozone

246
00:09:58,890 --> 00:09:55,870
which shield us from UVC is created by

247
00:10:00,269 --> 00:09:58,900
UVC so we'll have oxygen molecules

248
00:10:02,190 --> 00:10:00,279
flying around they'll get hit by a

249
00:10:05,160 --> 00:10:02,200
photon it needs to be a photon less than

250
00:10:06,840 --> 00:10:05,170
240 nanometers to break it apart so UVC

251
00:10:08,880 --> 00:10:06,850
and it'll recombine with a background

252
00:10:13,440 --> 00:10:08,890
molecule which is usually something like

253
00:10:15,269 --> 00:10:13,450
nitrogen so UVC creates what shields us

254
00:10:18,840 --> 00:10:15,279
from UVC and this causes some

255
00:10:21,480 --> 00:10:18,850
interesting relationships later on so if

256
00:10:23,760 --> 00:10:21,490
we look at the you the environments a

257
00:10:25,590 --> 00:10:23,770
planet at the 1a you have equivalent

258
00:10:28,230 --> 00:10:25,600
this is what you get

259
00:10:31,199 --> 00:10:28,240
so if you're into spectral types here

260
00:10:32,880 --> 00:10:31,209
they are these are nearby post- and

261
00:10:34,199 --> 00:10:32,890
stars but if you don't like spectral

262
00:10:35,519 --> 00:10:34,209
types or don't know they are all you

263
00:10:37,470 --> 00:10:35,529

need to know is these are the hottest

264
00:10:40,610 --> 00:10:37,480
and it progressively gets to cooler and

265
00:10:45,360 --> 00:10:40,620
the sun's there because we live there so

266
00:10:48,389 --> 00:10:45,370
so what's interesting here is that it is

267
00:10:50,850 --> 00:10:48,399
the cooler targets that have the most

268
00:10:52,440 --> 00:10:50,860
UVC to the ground so that might seem

269
00:10:54,630 --> 00:10:52,450
counterintuitive because stars are

270
00:10:56,819 --> 00:10:54,640
basically like black bodies so hotter

271
00:10:59,370 --> 00:10:56,829
stars are giving off more higher energy

272
00:11:02,100 --> 00:10:59,380
photons which means they're giving off

273
00:11:04,580 --> 00:11:02,110
more UV but it's these really hot stars

274
00:11:06,440 --> 00:11:04,590
they give off so much UV

275
00:11:10,580 --> 00:11:06,450
that means they're creating a lot of

276
00:11:12,560 --> 00:11:10,590
ozone and it's these low UV targets that

277
00:11:13,910 --> 00:11:12,570
even though there's not that much UV

278
00:11:16,450 --> 00:11:13,920
reaching the planet

279
00:11:20,360 --> 00:11:16,460
it just can't produce enough ozone to

280
00:11:22,160 --> 00:11:20,370
shield the planet so this has

281
00:11:23,960 --> 00:11:22,170
interesting implications not just for

282
00:11:26,390 --> 00:11:23,970
post main-sequence stars but anyone who

283
00:11:29,120 --> 00:11:26,400
cares about looking for planets around

284
00:11:31,760 --> 00:11:29,130
lower mass stars which is something that

285
00:11:33,560 --> 00:11:31,770
people like to do so even though just

286
00:11:35,900 --> 00:11:33,570
remember even though the star doesn't

287
00:11:37,280 --> 00:11:35,910
have as much UV it might actually have

288
00:11:41,420 --> 00:11:37,290

more UV on the surface because it just

289
00:11:44,720 --> 00:11:41,430
can't create this ozone and also along

290
00:11:46,310 --> 00:11:44,730
with doing the 1iu equivalent I modeled

291
00:11:48,980 --> 00:11:46,320
what a planet would be like if it was on

292
00:11:50,540 --> 00:11:48,990
this orbit of maximum habitability what

293
00:11:52,430 --> 00:11:50,550
it would look like during its lifetime

294
00:11:55,640 --> 00:11:52,440
on the post main sequence habitable zone

295
00:11:57,050 --> 00:11:55,650
so for this star I chose a 2.3 solar

296
00:12:00,140 --> 00:11:57,060
mass star because it is the longest

297
00:12:01,730 --> 00:12:00,150
habitable zone timescale and I modeled

298
00:12:03,140 --> 00:12:01,740
it at the beginning of the horizontal

299
00:12:07,460 --> 00:12:03,150
branch and at the beginning of the

300
00:12:10,970 --> 00:12:07,470
asymptotic giant branch so even though I

301
00:12:12,860 --> 00:12:10,980
just said that these cooler targets and

302
00:12:15,530 --> 00:12:12,870
this would be a cooler target it'd be

303
00:12:19,220 --> 00:12:15,540
around 4000 Kelvin it doesn't create as

304
00:12:21,530 --> 00:12:19,230
much ozone because with these habitable

305
00:12:23,930 --> 00:12:21,540
zones it has to be sort of near the edge

306
00:12:25,250 --> 00:12:23,940
of the outer edge of the habitable zone

307
00:12:28,100 --> 00:12:25,260
to stay habitable for as long as

308
00:12:29,660 --> 00:12:28,110
possible it actually cuts down the UV

309
00:12:32,090 --> 00:12:29,670
coming in by enough that even though

310
00:12:34,460 --> 00:12:32,100
much ozone isn't being created there's

311
00:12:37,010 --> 00:12:34,470
just not that much hitting it at all so

312
00:12:39,829 --> 00:12:37,020
this is actually safe which I know might

313
00:12:41,570 --> 00:12:39,839

be confusing so basically you always

314
00:12:43,010 --> 00:12:41,580
have to model the photochemistry in the

315
00:12:43,760 --> 00:12:43,020
ozone production because it is not

316
00:12:49,010 --> 00:12:43,770
intuitive

317
00:12:50,660 --> 00:12:49,020
but it will be like so if you aren't

318
00:12:53,960 --> 00:12:50,670
listening to anything I said just now

319
00:12:56,329 --> 00:12:53,970
which is fine I were all tired even the

320
00:12:58,940 --> 00:12:56,339
projectors tired apparently this is what

321
00:13:01,430 --> 00:12:58,950
I want you to remember so during the

322
00:13:03,740 --> 00:13:01,440
post main sequence the stars get really

323
00:13:05,510 --> 00:13:03,750
big the habitable zone moves out it's

324
00:13:08,000 --> 00:13:05,520
not going to be good for planets that

325
00:13:10,070 --> 00:13:08,010
were originally habitable like Earth but

326
00:13:12,740 --> 00:13:10,080
these planets that would have been past

327
00:13:14,780 --> 00:13:12,750
the frost line initially are going to be

328
00:13:17,210 --> 00:13:14,790
habitable so it could thaw a lot of

329
00:13:18,329 --> 00:13:17,220
things and it can reveal subsurface life

330
00:13:20,340 --> 00:13:18,339
if you

331
00:13:21,900 --> 00:13:20,350
look for something habitable it's good

332
00:13:23,369 --> 00:13:21,910
to look for a star on the horizontal

333
00:13:26,759 --> 00:13:23,379
branch which there are a bunch of them

334
00:13:28,590 --> 00:13:26,769
nearby actually so that's convenient

335
00:13:31,619 --> 00:13:28,600
you want to look there because it's a

336
00:13:33,660 --> 00:13:31,629
relatively stable time period the

337
00:13:35,879 --> 00:13:33,670
longest habitability timescales are

338
00:13:37,439 --> 00:13:35,889

actually for more massive stars so

339
00:13:39,480 --> 00:13:37,449
unlike when we look at me and sequence

340
00:13:41,670 --> 00:13:39,490
lifetimes we actually want to look at

341
00:13:43,110 --> 00:13:41,680
higher mass stars which is convenient

342
00:13:44,549 --> 00:13:43,120
because it's these higher mass stars

343
00:13:47,189 --> 00:13:44,559
that are already on the post main

344
00:13:51,150 --> 00:13:47,199
sequence so it's nice when reality is

345
00:13:53,160 --> 00:13:51,160
convenient and yeah so when these stars

346
00:13:55,610 --> 00:13:53,170
get big they expand the temperature goes

347
00:13:58,110 --> 00:13:55,620
down so there's less UV but that could

348
00:13:58,920 --> 00:13:58,120
result in more UV in the planet's

349
00:14:02,790 --> 00:13:58,930
surface

350
00:14:04,799 --> 00:14:02,800
so and if you want to learn more and our

351
00:14:07,410 --> 00:14:04,809
sad that this talk is short this is

352
00:14:12,259 --> 00:14:07,420
published this work in the Astrophysical

353
00:14:29,999 --> 00:14:26,819
any questions thank you well I talked

354
00:14:31,889 --> 00:14:30,009
about the presence of UV radiation and

355
00:14:34,079 --> 00:14:31,899
and its effects on life so you are

356
00:14:36,569 --> 00:14:34,089
looking for something to block UV

357
00:14:39,840 --> 00:14:36,579
radiation as effectively as possible but

358
00:14:45,239 --> 00:14:39,850
on earth we definitely know that even

359
00:14:46,110 --> 00:14:45,249
when UVC was basically unaltered life

360
00:14:47,610 --> 00:14:46,120
did evolve

361
00:14:49,860 --> 00:14:47,620
well before the great oxygenation event

362
00:14:52,049 --> 00:14:49,870
so yeah can you speculate a bit that's

363
00:14:54,329 --> 00:14:52,059

do you know how critical it even is to

364
00:14:56,340 --> 00:14:54,339
have this huy protected environments and

365
00:14:58,169 --> 00:14:56,350
and whether you know maybe it doesn't

366
00:15:00,749 --> 00:14:58,179
matter much of maybe to beneficial for

367
00:15:03,179 --> 00:15:00,759
the appearance of life to have Sun yeah

368
00:15:05,009 --> 00:15:03,189
so that's a really good question so in

369
00:15:06,660 --> 00:15:05,019
the time of early Earth there wasn't

370
00:15:09,509 --> 00:15:06,670
much oxygen there definitely was no

371
00:15:12,689 --> 00:15:09,519
ozone and we know that life did exist

372
00:15:15,299 --> 00:15:12,699
here on earth so it is debated then

373
00:15:17,999 --> 00:15:15,309
because it looks like life evolves when

374
00:15:22,319 --> 00:15:18,009
UVC was hitting the ground in really

375
00:15:24,210 --> 00:15:22,329
high quantities so it is a bit strange

376
00:15:25,889 --> 00:15:24,220
so some people believe that life started

377
00:15:28,650 --> 00:15:25,899
under the oceans so even though there

378
00:15:31,890 --> 00:15:28,660
wasn't a zone shilling water is really

379
00:15:33,930 --> 00:15:31,900
efficient at stopping UVC so some people

380
00:15:36,750 --> 00:15:33,940
think that it still wasn't an issue even

381
00:15:38,760 --> 00:15:36,760
though there was no ozone and some

382
00:15:40,620 --> 00:15:38,770
people actually think so there's a lot

383
00:15:43,230 --> 00:15:40,630
of different opinions here and since we

384
00:15:45,630 --> 00:15:43,240
can't travel back in time we don't

385
00:15:50,130 --> 00:15:45,640
really know the best part of

386
00:15:53,100 --> 00:15:50,140
astrobiology so so some people think

387
00:15:56,100 --> 00:15:53,110
that maybe like needed UVC to just sort

388
00:15:59,280 --> 00:15:56,110

of get sparked and start up so maybe you

389
00:16:01,710 --> 00:15:59,290
need UVC initially and then you need to

390
00:16:04,170 --> 00:16:01,720
be shielded from UVC because obviously

391
00:16:07,620 --> 00:16:04,180
if suddenly the ozone layer left we

392
00:16:09,600 --> 00:16:07,630
would all die pretty quickly so that's a

393
00:16:14,640 --> 00:16:09,610
yeah that's a good question I wish I

394
00:16:17,550 --> 00:16:14,650
knew the answer that question so yeah so

395
00:16:19,560 --> 00:16:17,560
for your models that you're eating on

396
00:16:21,240 --> 00:16:19,570
your climate you set an initial some

397
00:16:22,320 --> 00:16:21,250
sort of chemical abundance where did you

398
00:16:23,550 --> 00:16:22,330
get that was that from like stellar

399
00:16:26,580 --> 00:16:23,560
spectra or is that from like dis

400
00:16:28,590 --> 00:16:26,590
observations or would you use Duchy as

401
00:16:30,660 --> 00:16:28,600
your initial for the planetary

402
00:16:34,400 --> 00:16:30,670
atmosphere yeah yeah so we basically

403
00:16:36,930 --> 00:16:34,410
just use initial earth conditions so

404
00:16:38,550 --> 00:16:36,940
we've experimented with some other ones

405
00:16:39,660 --> 00:16:38,560
there are some people who was trying to

406
00:16:42,390 --> 00:16:39,670
do this stuff throughout Earth's

407
00:16:44,130 --> 00:16:42,400
geological history but for this work we

408
00:16:45,720 --> 00:16:44,140
just use basically earth like

409
00:16:47,880 --> 00:16:45,730
composition and then we let the model

410
00:16:49,830 --> 00:16:47,890
evolve to get to the point where it

411
00:16:59,480 --> 00:16:49,840
would be under those conditions okay