

1  
00:00:01,508 --> 00:00:06,259  
hello everybody and welcome to our

2  
00:00:03,740 --> 00:00:08,388  
latest Hubble hang out my name is Tony

3  
00:00:06,259 --> 00:00:10,399  
Darnell I am at the Space Telescope

4  
00:00:08,388 --> 00:00:13,458  
Science Institute and with me today is

5  
00:00:10,400 --> 00:00:15,530  
dr. again when one of our hangouts dr.

6  
00:00:13,458 --> 00:00:17,120  
mario livio and dr. carol christian from

7  
00:00:15,529 --> 00:00:19,460  
the Space Telescope Science Institute

8  
00:00:17,120 --> 00:00:21,140  
they've done many hangouts with me

9  
00:00:19,460 --> 00:00:24,019  
before on this but we're also joined by

10  
00:00:21,140 --> 00:00:26,870  
dr. Ava Villa ver from and let me get

11  
00:00:24,019 --> 00:00:30,259  
this right universidad autónoma de

12  
00:00:26,870 --> 00:00:31,640  
Madrid she's an astronomer and she is

13  
00:00:30,260 --> 00:00:33,588  
attending a symposium that we're having

14  
00:00:31,640 --> 00:00:35,448  
at the Institute this week that is I

15  
00:00:33,588 --> 00:00:38,929  
think one of the more interesting things

16  
00:00:35,448 --> 00:00:41,689  
we've had here at the Space Telescope

17  
00:00:38,929 --> 00:00:43,789  
Science Institute they are discussing

18  
00:00:41,689 --> 00:00:47,318  
and meeting this week to talk about

19  
00:00:43,789 --> 00:00:51,319  
issues associated with habitability

20  
00:00:47,319 --> 00:00:53,179  
habitability around planets moons what

21  
00:00:51,319 --> 00:00:54,800  
are the what does it mean what does

22  
00:00:53,179 --> 00:00:56,658  
something mean to be habitable and

23  
00:00:54,799 --> 00:00:58,608  
habitable for whom I mean what are we

24  
00:00:56,658 --> 00:01:00,920  
you know what are the what are the

25  
00:00:58,609 --> 00:01:04,519  
conditions that are necessary to have

26  
00:01:00,920 --> 00:01:06,439  
life out in the universe and at an issue

27  
00:01:04,519 --> 00:01:12,340  
that I'm particularly interested in also

28  
00:01:06,438 --> 00:01:14,779  
is how extensible is you know Earth's

29

00:01:12,340 --> 00:01:17,270  
habitability requirements to everything

30  
00:01:14,780 --> 00:01:18,859  
else and and so there astronomers are

31  
00:01:17,269 --> 00:01:20,899  
meeting discussing all these really

32  
00:01:18,859 --> 00:01:23,899  
great questions and we're going to touch

33  
00:01:20,899 --> 00:01:27,170  
on some of this this right now this with

34  
00:01:23,899 --> 00:01:28,789  
this with this hangout Mario and Ava

35  
00:01:27,170 --> 00:01:30,590  
were very kind of joy to give us some of

36  
00:01:28,789 --> 00:01:32,060  
their time and in Carol's with us to

37  
00:01:30,590 --> 00:01:34,728  
give her perspective which is always

38  
00:01:32,060 --> 00:01:36,710  
really good to discuss this idea of

39  
00:01:34,728 --> 00:01:38,030  
habitability so before I get started I

40  
00:01:36,709 --> 00:01:41,688  
want to let you know I'm monitoring

41  
00:01:38,030 --> 00:01:43,489  
youtube I monitoring Google+ and if you

42  
00:01:41,688 --> 00:01:45,048  
use that if you are want to tweet some

43  
00:01:43,489 --> 00:01:48,530

questions or comments using the Hubble

44

00:01:45,049 --> 00:01:50,118  
hang out hashtag I wall i'm also

45

00:01:48,530 --> 00:01:51,409  
monitoring those as well and we'll try

46

00:01:50,118 --> 00:01:52,909  
to get to them if there's time at the

47

00:01:51,409 --> 00:01:56,979  
end we only have a half an hour so I

48

00:01:52,909 --> 00:01:59,539  
want to just jump right in habitability

49

00:01:56,978 --> 00:02:01,789  
habitability i was at all this time i

50

00:01:59,539 --> 00:02:05,929  
had my head mario and ava big instead of

51

00:02:01,789 --> 00:02:09,080  
me what let's talk about what we mean by

52

00:02:05,929 --> 00:02:11,539  
that and some mario what what's your

53

00:02:09,080 --> 00:02:12,890  
impression when we say habitable what do

54

00:02:11,539 --> 00:02:14,239  
you guys what do you what goes in your

55

00:02:12,889 --> 00:02:16,799  
head we told my earth

56

00:02:14,240 --> 00:02:19,920  
mammals microbes what do we mean by

57

00:02:16,800 --> 00:02:22,610  
habitability no so unfortunately since

58  
00:02:19,919 --> 00:02:26,909  
we only so far discovered life on Earth

59  
00:02:22,610 --> 00:02:30,120  
and so we made the definition of what we

60  
00:02:26,909 --> 00:02:33,689  
mean by habitable so basically around

61  
00:02:30,120 --> 00:02:37,710  
every star you can define a range of

62  
00:02:33,689 --> 00:02:40,349  
distances from the star which allows for

63  
00:02:37,710 --> 00:02:44,400  
liquid water on the surface of that

64  
00:02:40,349 --> 00:02:47,310  
planet if there is a planet there then

65  
00:02:44,400 --> 00:02:49,800  
liquid water can exist in the particular

66  
00:02:47,310 --> 00:02:52,710  
case of the earth of course the earth is

67  
00:02:49,800 --> 00:02:56,040  
in the habitable zone around our star

68  
00:02:52,710 --> 00:02:58,860  
namely the Sun but because we think that

69  
00:02:56,039 --> 00:03:02,039  
water may be absolutely essential for

70  
00:02:58,860 --> 00:03:04,800  
life we define this region around any

71  
00:03:02,039 --> 00:03:07,650  
for any planet around any other star and

72  
00:03:04,800 --> 00:03:10,680  
then we've searched to see whether there

73  
00:03:07,650 --> 00:03:13,500  
are any planets in this habitable zone

74  
00:03:10,680 --> 00:03:16,530  
namely in that region that would allow

75  
00:03:13,500 --> 00:03:20,699  
for liquid water to be on the surface of

76  
00:03:16,530 --> 00:03:23,969  
that planet so this week there are a lot

77  
00:03:20,699 --> 00:03:27,839  
of talks being given in a wide variety

78  
00:03:23,969 --> 00:03:28,859  
of John wide varieties of subjects and

79  
00:03:27,840 --> 00:03:31,740  
we're looking at every single

80  
00:03:28,860 --> 00:03:34,140  
possibility so surely liquid water isn't

81  
00:03:31,740 --> 00:03:37,320  
the only real thing that we one would

82  
00:03:34,139 --> 00:03:38,789  
need right i mean there is that is that

83  
00:03:37,319 --> 00:03:40,979  
the defining characteristic of a

84  
00:03:38,789 --> 00:03:43,349  
habitable place a place where life can

85  
00:03:40,979 --> 00:03:46,709  
exist is that is that the only thing you

86

00:03:43,349 --> 00:03:48,389  
guys are looking at well I can I can

87  
00:03:46,710 --> 00:03:50,610  
jump in here a little bit that's the

88  
00:03:48,389 --> 00:03:52,439  
classic definition but of course when

89  
00:03:50,610 --> 00:03:54,660  
you think about it that is very earth

90  
00:03:52,439 --> 00:03:57,030  
centric and of course we're looking at

91  
00:03:54,659 --> 00:03:58,919  
Mars to see if it is habitable or was

92  
00:03:57,030 --> 00:04:01,830  
habitable and it's thought that it did

93  
00:03:58,919 --> 00:04:03,599  
have water now of course the star can

94  
00:04:01,830 --> 00:04:05,610  
change the parent star like we have our

95  
00:04:03,599 --> 00:04:07,650  
Sun it changes very slowly there are

96  
00:04:05,610 --> 00:04:09,840  
other stars that change more rapidly and

97  
00:04:07,650 --> 00:04:12,569  
there are stars that change more slowly

98  
00:04:09,840 --> 00:04:15,509  
in their lifetimes so you're right the

99  
00:04:12,569 --> 00:04:17,670  
habitability can change so for a star

100  
00:04:15,509 --> 00:04:20,370

that lives very fast there might be a

101

00:04:17,670 --> 00:04:22,590

region that is what fits our definition

102

00:04:20,370 --> 00:04:24,870

of habitable but because the star

103

00:04:22,589 --> 00:04:27,209

changes its brightness and energy so fast

104

00:04:24,870 --> 00:04:27,959

there's no chance that life will evolve

105

00:04:27,209 --> 00:04:31,769

and then there

106

00:04:27,959 --> 00:04:34,288

our other stars planets possibly around

107

00:04:31,769 --> 00:04:36,750

stars that take a very long time and are

108

00:04:34,288 --> 00:04:41,788

very stable and there's lots of chances

109

00:04:36,750 --> 00:04:43,709

that they could have a habitable area so for

110

00:04:41,788 --> 00:04:46,500

a moment in time the fact that a planet

111

00:04:43,709 --> 00:04:49,228

might be habitable does not mean okay

112

00:04:46,500 --> 00:04:51,029

now life is going to form for sure but

113

00:04:49,228 --> 00:04:52,649

it's a starting place it's yeah it's

114

00:04:51,029 --> 00:04:54,418

it's a starting place but it was as I



115  
00:04:52,649 --> 00:04:55,409  
look at the at the talks of some of

116  
00:04:54,418 --> 00:04:58,038  
these things that people were given

117  
00:04:55,410 --> 00:05:00,210  
there's one there was one on whether a

118  
00:04:58,038 --> 00:05:02,399  
series the dwarf planet ceres is

119  
00:05:00,209 --> 00:05:04,500  
habitable and you know there's talking

120  
00:05:02,399 --> 00:05:06,629  
you know and in Ava's talk was also

121  
00:05:04,500 --> 00:05:08,879  
about in which we're going to get to it

122  
00:05:06,629 --> 00:05:11,699  
here in a little bit more detail even

123  
00:05:08,879 --> 00:05:14,939  
about what is the survivability of I

124  
00:05:11,699 --> 00:05:16,410  
mean of going through a main sequence

125  
00:05:14,939 --> 00:05:18,449  
when when the star leaves the main

126  
00:05:16,410 --> 00:05:20,070  
sequence becomes a red giant what's the

127  
00:05:18,449 --> 00:05:22,319  
survivability of that and is there any

128  
00:05:20,069 --> 00:05:24,418  
chance for them to come back so we're

129  
00:05:22,319 --> 00:05:29,149  
looking way beyond liquid water here and

130  
00:05:24,418 --> 00:05:31,680  
so it's a really importance of I think

131  
00:05:29,149 --> 00:05:33,209  
in-depth look at this whole concept

132  
00:05:31,680 --> 00:05:35,098  
because they're really one of the things

133  
00:05:33,209 --> 00:05:39,209  
that I always get when I talk to people

134  
00:05:35,098 --> 00:05:40,769  
or do we do stories on exoplanets is why

135  
00:05:39,209 --> 00:05:42,810  
are we always so concerned about liquid

136  
00:05:40,769 --> 00:05:44,908  
water why can't you have like a sulfuric

137  
00:05:42,810 --> 00:05:46,949  
acid oceans or a Venus like place with

138  
00:05:44,908 --> 00:05:50,728  
with life could isn't it possible well

139  
00:05:46,949 --> 00:05:53,129  
sure it is but you know is it uh is it

140  
00:05:50,728 --> 00:05:54,478  
likely and when we know what is likely

141  
00:05:53,129 --> 00:05:57,750  
is the fact that we start with earth

142  
00:05:54,478 --> 00:05:58,860  
earth that's our one data point so even

143

00:05:57,750 --> 00:06:00,560  
let me get you into this conversation

144  
00:05:58,860 --> 00:06:03,270  
what do you think of this idea of

145  
00:06:00,560 --> 00:06:06,750  
habitability in general do you think for

146  
00:06:03,269 --> 00:06:08,908  
example that the earth is typical are we

147  
00:06:06,750 --> 00:06:11,519  
are there a lot of us are there are a

148  
00:06:08,908 --> 00:06:13,199  
lot of planets like ours out there well

149  
00:06:11,519 --> 00:06:14,609  
in fact it is one of the most important

150  
00:06:13,199 --> 00:06:16,620  
parameters that we are trying to

151  
00:06:14,610 --> 00:06:18,689  
determine what is the percentage of

152  
00:06:16,620 --> 00:06:21,780  
planets out I mean of stars out there

153  
00:06:18,689 --> 00:06:26,728  
that have planets like Earth at the

154  
00:06:21,779 --> 00:06:28,709  
right distance and thus that's a very

155  
00:06:26,728 --> 00:06:30,990  
important question to answer because

156  
00:06:28,709 --> 00:06:33,149  
once we have this number we can assess

157  
00:06:30,990 --> 00:06:36,269

what is the percentage of stars out

158

00:06:33,149 --> 00:06:37,829

there am I have at least a planet with

159

00:06:36,269 --> 00:06:39,718

the right conditions at the right

160

00:06:37,829 --> 00:06:41,039

distance in order to be able to host

161

00:06:39,718 --> 00:06:43,560

life

162

00:06:41,040 --> 00:06:46,319

as you mentioned yes we we look into

163

00:06:43,560 --> 00:06:47,639

liquid water because this is what we

164

00:06:46,319 --> 00:06:50,490

know but there might be other

165

00:06:47,639 --> 00:06:52,229

disciplines that are good for life the

166

00:06:50,490 --> 00:06:54,960

good thing about water is that it stands

167

00:06:52,230 --> 00:06:57,330

a broad range of conditions I mean we

168

00:06:54,959 --> 00:06:59,879

have more than 100 degrees between the

169

00:06:57,329 --> 00:07:01,800

point where the water freezes to the

170

00:06:59,879 --> 00:07:04,439

point where water gets evaporated and

171

00:07:01,800 --> 00:07:07,199

that's good for life a other forms of

172  
00:07:04,439 --> 00:07:10,860  
light my assists for example in a we say

173  
00:07:07,199 --> 00:07:12,899  
kind of this orbit but that would be

174  
00:07:10,860 --> 00:07:15,629  
hard to look for at me we have to start

175  
00:07:12,899 --> 00:07:20,039  
with the basic things and build up it

176  
00:07:15,629 --> 00:07:23,159  
slowly from there okay so you're you

177  
00:07:20,040 --> 00:07:24,780  
guys in your talk this afternoon I saw

178  
00:07:23,160 --> 00:07:26,220  
that you had a lot of references to work

179  
00:07:24,779 --> 00:07:29,449  
that you had done with Mario so

180  
00:07:26,220 --> 00:07:32,160  
presumably you guys have looked into

181  
00:07:29,449 --> 00:07:34,860  
this research of habitability and post

182  
00:07:32,160 --> 00:07:36,960  
main-sequence stars before so let's

183  
00:07:34,860 --> 00:07:39,300  
let's go into that a little bit your

184  
00:07:36,959 --> 00:07:43,289  
talk was called all our post

185  
00:07:39,300 --> 00:07:47,310  
main-sequence planets doomed and you

186  
00:07:43,290 --> 00:07:49,460  
were lookin by that what is a post main

187  
00:07:47,310 --> 00:07:53,399  
sequence star can you describe it for us

188  
00:07:49,459 --> 00:07:56,339  
it just as you know I mean we are

189  
00:07:53,399 --> 00:07:59,819  
orbiting a star that is burning burning

190  
00:07:56,339 --> 00:08:02,699  
hydrogen in the core but they start will

191  
00:07:59,819 --> 00:08:04,709  
eventually run out of hydrogen and as

192  
00:08:02,699 --> 00:08:08,370  
soon as that happens he will move into a

193  
00:08:04,709 --> 00:08:10,169  
different evolutionary stage a for a

194  
00:08:08,370 --> 00:08:12,180  
study in order to fight gravity has two

195  
00:08:10,170 --> 00:08:15,300  
persons in either in the cold in a shell

196  
00:08:12,180 --> 00:08:18,420  
outside of the outside of the core the

197  
00:08:15,300 --> 00:08:22,680  
rest nuclear fuel that the star like the

198  
00:08:18,420 --> 00:08:25,230  
Sun can burn is helium and that's it it

199  
00:08:22,680 --> 00:08:28,019  
cannot burn anything else so we talked

200

00:08:25,230 --> 00:08:30,390  
about its master or well yes because of

201  
00:08:28,019 --> 00:08:33,590  
his mass if it were a more massive study

202  
00:08:30,389 --> 00:08:37,049  
will be able to burn much much higher

203  
00:08:33,590 --> 00:08:39,750  
element but I star like the Sun you will

204  
00:08:37,049 --> 00:08:42,509  
stop after helium you will be the carbon

205  
00:08:39,750 --> 00:08:45,059  
oxygen core and it will have the

206  
00:08:42,509 --> 00:08:47,939  
envelope removed by processes like winds

207  
00:08:45,059 --> 00:08:50,549  
and this is exactly what we mean by a

208  
00:08:47,940 --> 00:08:53,280  
post main sequence star am in sequence

209  
00:08:50,549 --> 00:08:54,539  
main sequence star a star is a star that

210  
00:08:53,279 --> 00:08:58,049  
is burning hi

211  
00:08:54,539 --> 00:08:59,909  
it was many sequences that he has run

212  
00:08:58,049 --> 00:09:07,139  
out of hydrogen in the core and it goes

213  
00:08:59,909 --> 00:09:09,120  
through a very let's say not not stable

214  
00:09:07,139 --> 00:09:11,399

phases of evolution yeah it starts to

215

00:09:09,120 --> 00:09:13,409

get big right it starts to expand and

216

00:09:11,399 --> 00:09:15,360

then get and get larger right that when

217

00:09:13,409 --> 00:09:18,809

it when it turns into a red giant yes

218

00:09:15,360 --> 00:09:22,379

yes okay so I was just going to say main

219

00:09:18,809 --> 00:09:24,689

sequence refers to the majority of the

220

00:09:22,379 --> 00:09:26,399

time the star spends in a stable state

221

00:09:24,690 --> 00:09:28,560

and we call that main sequence for

222

00:09:26,399 --> 00:09:31,639

different stars of different masses the

223

00:09:28,559 --> 00:09:34,739

amount of time that occurs is different

224

00:09:31,639 --> 00:09:37,589

luckily for us that for the Sun it's a

225

00:09:34,740 --> 00:09:41,009

long time and then post main sequence is

226

00:09:37,589 --> 00:09:42,660

as Eva said now you've got problems in

227

00:09:41,009 --> 00:09:44,730

the core you've exhausted some of the

228

00:09:42,659 --> 00:09:46,980

fuel and now the structure of the star



229

00:09:44,730 --> 00:09:49,139

is trying to readjust to its

230

00:09:46,980 --> 00:09:50,940

circumstance that's got gravity pushing

231

00:09:49,139 --> 00:09:54,419

in and energy putting pushing out and

232

00:09:50,940 --> 00:09:57,870

that isn't so good for a planet that is

233

00:09:54,419 --> 00:10:00,208

out in orbit around that star okay so

234

00:09:57,870 --> 00:10:02,519

Mario did you do some work with did you

235

00:10:00,208 --> 00:10:03,989

Ava work together earlier on some of

236

00:10:02,519 --> 00:10:06,720

these questions as well I saw your name

237

00:10:03,990 --> 00:10:09,448

on a lot of slides yeah we we started

238

00:10:06,720 --> 00:10:12,480

working on this I don't know around two

239

00:10:09,448 --> 00:10:15,328

thousand five six I think maybe

240

00:10:12,480 --> 00:10:18,149

published our first work in 2007 or

241

00:10:15,328 --> 00:10:20,939

thereabout and then published a few more

242

00:10:18,149 --> 00:10:24,629

works following that so so the idea is

243  
00:10:20,940 --> 00:10:28,079  
very simple since we now know that most

244  
00:10:24,629 --> 00:10:30,028  
stars have planets around them the

245  
00:10:28,078 --> 00:10:33,359  
question is what happens to these

246  
00:10:30,028 --> 00:10:36,568  
planets as the star as we said you know

247  
00:10:33,360 --> 00:10:39,629  
exhausts its its hydrogen and a star

248  
00:10:36,568 --> 00:10:42,500  
like the Sun is going to increase in

249  
00:10:39,629 --> 00:10:45,269  
radius you know x factor of hundreds

250  
00:10:42,500 --> 00:10:47,429  
when when it becomes a you know a red

251  
00:10:45,269 --> 00:10:51,028  
giant star I'll pass to the orbit of

252  
00:10:47,429 --> 00:10:54,208  
Earth presumable well actually the earth

253  
00:10:51,028 --> 00:10:57,838  
turns out to be the most difficult thing

254  
00:10:54,208 --> 00:11:01,679  
to calculate if it while it's true that

255  
00:10:57,839 --> 00:11:04,079  
the the Sun can out past the orbit the

256  
00:11:01,679 --> 00:11:06,838  
current orbit of Earth earth itself

257

00:11:04,078 --> 00:11:08,189  
might move a little bit outwards by that

258  
00:11:06,839 --> 00:11:10,860  
time oh that's right

259  
00:11:08,190 --> 00:11:12,630  
course yes so so it you know so it's

260  
00:11:10,860 --> 00:11:15,720  
it's a touch and go what will actually

261  
00:11:12,629 --> 00:11:17,610  
happen to earth but but let's talk more

262  
00:11:15,720 --> 00:11:19,950  
generally about many of these planets

263  
00:11:17,610 --> 00:11:22,680  
that are in there so now you have this

264  
00:11:19,950 --> 00:11:25,500  
giant star and you have a planet that

265  
00:11:22,679 --> 00:11:27,779  
you know okay was not directly engulfed

266  
00:11:25,500 --> 00:11:30,289  
in it it was just you know was left

267  
00:11:27,779 --> 00:11:33,600  
there but what happens at that point

268  
00:11:30,289 --> 00:11:37,439  
according to our calculations is that

269  
00:11:33,600 --> 00:11:40,860  
the the planet raises tides on the star

270  
00:11:37,440 --> 00:11:45,140  
just like the moon raises tides on on

271  
00:11:40,860 --> 00:11:48,120

the earth and as it raises those tides

272

00:11:45,139 --> 00:11:51,000

the orbit starts to dissipate and the

273

00:11:48,120 --> 00:11:53,700

planet starts to move inward and we

274

00:11:51,000 --> 00:11:56,070

wanted to know which planets would

275

00:11:53,700 --> 00:11:58,560

actually be eventually engulfed by the

276

00:11:56,070 --> 00:12:02,250

star which planets would manage to

277

00:11:58,559 --> 00:12:04,799

survive and and so on so for example the

278

00:12:02,250 --> 00:12:07,080

earth really turns out to be a dep

279

00:12:04,799 --> 00:12:09,089

touch-and-go place where some

280

00:12:07,080 --> 00:12:11,700

calculations show that it will be

281

00:12:09,090 --> 00:12:15,000

eventually engulf some show that it may

282

00:12:11,700 --> 00:12:17,129

just barely survived now planets of

283

00:12:15,000 --> 00:12:20,730

course that are farther than where the

284

00:12:17,129 --> 00:12:22,889

earth is now will survive but even if

285

00:12:20,730 --> 00:12:25,710

they survive in terms of you know that

286  
00:12:22,889 --> 00:12:28,019  
physically they are still there that

287  
00:12:25,710 --> 00:12:30,690  
doesn't mean that life on them can

288  
00:12:28,019 --> 00:12:33,360  
survive drivin for example the earth

289  
00:12:30,690 --> 00:12:36,260  
will be scorched I mean even if it's not

290  
00:12:33,360 --> 00:12:39,810  
enough it will be totally scorched so

291  
00:12:36,259 --> 00:12:42,210  
there there are all these deep questions

292  
00:12:39,809 --> 00:12:44,729  
as to what happens to if there is life

293  
00:12:42,210 --> 00:12:48,720  
on any kinds of these planets what

294  
00:12:44,730 --> 00:12:50,940  
happens to them is their stars evolve so

295  
00:12:48,720 --> 00:12:52,950  
Ava in your talk you actually address

296  
00:12:50,940 --> 00:12:54,780  
that your talk was split up into two

297  
00:12:52,950 --> 00:12:57,060  
main parts as I understood it you were

298  
00:12:54,779 --> 00:13:00,600  
trying to answer the question would life

299  
00:12:57,059 --> 00:13:02,969  
have to endure after this what Mario

300  
00:13:00,600 --> 00:13:05,430  
just happened what would life have to go

301  
00:13:02,970 --> 00:13:07,440  
through describe it presumably if it

302  
00:13:05,429 --> 00:13:09,269  
even could and the second question were

303  
00:13:07,440 --> 00:13:13,140  
asking is are there any suitable

304  
00:13:09,269 --> 00:13:16,049  
conditions that might form after the

305  
00:13:13,139 --> 00:13:19,169  
goat the red giant phase that might be

306  
00:13:16,049 --> 00:13:21,419  
my give life a second chance to start up

307  
00:13:19,169 --> 00:13:22,049  
on earth and you can you comment on that

308  
00:13:21,419 --> 00:13:23,519  
a little bit

309  
00:13:22,049 --> 00:13:28,349  
especially to the first point what would

310  
00:13:23,519 --> 00:13:30,480  
life have to endure to get to survive

311  
00:13:28,350 --> 00:13:33,209  
the red giant phase if it even could and

312  
00:13:30,480 --> 00:13:35,339  
do you think it could well first of all

313  
00:13:33,208 --> 00:13:38,250  
before even the star leaves the main

314

00:13:35,339 --> 00:13:41,670  
sequence this stage of evolution where

315  
00:13:38,250 --> 00:13:43,350  
the Sun is stable the luminosity of the

316  
00:13:41,669 --> 00:13:45,419  
Sun will increase I mean the energy that

317  
00:13:43,350 --> 00:13:47,700  
the Sun will emit per second is going to

318  
00:13:45,419 --> 00:13:52,229  
increase and these guys got brighter on

319  
00:13:47,700 --> 00:13:54,420  
earth exactly and that will have I mean

320  
00:13:52,230 --> 00:13:56,940  
it's not clear where the weather at the

321  
00:13:54,419 --> 00:13:59,699  
atmosphere will be i were to adjust to

322  
00:13:56,940 --> 00:14:03,450  
the changes provided by the increasing

323  
00:13:59,700 --> 00:14:05,759  
luminosity of the Sun over the over the

324  
00:14:03,450 --> 00:14:07,410  
time span that will happen but most

325  
00:14:05,759 --> 00:14:08,819  
likely not I mean most likely the

326  
00:14:07,409 --> 00:14:10,319  
atmosphere will get it because the

327  
00:14:08,820 --> 00:14:12,570  
stellar the solar wind will be also

328  
00:14:10,320 --> 00:14:16,260

increased quite a bit tues i right hey

329

00:14:12,570 --> 00:14:18,120

yes yes in the radiation but we have the

330

00:14:16,259 --> 00:14:19,740

magnetic field that brought from the air

331

00:14:18,120 --> 00:14:22,110

that will protect it from the solar wind

332

00:14:19,740 --> 00:14:24,389

so the solar wind is not such a big

333

00:14:22,110 --> 00:14:27,750

problem is increasing the energy of the

334

00:14:24,389 --> 00:14:30,689

emitted by the Sun that will will make

335

00:14:27,750 --> 00:14:32,309

this planet a very hot place and we will

336

00:14:30,690 --> 00:14:35,010

have probably a runaway of red light

337

00:14:32,309 --> 00:14:37,349

like the one that happened in India nose

338

00:14:35,009 --> 00:14:38,939

and got rid of the atmosphere so that

339

00:14:37,350 --> 00:14:42,149

will be the first thing before even the

340

00:14:38,940 --> 00:14:44,399

Sun gets bigger the design with a start

341

00:14:42,149 --> 00:14:47,700

to get bigger in radios so we are going

342

00:14:44,399 --> 00:14:50,759

to have a planet that in my move



343  
00:14:47,700 --> 00:14:52,140  
outwards a little bit but we have the

344  
00:14:50,759 --> 00:14:55,409  
surface of the sun de will be

345  
00:14:52,139 --> 00:14:56,939  
approaching us as the Sun evolves so we

346  
00:14:55,409 --> 00:15:01,139  
are going to get very close to the

347  
00:14:56,940 --> 00:15:04,140  
surface of a sudden principle that that

348  
00:15:01,139 --> 00:15:07,559  
is another of the of the things that

349  
00:15:04,139 --> 00:15:09,870  
life will have to endure if it has

350  
00:15:07,559 --> 00:15:14,009  
already managed to survive increase in

351  
00:15:09,870 --> 00:15:16,409  
luminosity a infrared reason luminosity

352  
00:15:14,009 --> 00:15:18,389  
and we're gonna get closer to the to the

353  
00:15:16,409 --> 00:15:21,778  
star or the stars going closer to us

354  
00:15:18,389 --> 00:15:24,689  
yeah we might get that close that we

355  
00:15:21,778 --> 00:15:27,659  
might even get inside of the office and

356  
00:15:24,690 --> 00:15:29,459  
and if we get inside of the Sun forget

357  
00:15:27,659 --> 00:15:31,559  
it I mean the planet will eventually a

358  
00:15:29,458 --> 00:15:34,500  
spiral in very quickly and it will merge

359  
00:15:31,559 --> 00:15:35,579  
with the core of the star so that will

360  
00:15:34,500 --> 00:15:37,049  
be

361  
00:15:35,580 --> 00:15:40,670  
that would have to be some pretty robust

362  
00:15:37,049 --> 00:15:40,669  
life to make it through that I suppose

363  
00:15:41,029 --> 00:15:47,459  
yeah so if the planet managed to survive

364  
00:15:45,240 --> 00:15:50,399  
this face then it would be a very stable

365  
00:15:47,460 --> 00:15:53,670  
phase following that of helium burning

366  
00:15:50,399 --> 00:15:56,730  
in the core in which if life had managed

367  
00:15:53,669 --> 00:15:59,699  
to survive somehow and he might be able

368  
00:15:56,730 --> 00:16:03,090  
to do have a second chance to to develop

369  
00:15:59,700 --> 00:16:05,340  
for to enjoy a few more he got years

370  
00:16:03,090 --> 00:16:07,800  
it's better to move before it's too late

371

00:16:05,340 --> 00:16:09,899  
yeah yeah yeah well we're luckily we've

372  
00:16:07,799 --> 00:16:11,490  
got some time when twin let's just go

373  
00:16:09,899 --> 00:16:13,019  
ahead and say when you're expected when

374  
00:16:11,490 --> 00:16:15,750  
is this expected to happen with that

375  
00:16:13,019 --> 00:16:18,210  
with our son in about five billion years

376  
00:16:15,750 --> 00:16:20,340  
oh good so all right so there's no

377  
00:16:18,210 --> 00:16:21,840  
immediate cause for alarm at least right

378  
00:16:20,340 --> 00:16:24,899  
now but the fact that you're looking at

379  
00:16:21,840 --> 00:16:26,850  
this and in a in a bigger picture is

380  
00:16:24,899 --> 00:16:28,620  
really fascinating to me I mean you're

381  
00:16:26,850 --> 00:16:31,200  
looking at not just you know obviously I

382  
00:16:28,620 --> 00:16:33,389  
like to bring it home because earth is a

383  
00:16:31,200 --> 00:16:36,030  
typical thing that we can you know

384  
00:16:33,389 --> 00:16:37,949  
visualize and so to see how this how our

385  
00:16:36,029 --> 00:16:41,129

Sun evolves and what might happen to

386

00:16:37,950 --> 00:16:45,030

life here is an important one but in

387

00:16:41,129 --> 00:16:47,129

your talk uh use you use a really scary

388

00:16:45,029 --> 00:16:55,199

term cold I remember laughing when i saw

389

00:16:47,129 --> 00:16:57,240

it planet evaporation rates um yikes so

390

00:16:55,200 --> 00:16:59,340

why don't you tell it so what so what

391

00:16:57,240 --> 00:17:02,180

does that mean the planet of a these are

392

00:16:59,340 --> 00:17:04,799

when planets just simply don't survive

393

00:17:02,179 --> 00:17:06,899

yes this is a different phase of

394

00:17:04,799 --> 00:17:09,509

evolution that a planet will have to

395

00:17:06,900 --> 00:17:11,670

endure after the postman sequencing it's

396

00:17:09,509 --> 00:17:16,349

the planetary nebula phase in which we

397

00:17:11,670 --> 00:17:20,160

have a very huge flares of radiation that

398

00:17:16,349 --> 00:17:22,619

is neutral eye on it so something I mean

399

00:17:20,160 --> 00:17:24,690

we have the ozone layer now protect us

400  
00:17:22,619 --> 00:17:26,879  
from protecting us from the ultraviolet

401  
00:17:24,690 --> 00:17:30,180  
radiation from the Sun imagine a

402  
00:17:26,880 --> 00:17:33,300  
radiation that is much much much higher

403  
00:17:30,180 --> 00:17:36,150  
orders of magnitude higher in a star

404  
00:17:33,299 --> 00:17:39,779  
that is has a wolf of the main sequence

405  
00:17:36,150 --> 00:17:42,120  
and that this radiation has so much

406  
00:17:39,779 --> 00:17:44,609  
energy that literally evaporates the

407  
00:17:42,119 --> 00:17:46,649  
surface of a planet of a gas planet and

408  
00:17:44,609 --> 00:17:49,469  
this is the controlling super late the

409  
00:17:46,650 --> 00:17:52,740  
ultra pile energy front of her napkin

410  
00:17:49,470 --> 00:17:54,419  
gave a black row can you um little

411  
00:17:52,740 --> 00:17:58,829  
background on a planetary nebula huh

412  
00:17:54,419 --> 00:18:00,509  
will she talk about that I could

413  
00:17:58,829 --> 00:18:03,149  
understand the question story you're

414  
00:18:00,509 --> 00:18:06,390  
breaking up Tony you've been breaking up

415  
00:18:03,150 --> 00:18:08,460  
yeah we could hear the question can I

416  
00:18:06,390 --> 00:18:12,179  
ask a question while we figure that out

417  
00:18:08,460 --> 00:18:15,480  
my question to Eva and Mario is that I

418  
00:18:12,179 --> 00:18:17,309  
know so you have this phase where the

419  
00:18:15,480 --> 00:18:19,259  
surface of you know the the Sun is

420  
00:18:17,308 --> 00:18:20,849  
getting bigger stars like the Sun is

421  
00:18:19,259 --> 00:18:24,808  
getting bigger and then you talk about

422  
00:18:20,849 --> 00:18:27,599  
okay that may be the demise of Earth but

423  
00:18:24,808 --> 00:18:29,700  
what about like moons and planets that

424  
00:18:27,599 --> 00:18:32,009  
are further out that may have water on

425  
00:18:29,700 --> 00:18:34,470  
them what happens to them because

426  
00:18:32,009 --> 00:18:35,730  
presumably they get warmer and I know

427  
00:18:34,470 --> 00:18:37,798  
there are some people that are

428

00:18:35,730 --> 00:18:40,980  
interested in you know what could happen

429  
00:18:37,798 --> 00:18:42,658  
to a moon that has ice on it now will it

430  
00:18:40,980 --> 00:18:45,089  
have water and it will it be in that

431  
00:18:42,659 --> 00:18:50,909  
state long enough for even the tiniest

432  
00:18:45,089 --> 00:18:54,089  
microbe to form well as the Santa volts

433  
00:18:50,909 --> 00:18:56,340  
the abbot ability so we'll move outwards

434  
00:18:54,089 --> 00:18:59,730  
so it will reach the region where we

435  
00:18:56,339 --> 00:19:02,819  
don't have planned I mean we can't have

436  
00:18:59,730 --> 00:19:05,190  
planets with moons out there where what

437  
00:19:02,819 --> 00:19:07,079  
life can be sustainable you have to keep

438  
00:19:05,190 --> 00:19:09,210  
in mind that the faces of evolution

439  
00:19:07,079 --> 00:19:12,538  
after the main sequence are shorter so

440  
00:19:09,210 --> 00:19:16,980  
we are going to talk about of the order

441  
00:19:12,538 --> 00:19:21,690  
of a billion years one being yeah so I

442  
00:19:16,980 --> 00:19:25,529

mean that's not long enough probably not

443

00:19:21,690 --> 00:19:29,880

you know maybe for microbes yes but for

444

00:19:25,529 --> 00:19:31,970

elephants probably all in my back eyes

445

00:19:29,880 --> 00:19:34,169

can you yeah yeah yeah we hear you

446

00:19:31,970 --> 00:19:36,058

alright what I wanted it what I wanted

447

00:19:34,169 --> 00:19:37,470

to get into right there was planetary

448

00:19:36,058 --> 00:19:39,048

nebula I wanted to go back to that idea

449

00:19:37,470 --> 00:19:42,720

and I wanted Carol to kind of explain

450

00:19:39,048 --> 00:19:44,279

how the earth gets over how the Sun gets

451

00:19:42,720 --> 00:19:45,360

to a planetary nebula just give this

452

00:19:44,279 --> 00:19:48,418

whole background on in case people don't

453

00:19:45,359 --> 00:19:52,168

know what that is so so just about the

454

00:19:48,419 --> 00:19:54,360

term you know astronomers are you know

455

00:19:52,169 --> 00:19:55,679

when they look through the telescope and

456

00:19:54,359 --> 00:19:57,779

they see something and it reminds them



457  
00:19:55,679 --> 00:19:59,909  
of something else a word comes out of

458  
00:19:57,779 --> 00:20:03,089  
their mouth and it may not happy have

459  
00:19:59,909 --> 00:20:05,430  
Astrophysical significance so planetary

460  
00:20:03,089 --> 00:20:07,379  
were thought to be when they they were

461  
00:20:05,430 --> 00:20:09,029  
first seen through a telescope so a star

462  
00:20:07,380 --> 00:20:11,010  
with some kind of planetary system

463  
00:20:09,029 --> 00:20:13,170  
around it well it turns out there

464  
00:20:11,009 --> 00:20:15,509  
actually nebula and they really have

465  
00:20:13,170 --> 00:20:16,890  
nothing to do with planets or probably

466  
00:20:15,509 --> 00:20:19,140  
don't have mean that's not their main

467  
00:20:16,890 --> 00:20:22,740  
function actually Mario is an expert on

468  
00:20:19,140 --> 00:20:24,240  
this but anyway the idea is as they've

469  
00:20:22,740 --> 00:20:26,039  
been discussing even Mario been

470  
00:20:24,240 --> 00:20:28,769  
discussing the core of the star

471  
00:20:26,039 --> 00:20:30,990  
collapses it starts to push its outer

472  
00:20:28,769 --> 00:20:34,859  
atmosphere out it gets bigger it's

473  
00:20:30,990 --> 00:20:37,670  
pumping out energy at some point it may

474  
00:20:34,859 --> 00:20:40,439  
have a more dramatic structure

475  
00:20:37,670 --> 00:20:43,410  
rearrangement which will force the outer

476  
00:20:40,440 --> 00:20:46,230  
part a lot of them material on the outer

477  
00:20:43,410 --> 00:20:48,690  
part of the star it won't explode per se

478  
00:20:46,230 --> 00:20:50,789  
but it will push a lot of material out

479  
00:20:48,690 --> 00:20:53,759  
and we used to think that was a nice

480  
00:20:50,789 --> 00:20:56,069  
little gentle process and it's a nice

481  
00:20:53,759 --> 00:20:57,930  
fear achill nebula well it turns out

482  
00:20:56,069 --> 00:21:00,480  
with Hubble we found out that the

483  
00:20:57,930 --> 00:21:02,789  
structures of planetary nebula are quite

484  
00:21:00,480 --> 00:21:06,059  
complicated and that process of

485

00:21:02,789 --> 00:21:08,220  
readjusting the structure is complicated

486  
00:21:06,059 --> 00:21:10,289  
but gives rise to I think some of the

487  
00:21:08,220 --> 00:21:12,750  
most beautiful nebula we have imaged

488  
00:21:10,289 --> 00:21:15,839  
with Hubble so Mario and Eva can take it

489  
00:21:12,750 --> 00:21:17,940  
from there yeah let me just add that you

490  
00:21:15,839 --> 00:21:20,429  
know just do this last point that that

491  
00:21:17,940 --> 00:21:23,460  
Carol made it you know if you look at

492  
00:21:20,430 --> 00:21:26,100  
some of the most fantastic images that

493  
00:21:23,460 --> 00:21:28,920  
Hubble has taken they are of planetary

494  
00:21:26,099 --> 00:21:31,859  
nebulae because what happens is this as

495  
00:21:28,920 --> 00:21:35,610  
this outer layers are pushed into space

496  
00:21:31,859 --> 00:21:37,679  
you expose this hot core that ever was

497  
00:21:35,609 --> 00:21:40,979  
talking about which emits this

498  
00:21:37,680 --> 00:21:44,730  
ultraviolet radiation and that really

499  
00:21:40,980 --> 00:21:47,490

hits all this gas that was ejected and

500

00:21:44,730 --> 00:21:49,950

it causes it to fluoresce and so you see

501

00:21:47,490 --> 00:21:52,950

all these fantastic colors in it and

502

00:21:49,950 --> 00:21:56,309

really those are truly breathtaking

503

00:21:52,950 --> 00:21:58,080

images of these planetary nebulae and

504

00:21:56,309 --> 00:22:00,240

they are all different I mean you know

505

00:21:58,079 --> 00:22:02,909

like snowflakes each one of them looks

506

00:22:00,240 --> 00:22:04,079

differently a very famous example for

507

00:22:02,910 --> 00:22:05,370

those of you who want to know is the

508

00:22:04,079 --> 00:22:07,649

ring nebula that's a very famous

509

00:22:05,369 --> 00:22:10,379

planetary nebulas like a smoke ring in

510

00:22:07,650 --> 00:22:11,820

space in Mali that that's the one I

511

00:22:10,380 --> 00:22:13,050

learned about and forth I always say I

512

00:22:11,819 --> 00:22:16,470

learned about that in fourth grade and

513

00:22:13,049 --> 00:22:18,089

everybody thought it was a nice uniform

514  
00:22:16,470 --> 00:22:19,589  
as you said smoke ring but actually when

515  
00:22:18,089 --> 00:22:21,750  
you look at it in the Hubble images in

516  
00:22:19,589 --> 00:22:26,250  
detail it has all kinds of very

517  
00:22:21,750 --> 00:22:29,940  
interesting structures yes I realize so

518  
00:22:26,250 --> 00:22:34,019  
Ava in your talk on this unsub like you

519  
00:22:29,940 --> 00:22:38,480  
said that the bad thing is that has 10

520  
00:22:34,019 --> 00:22:43,200  
memory in them but don't he's funny you

521  
00:22:38,480 --> 00:22:46,740  
got again I didn't quite get the sense

522  
00:22:43,200 --> 00:22:49,529  
of your question okay so in your time i

523  
00:22:46,740 --> 00:22:52,140  
am i okay now yes you're in your talk

524  
00:22:49,529 --> 00:22:54,990  
you with the planetary nebula you said

525  
00:22:52,140 --> 00:22:57,630  
the bad thing is that planets tend to

526  
00:22:54,990 --> 00:22:59,308  
evaporate inside of them but there's a

527  
00:22:57,630 --> 00:23:01,679  
good side to it and the good side is

528  
00:22:59,308 --> 00:23:04,319  
that there's also lots of really good

529  
00:23:01,679 --> 00:23:06,590  
complex molecules inside these things do

530  
00:23:04,319 --> 00:23:09,058  
you think that for planets that survive

531  
00:23:06,589 --> 00:23:10,319  
that don't manage to evaporate there

532  
00:23:09,058 --> 00:23:13,558  
might be something there for them to

533  
00:23:10,319 --> 00:23:15,389  
work with yeah I think I mean we're made

534  
00:23:13,558 --> 00:23:17,730  
of carbon after all and one of the main

535  
00:23:15,390 --> 00:23:19,650  
producers of carbon in space are the

536  
00:23:17,730 --> 00:23:22,409  
stars like the Sun that evolved into the

537  
00:23:19,650 --> 00:23:25,890  
planetary nebula state so the fact that

538  
00:23:22,409 --> 00:23:29,039  
we have carbon producers building big

539  
00:23:25,890 --> 00:23:31,830  
molecules of as I mentioned it was a

540  
00:23:29,038 --> 00:23:34,619  
carbon 60 fullerene molecules out there

541  
00:23:31,829 --> 00:23:37,798  
I think it's a good news for for life

542

00:23:34,619 --> 00:23:39,959  
and only material would have we are made

543  
00:23:37,798 --> 00:23:42,710  
of fatty and kind came from the interior

544  
00:23:39,960 --> 00:23:46,590  
of stars and these stars are literally

545  
00:23:42,710 --> 00:23:48,569  
bringing the vibrance of nucleosynthesis

546  
00:23:46,589 --> 00:23:51,629  
into the interstellar million again

547  
00:23:48,569 --> 00:23:56,490  
we're a generation of stars and planets

548  
00:23:51,630 --> 00:23:59,100  
is formed so if we have already complex

549  
00:23:56,490 --> 00:24:01,589  
material over there and we have a chance

550  
00:23:59,099 --> 00:24:04,048  
in order to build planets around these

551  
00:24:01,589 --> 00:24:05,849  
systems that we don't have to wait for

552  
00:24:04,048 --> 00:24:07,859  
the next generation of start to build in

553  
00:24:05,849 --> 00:24:10,529  
a generation of planets I think that's

554  
00:24:07,859 --> 00:24:12,058  
that's good news for life well what

555  
00:24:10,529 --> 00:24:16,500  
about the water question though I mean

556  
00:24:12,058 --> 00:24:18,538

the the the conditions inside these

557

00:24:16,500 --> 00:24:20,730

nebulae and even after that that phase

558

00:24:18,538 --> 00:24:22,829

are we going to get water back or is it

559

00:24:20,730 --> 00:24:25,140

is it gone forever does it survive how

560

00:24:22,829 --> 00:24:27,779

does it survive well not where it's very

561

00:24:25,140 --> 00:24:30,240

hard you will not get it to where it's

562

00:24:27,779 --> 00:24:31,980

very hot but but as we say then

563

00:24:30,240 --> 00:24:34,829

you know the habitable zone moves

564

00:24:31,980 --> 00:24:37,200

outwards is that star evolves and

565

00:24:34,829 --> 00:24:39,178

becomes more luminous and hotter so

566

00:24:37,200 --> 00:24:43,009

there will be some region which is

567

00:24:39,179 --> 00:24:45,120

farther out which could still have water

568

00:24:43,009 --> 00:24:48,420

okay and so what are we left with after

569

00:24:45,119 --> 00:24:50,789

this phase after the after the planetary

570

00:24:48,420 --> 00:24:53,850

nebula phase we're left with a white



571  
00:24:50,789 --> 00:24:56,879  
dwarf right so hopefully we've got a

572  
00:24:53,849 --> 00:24:58,558  
white dwarf star with some planets in a

573  
00:24:56,880 --> 00:25:02,460  
stable orbit that survived everything

574  
00:24:58,558 --> 00:25:04,678  
somewhere near a new habitable zone is

575  
00:25:02,460 --> 00:25:08,730  
there a time scale that is conducive to

576  
00:25:04,679 --> 00:25:10,860  
life reforming here it is a time scale

577  
00:25:08,730 --> 00:25:12,720  
if we are very close to the star and the

578  
00:25:10,859 --> 00:25:14,369  
problem is that is very hard to bring a

579  
00:25:12,720 --> 00:25:17,039  
planet that goes to the star at that

580  
00:25:14,369 --> 00:25:19,199  
point because as I mentioned in my talk

581  
00:25:17,039 --> 00:25:21,240  
every planet that we sped out of the

582  
00:25:19,200 --> 00:25:23,220  
systems are going to be very far away so

583  
00:25:21,240 --> 00:25:25,140  
we have to put to build a mechanism in

584  
00:25:23,220 --> 00:25:27,990  
order to throw a planet close to the

585  
00:25:25,140 --> 00:25:31,470  
white dwarf and that's a very unlikely

586  
00:25:27,990 --> 00:25:33,599  
process but it may happen I mean we know

587  
00:25:31,470 --> 00:25:37,710  
life is a very unlikely processor we are

588  
00:25:33,599 --> 00:25:39,329  
here so to keep in mind well that's a

589  
00:25:37,710 --> 00:25:41,910  
question isn't it that's one of the

590  
00:25:39,329 --> 00:25:46,649  
things I wanted to address in my opinion

591  
00:25:41,910 --> 00:25:49,470  
life is either incredibly easy to bring

592  
00:25:46,650 --> 00:25:51,210  
about or it's very very hard and there

593  
00:25:49,470 --> 00:25:54,150  
are all kinds of you know I've always

594  
00:25:51,210 --> 00:25:57,240  
wondered what does it take to go from a

595  
00:25:54,150 --> 00:26:01,140  
system with zero life no life whatsoever

596  
00:25:57,240 --> 00:26:02,759  
to having life like amino acids my form

597  
00:26:01,140 --> 00:26:05,429  
in an earlier that we might get all

598  
00:26:02,759 --> 00:26:08,009  
kinds of gases and primordial soups and

599

00:26:05,429 --> 00:26:10,080  
everything that won't be alive so it one

600  
00:26:08,009 --> 00:26:12,450  
day we wake up and there's life in there

601  
00:26:10,079 --> 00:26:15,119  
that step going from something that's

602  
00:26:12,450 --> 00:26:19,019  
not alive to something that's live I

603  
00:26:15,119 --> 00:26:21,808  
want to know how hard that is so so that

604  
00:26:19,019 --> 00:26:24,079  
first step it appears to be at least

605  
00:26:21,808 --> 00:26:27,210  
from the one example we have on earth

606  
00:26:24,079 --> 00:26:29,939  
appears to be not that hard that very

607  
00:26:27,210 --> 00:26:32,490  
first step and the reason I say this is

608  
00:26:29,940 --> 00:26:35,850  
there are two reasons really one is that

609  
00:26:32,490 --> 00:26:38,099  
life on Earth appeared almost as soon as

610  
00:26:35,849 --> 00:26:40,529  
it could have appeared namely you know

611  
00:26:38,099 --> 00:26:42,629  
that the very very early Earth things

612  
00:26:40,529 --> 00:26:44,609  
were very hot there was a lot of boom

613  
00:26:42,630 --> 00:26:47,370

argument and so on by all kinds of

614

00:26:44,609 --> 00:26:50,609

asteroids and meteors and whatnot and so

615

00:26:47,369 --> 00:26:53,129

on but as soon as you know the situation

616

00:26:50,609 --> 00:26:56,429

stabilized a little bit we find already

617

00:26:53,130 --> 00:26:58,560

signs to life so clearly on earth it

618

00:26:56,430 --> 00:27:00,750

didn't take too long for life to appear

619

00:26:58,559 --> 00:27:04,799

the second reason I say that first step

620

00:27:00,750 --> 00:27:06,539

may not be hard is that I have a friend

621

00:27:04,799 --> 00:27:08,909

Jack Shaw stuck with a Nobel laureate

622

00:27:06,539 --> 00:27:13,139

who works at Harvard in trying to

623

00:27:08,910 --> 00:27:15,330

produce life in the lab and the last

624

00:27:13,140 --> 00:27:17,700

time I asked him so how long do you

625

00:27:15,329 --> 00:27:20,460

think it will be before you actually can

626

00:27:17,700 --> 00:27:24,420

produce life in the lab and his answer

627

00:27:20,460 --> 00:27:27,779

was about five years so you know if you

628  
00:27:24,420 --> 00:27:30,509  
do yeah yeah so you if you can produce

629  
00:27:27,779 --> 00:27:33,720  
life in the lab it means it's really not

630  
00:27:30,509 --> 00:27:35,339  
that hard now again if you take a lesson

631  
00:27:33,720 --> 00:27:38,519  
from Earth and you should be very

632  
00:27:35,339 --> 00:27:42,869  
careful doing this because it is one

633  
00:27:38,519 --> 00:27:47,009  
example then the step to get from very

634  
00:27:42,869 --> 00:27:49,759  
primitive life to very complex life that

635  
00:27:47,009 --> 00:27:53,480  
actually took a long time on earth

636  
00:27:49,759 --> 00:27:57,480  
billions of years and also required all

637  
00:27:53,480 --> 00:28:00,809  
kinds of fine tunings and in you know

638  
00:27:57,480 --> 00:28:03,990  
chance events and so on so that may be

639  
00:28:00,809 --> 00:28:05,490  
the part that's really hard wow there's

640  
00:28:03,990 --> 00:28:07,289  
there's a hangout I need to have we need

641  
00:28:05,490 --> 00:28:08,670  
to get you and Seth together and talk

642  
00:28:07,289 --> 00:28:10,109  
about this more in depth at some point

643  
00:28:08,670 --> 00:28:13,830  
in the future that sounds like a great a

644  
00:28:10,109 --> 00:28:15,419  
great one okay so we're out of time but

645  
00:28:13,829 --> 00:28:18,240  
I want to get to one quick question uh

646  
00:28:15,420 --> 00:28:21,509  
Brian catnip on the Q&A app is asking

647  
00:28:18,240 --> 00:28:24,059  
can organisms survive off gases other

648  
00:28:21,509 --> 00:28:30,269  
than oxygen and co2 who wants to take

649  
00:28:24,059 --> 00:28:33,509  
that one well I mean yeah I'm a great

650  
00:28:30,269 --> 00:28:35,430  
expert on it I only know I own a little

651  
00:28:33,509 --> 00:28:37,890  
bit about this but there are actually

652  
00:28:35,430 --> 00:28:41,450  
there are quite a number of biologists

653  
00:28:37,890 --> 00:28:43,650  
who are working on these questions and

654  
00:28:41,450 --> 00:28:45,509  
there's there's another kind of

655  
00:28:43,650 --> 00:28:46,890  
survivability that they are interested

656

00:28:45,509 --> 00:28:48,690  
in it's not so much the planet

657  
00:28:46,890 --> 00:28:51,110  
survivability they are interested in the

658  
00:28:48,690 --> 00:28:54,029  
survivability and adaptability of

659  
00:28:51,109 --> 00:28:56,219  
organisms and so there do seem to be

660  
00:28:54,029 --> 00:28:59,220  
some organisms that Canada

661  
00:28:56,220 --> 00:29:01,019  
adapt to what we would consider a very

662  
00:28:59,220 --> 00:29:03,808  
hostile living in environment but they

663  
00:29:01,019 --> 00:29:06,509  
are organisms they are not elephants is

664  
00:29:03,808 --> 00:29:09,389  
new files aren't they in the right

665  
00:29:06,509 --> 00:29:11,519  
Mentos as far as Mario Mario nima made

666  
00:29:09,390 --> 00:29:14,220  
no different but as far as I know there

667  
00:29:11,519 --> 00:29:16,710  
has not been any building blocks of life

668  
00:29:14,220 --> 00:29:20,269  
formed in one of those adverse

669  
00:29:16,710 --> 00:29:22,529  
environment environments but the biology

670  
00:29:20,269 --> 00:29:25,440

biologists who are looking at something

671

00:29:22,529 --> 00:29:30,829  
called extremophiles are studying

672

00:29:25,440 --> 00:29:32,788  
whether life can adapt or survive

673

00:29:30,829 --> 00:29:34,439  
conditions and that goes back a little

674

00:29:32,788 --> 00:29:36,150  
bit to the question you asked you notice

675

00:29:34,440 --> 00:29:38,909  
that these catastrophic events happen

676

00:29:36,150 --> 00:29:41,460  
maybe in the outer solar system microbes

677

00:29:38,909 --> 00:29:43,380  
form then they freeze or they get hot

678

00:29:41,460 --> 00:29:45,390  
can they survive and then come back to

679

00:29:43,380 --> 00:29:47,640  
life in it and they're trying to study

680

00:29:45,390 --> 00:29:50,220  
that and there are microorganisms that

681

00:29:47,640 --> 00:29:53,340  
hibernate and really horrific conditions

682

00:29:50,220 --> 00:29:56,370  
you know and we're like really yeah

683

00:29:53,339 --> 00:29:59,519  
really nasty chemicals and they can

684

00:29:56,369 --> 00:30:01,949  
be revived at different temperatures so



685  
00:29:59,519 --> 00:30:03,450  
so it's an active area of study yeah

686  
00:30:01,950 --> 00:30:06,659  
okay one more and then I'll let you guys

687  
00:30:03,450 --> 00:30:08,308  
go this one is from Hugo Burnham who's

688  
00:30:06,659 --> 00:30:11,370  
going and this one all addressed to you

689  
00:30:08,308 --> 00:30:12,960  
Ava you might know is there something

690  
00:30:11,369 --> 00:30:18,288  
similar to the hertzprung-russell

691  
00:30:12,960 --> 00:30:18,288  
diagram but for planets instead of stars

692  
00:30:18,919 --> 00:30:26,700  
yes well I mean no yes and no I mean we

693  
00:30:24,000 --> 00:30:30,029  
have to like planets you've got rocky or

694  
00:30:26,700 --> 00:30:32,009  
super Earths and yeah the hospital a

695  
00:30:30,029 --> 00:30:34,200  
certain item is a question of evolution

696  
00:30:32,009 --> 00:30:36,779  
that I mean by the nuclear source of the

697  
00:30:34,200 --> 00:30:39,390  
start I mean if we can look at the

698  
00:30:36,779 --> 00:30:41,428  
diagram for planets in terms of

699  
00:30:39,390 --> 00:30:44,580  
luminosity ventures temperature that

700  
00:30:41,429 --> 00:30:46,980  
tell us how is going to cool off just

701  
00:30:44,579 --> 00:30:49,439  
provided that they have some energy

702  
00:30:46,980 --> 00:30:52,529  
source that that remains are the active

703  
00:30:49,440 --> 00:30:54,330  
energy releases from the contraction of

704  
00:30:52,529 --> 00:30:57,298  
the planet and things like that but

705  
00:30:54,329 --> 00:31:01,230  
those are much more simple drugs for a

706  
00:30:57,298 --> 00:31:02,400  
planet ok all right well um i guess i'm

707  
00:31:01,230 --> 00:31:05,429  
going to go ahead and stop there because

708  
00:31:02,400 --> 00:31:07,110  
you guys have to get going and i wanted

709  
00:31:05,429 --> 00:31:08,820  
there's just so much more i was hoping

710  
00:31:07,109 --> 00:31:10,379  
to be able to talk about this is a huge

711  
00:31:08,819 --> 00:31:12,349  
hugely interesting sub

712  
00:31:10,380 --> 00:31:15,540  
there's a whole there's a there is a

713

00:31:12,349 --> 00:31:17,219  
symposium being held all week long here

714  
00:31:15,539 --> 00:31:18,869  
at the Institute many of the videos and

715  
00:31:17,220 --> 00:31:22,350  
talks are already posted i put the link

716  
00:31:18,869 --> 00:31:24,839  
to those webcast videos on our way on

717  
00:31:22,349 --> 00:31:27,539  
the event page here it's web cast out

718  
00:31:24,839 --> 00:31:29,519  
stsci.edu and you go there and you can

719  
00:31:27,539 --> 00:31:31,079  
watch these talks you can that many of

720  
00:31:29,519 --> 00:31:33,750  
them are already archive some of them

721  
00:31:31,079 --> 00:31:35,939  
aren't but many of them are I don't know

722  
00:31:33,750 --> 00:31:37,319  
if avis is up yet or not she just gave

723  
00:31:35,940 --> 00:31:39,269  
it only about an hour ago a little over

724  
00:31:37,319 --> 00:31:41,819  
an hour ago so but I highly encourage

725  
00:31:39,269 --> 00:31:42,869  
you guys to check out these talks if

726  
00:31:41,819 --> 00:31:44,490  
you're interested in this question of

727  
00:31:42,869 --> 00:31:45,899

habitability because they're being it's

728

00:31:44,490 --> 00:31:48,059

being looked at and discussed very

729

00:31:45,900 --> 00:31:50,400

seriously by astronomers right now at

730

00:31:48,059 --> 00:31:51,960

the Space Telescope Science Institute so

731

00:31:50,400 --> 00:31:54,930

I'm going to stop here guys I don't want

732

00:31:51,960 --> 00:31:56,430

to thank Mario Livio and Ava and Carol

733

00:31:54,930 --> 00:31:59,700

all of you guys thank you very much for

734

00:31:56,430 --> 00:32:01,710

joining me and talking about this i will

735

00:31:59,700 --> 00:32:03,390

look for more Hubble hangouts coming up

736

00:32:01,710 --> 00:32:06,210

in the future I think our next one Carol

737

00:32:03,390 --> 00:32:07,920

and I have scheduled will be with dr.

738

00:32:06,210 --> 00:32:10,319

Amy sumera we're going to be talking

739

00:32:07,920 --> 00:32:13,680

about looking at protoplanetary disks

740

00:32:10,319 --> 00:32:16,049

and exoplanets from Nick moss data and

741

00:32:13,680 --> 00:32:18,269

all kinds of other interesting topics so

742

00:32:16,049 --> 00:32:20,460

look for those in the coming weeks and

743

00:32:18,269 --> 00:32:26,509

months ahead thank you all for watching

744

00:32:20,460 --> 00:32:26,509

and as always keep looking up thank you