Hubble Public Lecture Series

Topic: From Cosmic Birth to Living Earth:
The Next Great Space Telescope Beyond JWST

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1
00:00:04,519 --> 00:00:02,659
unless you delve into the details so I

2
00:00:06,769 --> 00:00:04,529
wasn't able to delve into the details in

3
00:00:09,799 --> 00:00:06,779
my talk last month I'll do it this month

4
00:00:11,240 --> 00:00:09,809
in the news summary so here is a let me

5
00:00:13,039 --> 00:00:11,250
go back here I'm we're gonna go into

6
00:00:15,620 --> 00:00:13,049
this region right here on the left

7
00:00:17,960 --> 00:00:15,630
pillar okay about two-thirds of the way

8
00:00:21,500 --> 00:00:17,970
down the left pillar and on the left you

9
00:00:24,740 --> 00:00:21,510
see the 1995 image and on the right you

10
00:00:26,870 --> 00:00:24,750
see the 2015 image and you can see that

11
00:00:29,419 --> 00:00:26,880
the 2015 image has twice the resolution

12
00:00:32,269 --> 00:00:29,429
we had tenth of an arcsecond resolution

13
00:00:35,060 --> 00:00:32,279

in 1995 we have a 20th of an arcsecond

14
00:00:38,540 --> 00:00:35,070
resolution in 2015 and you see it's just

15
00:00:42,680 --> 00:00:38,550
that much crisper all right one of the

16
00:00:45,279 --> 00:00:42,690
results of the 1995 scientific papers

17
00:00:49,610 --> 00:00:45,289
was that these yellow regions this

18
00:00:51,770 --> 00:00:49,620
ionization front where as thin as Hubble

19
00:00:55,130 --> 00:00:51,780
could resolve you know one of the

20
00:00:57,950 --> 00:00:55,140
results from 2015 is they are still as

21
00:01:00,049 --> 00:00:57,960
thin as Hubble can resolve these

22
00:01:03,709 --> 00:01:00,059
ionization fronts are the regions where

23
00:01:05,990 --> 00:01:03,719
the dense molecular gas turns into the

24
00:01:08,120 --> 00:01:06,000
rarefied ionized gas okay

25
00:01:10,700 --> 00:01:08,130
ionization the process where high-energy

26
00:01:11,300 --> 00:01:10,710
hits the atom and the electrons are

27
00:01:13,310 --> 00:01:11,310
removed

28
00:01:15,200 --> 00:01:13,320
that's the ionization process well you

29
00:01:17,480 --> 00:01:15,210
can see that ionization front is really

30
00:01:19,730 --> 00:01:17,490
as thin as Hubble can resolve it it's

31
00:01:21,620 --> 00:01:19,740
still below the resolution and I got to

32
00:01:23,270 --> 00:01:21,630
say in graduate school you learn that

33
00:01:26,030 --> 00:01:23,280
the transition region is really really

34
00:01:28,550 --> 00:01:26,040
thin but to see it visually is really

35
00:01:32,200 --> 00:01:28,560
kind of cool now if we look at the

36
00:01:35,390 --> 00:01:32,210
Senate that sense the central pillar in

37
00:01:37,670 --> 00:01:35,400
1995 that was done with the PC chip the

38
00:01:39,950 --> 00:01:37,680

planetary camera chip which actually had

39
00:01:42,740 --> 00:01:39,960
one twentieth of an arcsecond resolution

40
00:01:44,450 --> 00:01:42,750
all right the wif pictu had three chips

41
00:01:46,609 --> 00:01:44,460
that had tenth of an arc second

42
00:01:48,560 --> 00:01:46,619
resolution and then one ship that had

43
00:01:51,770 --> 00:01:48,570
20th of our executive resolution pixels

44
00:01:54,039 --> 00:01:51,780
were all down a smaller angle so you can

45
00:01:57,109 --> 00:01:54,049
see that some of the detail here is

46
00:01:59,300 --> 00:01:57,119
reflected here but you can see that the

47
00:02:01,760 --> 00:01:59,310
signal-to-noise the improvement in the

48
00:02:04,160 --> 00:02:01,770
detectors is a lot you can see there's a

49
00:02:06,770 --> 00:02:04,170
lot of ups let's go back a lot of noise

50
00:02:08,630 --> 00:02:06,780
in here that you just don't see in here

51
00:02:11,360 --> 00:02:08,640
so the structure that you

52
00:02:14,030 --> 00:02:11,370
is improved not just by an improvement

53
00:02:16,400 --> 00:02:14,040
in resolution but by an improvement in

54
00:02:19,280 --> 00:02:16,410
the detectors and the efficiency of

55
00:02:21,710 --> 00:02:19,290
those detectors in getting and getting

56
00:02:23,690 --> 00:02:21,720
the light from distant cosmic objects I

57
00:02:35,030 --> 00:02:23,700
also like this little object up here you

58
00:02:36,740 --> 00:02:35,040
see this top of the left pillar and the

59
00:02:40,070 --> 00:02:36,750
place where all these stars are forming

60
00:02:44,000 --> 00:02:40,080
and again on the left is 1995 on the

61
00:02:46,610 --> 00:02:44,010
right is 2015 and again just that much

62
00:02:50,090 --> 00:02:46,620
more detail looking at the structures

63
00:02:52,550 --> 00:02:50,100

that are forming so in which stars are

64
00:02:55,790 --> 00:02:52,560
forming these little fingers here these

65
00:02:57,350 --> 00:02:55,800
are places where dense objects and stars

66
00:03:00,170 --> 00:02:57,360
may be forming inside them

67
00:03:02,800 --> 00:03:00,180
now down bottom here you see this jet

68
00:03:05,570 --> 00:03:02,810
here and that is a signature of

69
00:03:08,360 --> 00:03:05,580
starvation now to call this a birth

70
00:03:11,090 --> 00:03:08,370
announcement because as a star forms

71
00:03:14,420 --> 00:03:11,100
material is flowing on streaming on to

72
00:03:16,430 --> 00:03:14,430
that star from a disc and other material

73
00:03:19,520 --> 00:03:16,440
is then flung off in these oppositely

74
00:03:21,440 --> 00:03:19,530
directed by polar Jets and you can see

75
00:03:23,780 --> 00:03:21,450
the Jets streaming out from a newborn

76
00:03:25,069 --> 00:03:23,790
star but here's where you can really see

77
00:03:27,550 --> 00:03:25,079
because I've blown this up a lot

78
00:03:31,550 --> 00:03:27,560
the resolution difference between 1995

79
00:03:34,610 --> 00:03:31,560
versus 2015 in the resolution of that

80
00:03:38,229 --> 00:03:34,620
jet the other cool thing about that jet

81
00:03:40,550 --> 00:03:38,239
is we actually saw it move the jets

82
00:03:44,600 --> 00:03:40,560
material flowing away from that newborn

83
00:03:47,509 --> 00:03:44,610
star was here in 1995 and moved to here

84
00:03:49,460 --> 00:03:47,519
in 2014 when the picture was imaging I'm

85
00:03:51,680 --> 00:03:49,470
calling it the 2015 image because we

86
00:03:55,610 --> 00:03:51,690
released it in 2015 but of course we

87
00:03:59,150 --> 00:03:55,620
took the data in 2014 so in the 19 years

88
00:04:05,500 --> 00:03:59,160

you can actually measure motion of that

89
00:04:07,940 --> 00:04:05,510
material flowing across the nebula cool

90
00:04:09,740 --> 00:04:07,950
so there are some other things of course

91
00:04:11,120 --> 00:04:09,750
that's just a comparison between those

92
00:04:12,530 --> 00:04:11,130
two images there are other things that

93
00:04:15,550 --> 00:04:12,540
are peer in this image that of course

94
00:04:17,650 --> 00:04:15,560
don't appear in the other image

95
00:04:19,150 --> 00:04:17,660
you see what the bottom of the pillars

96
00:04:22,570 --> 00:04:19,160
look like and you can see that they

97
00:04:25,270 --> 00:04:22,580
actually flow out that we talk about the

98
00:04:27,850 --> 00:04:25,280
Stars way way up here that their

99
00:04:30,129 --> 00:04:27,860
material their amazing region and winds

100
00:04:33,129 --> 00:04:30,139
are streaming down streaming across

101
00:04:34,900 --> 00:04:33,139
these pillars creating these these

102
00:04:37,240 --> 00:04:34,910
pillars but here you can see the

103
00:04:39,330 --> 00:04:37,250
material streaming down matter of fact a

104
00:04:41,680 --> 00:04:39,340
friend of mine who likes science fiction

105
00:04:43,900 --> 00:04:41,690
looked at this and said oh I know what

106
00:04:49,480 --> 00:04:43,910
that is this pillar it looks like the

107
00:04:51,129 --> 00:04:49,490
Dementors from Harry Potter gaseous

108
00:04:53,920 --> 00:04:51,139
effect that they used for the Dementors

109
00:04:57,090 --> 00:04:53,930
in Harry Potter also at the bottom you

110
00:04:59,650 --> 00:04:57,100
can see an amazing art of yellow

111
00:05:00,909 --> 00:04:59,660
ionizing emission which usually expect

112
00:05:03,610 --> 00:05:00,919
the ionizing mission to be along the

113
00:05:05,350 --> 00:05:03,620

ionization fronts I'm not exactly sure

114
00:05:07,090 --> 00:05:05,360
what this is I'm not a specialist in

115
00:05:09,850 --> 00:05:07,100
star formation but it really caught my

116
00:05:12,310 --> 00:05:09,860
eye is something cool as well as these

117
00:05:15,520 --> 00:05:12,320
tiny little pillars off in the lower

118
00:05:17,760 --> 00:05:15,530
right corner of the image our image

119
00:05:20,200 --> 00:05:17,770
processes result of a calls this mini-me

120
00:05:22,420 --> 00:05:20,210
because it looks very much like it's

121
00:05:26,170 --> 00:05:22,430
these tiny little pillars these pillars

122
00:05:28,000 --> 00:05:26,180
and things appear on all scales the

123
00:05:30,490 --> 00:05:28,010
other thing we got to do with the 2015

124
00:05:33,420 --> 00:05:30,500
image is not just do visible light but

125
00:05:35,409 --> 00:05:33,430
also do an infrared version of it

126
00:05:40,420 --> 00:05:35,419
they're kind of cool let me go back

127
00:05:42,760 --> 00:05:40,430
visible infrared all right with Y Field

128
00:05:44,680 --> 00:05:42,770
Camera 3 we have we can go into the

129
00:05:46,960 --> 00:05:44,690
infrared I put the two of them up next

130
00:05:49,540 --> 00:05:46,970
to each other you can see that there's a

131
00:05:51,969 --> 00:05:49,550
lot of correlation but a lot of

132
00:05:53,500 --> 00:05:51,979
differences between them so let's jump

133
00:05:56,680 --> 00:05:53,510
through some of those features again

134
00:05:59,860 --> 00:05:56,690
here is the visible light 2015 here is

135
00:06:02,260 --> 00:05:59,870
the infrared all right and looking at

136
00:06:05,409 --> 00:06:02,270
the detail you can still see the

137
00:06:08,080 --> 00:06:05,419
structure infrared light is longer

138
00:06:10,150 --> 00:06:08,090

wavelength it can penetrate through much

139
00:06:12,190 --> 00:06:10,160
of the gas and dust and see details

140
00:06:13,900 --> 00:06:12,200
inside but of course where you see it

141
00:06:18,129 --> 00:06:13,910
dark in the infrared that means where it

142
00:06:20,950 --> 00:06:18,139
really is these dark dense clouds go to

143
00:06:23,890 --> 00:06:20,960
the top of the central pillar here is

144
00:06:26,620 --> 00:06:23,900
that that jellyfish here you can almost

145
00:06:28,210 --> 00:06:26,630
see a little bit of it here that doesn't

146
00:06:30,700 --> 00:06:28,220
look like it's got a star forming

147
00:06:33,580 --> 00:06:30,710
inside it okay it's not a really dense

148
00:06:35,410 --> 00:06:33,590
piece but you can see some star

149
00:06:37,420 --> 00:06:35,420
formation going on in here looking down

150
00:06:39,940 --> 00:06:37,430
into the gas you can see star formation

151
00:06:41,650 --> 00:06:39,950
here which is only hinted at you can see

152
00:06:46,000 --> 00:06:41,660
one of the stars here but it's hinted at

153
00:06:48,520 --> 00:06:46,010
here on the in the visible light also if

154
00:06:51,340 --> 00:06:48,530
you go up to the upper region of the up

155
00:06:54,010 --> 00:06:51,350
top of the left pillar you can see the

156
00:06:56,470 --> 00:06:54,020
the the fingers here well the fingers

157
00:06:59,620 --> 00:06:56,480
aren't so prominent but if you look you

158
00:07:02,440 --> 00:06:59,630
can see up there you go this star

159
00:07:05,260 --> 00:07:02,450
forming place here which is not shown

160
00:07:06,670 --> 00:07:05,270
here you see the red here looking inside

161
00:07:13,540 --> 00:07:06,680
the gas you can start to see what's

162
00:07:16,000 --> 00:07:13,550
happening inside these pillars the most

163
00:07:18,610 --> 00:07:16,010

more telling views is from the larger

164
00:07:20,650 --> 00:07:18,620
point of view this is that left pillar

165
00:07:23,710 --> 00:07:20,660
which we tend to sort of think of as

166
00:07:26,830 --> 00:07:23,720
being this tall solid pillar but we

167
00:07:31,480 --> 00:07:26,840
often say it's not necessarily well look

168
00:07:33,370 --> 00:07:31,490
in the infrared what do you see here you

169
00:07:35,380 --> 00:07:33,380
can see oh you can see through the

170
00:07:37,210 --> 00:07:35,390
pillar what you're really seeing is

171
00:07:39,909 --> 00:07:37,220
you're seeing this dense gas cloud up

172
00:07:41,920 --> 00:07:39,919
here and then the shadow through here

173
00:07:44,920 --> 00:07:41,930
all of this in here is the shadow of

174
00:07:47,020 --> 00:07:44,930
this dense cloud the ionizing radiation

175
00:07:50,170 --> 00:07:47,030
isn't hitting that region so it looks

176
00:07:51,909 --> 00:07:50,180
dark when we see it an optical but when

177
00:07:54,670 --> 00:07:51,919
you look at an infrared you can see that

178
00:07:57,840 --> 00:07:54,680
the emperor has no clothes that it

179
00:08:00,850 --> 00:07:57,850
really is transparent in the infrared

180
00:08:03,010 --> 00:08:00,860
one other cool thing is that here is a

181
00:08:05,770 --> 00:08:03,020
region in optical take a look at these

182
00:08:09,070 --> 00:08:05,780
four stars here because this is the very

183
00:08:12,640 --> 00:08:09,080
same region okay and it looks like that

184
00:08:15,730 --> 00:08:12,650
and infrared okay

185
00:08:18,010 --> 00:08:15,740
these four stars here the four stars

186
00:08:20,170 --> 00:08:18,020
that you that match and these four stars

187
00:08:22,990 --> 00:08:20,180
suddenly appear out of nowhere really

188
00:08:24,969 --> 00:08:23,000

what they are is they're behind the gas

189
00:08:27,760 --> 00:08:24,979
you're seeing through the gas to see

190
00:08:30,730 --> 00:08:27,770
these you can see a lot more stars and

191
00:08:32,079 --> 00:08:30,740
stars that glow in the infrared are

192
00:08:33,969 --> 00:08:32,089
different than stars that glow and

193
00:08:36,310 --> 00:08:33,979
visible light visible light you need

194
00:08:38,140 --> 00:08:36,320
tens of thousands of degrees thousands

195
00:08:40,480 --> 00:08:38,150
to tens of thousands only a couple

196
00:08:41,709 --> 00:08:40,490
thousand degrees and stars that are like

197
00:08:43,929 --> 00:08:41,719
two thousand three thousand

198
00:08:47,019 --> 00:08:43,939
these actually glow more in the infrared

199
00:08:49,749 --> 00:08:47,029
than they do with the optical all right

200
00:08:51,879 --> 00:08:49,759
so here we had three cool images of the

201
00:08:54,009 --> 00:08:51,889
pillars of creation and just a nice

202
00:08:58,869 --> 00:08:54,019
little exploration to take a look at it

203
00:09:01,720 --> 00:08:58,879
okay so this pillar here is about three

204
00:09:03,730 --> 00:09:01,730
light years long so we take that three

205
00:09:06,449 --> 00:09:03,740
call about 6 light years top to bottom

206
00:09:09,910 --> 00:09:06,459
at the distance of the Eagle Nebula okay

207
00:09:12,160 --> 00:09:09,920
yeah kind of cool all right we got one

208
00:09:14,350 --> 00:09:12,170
more story for you which has sort of

209
00:09:18,460 --> 00:09:14,360
been preempted by our lobby display but

210
00:09:21,129 --> 00:09:18,470
I call it in your dreams Hubble okay so

211
00:09:23,800 --> 00:09:21,139
this is a picture of the great nebula in

212
00:09:27,699 --> 00:09:23,810
Andromeda I found it in a book published

213
00:09:31,600 --> 00:09:27,709

in 1915 from the Yerkes Observatory this

214
00:09:35,710 --> 00:09:31,610
was taken a September 1901 this is the

215
00:09:38,920 --> 00:09:35,720
nebula in Andromeda because we didn't

216
00:09:42,040 --> 00:09:38,930
know what it was for sure until Hubble

217
00:09:46,660 --> 00:09:42,050
came along in the 1920s so here is

218
00:09:49,660 --> 00:09:46,670
Hubble's 1923 discovery observation of a

219
00:09:51,340 --> 00:09:49,670
variable star in the Andromeda nebula as

220
00:09:54,490 --> 00:09:51,350
you can see he's got these end marks

221
00:09:56,290 --> 00:09:54,500
here looking for nove you know in in

222
00:09:59,019 --> 00:09:56,300
this in this nebula to see what he could

223
00:10:01,210 --> 00:09:59,029
see he had one mark that he thought was

224
00:10:04,629 --> 00:10:01,220
a nova and then found out no it's a

225
00:10:07,780 --> 00:10:04,639
variable star and the variable stars are

226
00:10:09,790 --> 00:10:07,790
really cool because if it's a specific

227
00:10:12,819 --> 00:10:09,800
type of variable star called a Cepheid

228
00:10:15,549 --> 00:10:12,829
variable star the period which it

229
00:10:19,299 --> 00:10:15,559
brightens and dims brightens and dims

230
00:10:22,090 --> 00:10:19,309
that timescale is proportional to its

231
00:10:24,069 --> 00:10:22,100
absolute magnitude so you can measure

232
00:10:26,650 --> 00:10:24,079
the brightening and dimming timescale

233
00:10:29,019 --> 00:10:26,660
and then know how bright that star

234
00:10:31,090 --> 00:10:29,029
really is and then once you know how

235
00:10:35,290 --> 00:10:31,100
bright it is you can measure how far

236
00:10:35,950 --> 00:10:35,300
away Andromeda is at how it will do this

237
00:10:39,250 --> 00:10:35,960
in 19

238
00:10:41,830 --> 00:10:39,260

three and set the stage that it is not a

239
00:10:44,560 --> 00:10:41,840
nebula but it is a galaxy unto itself

240
00:10:45,880 --> 00:10:44,570
that this nebula is definitely outside

241
00:10:49,600 --> 00:10:45,890
of our galaxy

242
00:10:52,060 --> 00:10:49,610
well Hubble's namesake telescope looked

243
00:10:54,730 --> 00:10:52,070
at that exact same star we called it

244
00:10:59,350 --> 00:10:54,740
Hubble variable one and got images like

245
00:11:01,920 --> 00:10:59,360
this so these are four images of HV one

246
00:11:05,980 --> 00:11:01,930
over the course of December to January

247
00:11:09,120 --> 00:11:05,990
2010 2011 and if we put these in motion

248
00:11:16,000 --> 00:11:09,130
this is an animated gif you can see it

249
00:11:19,140 --> 00:11:16,010
brightening and dimming so the star that

250
00:11:23,350 --> 00:11:19,150
changed the universe but you can see

251
00:11:30,310 --> 00:11:23,360
that Hubble can see what Hubble could

252
00:11:32,290 --> 00:11:30,320
only dream of called the stellar Deep

253
00:11:34,660 --> 00:11:32,300
Field when the advanced camera for

254
00:11:38,200 --> 00:11:34,670
surveys was was brand-new on Hubble you

255
00:11:41,140 --> 00:11:38,210
can see this amazing image and if i zoom

256
00:11:44,170 --> 00:11:41,150
into it to show you the detail that star

257
00:11:48,720 --> 00:11:44,180
is in our Milky Way galaxy and every

258
00:11:52,510 --> 00:11:48,730
other star is in the Andromeda galaxy

259
00:11:54,940 --> 00:11:52,520
examining star field in another galaxy

260
00:11:59,440 --> 00:11:54,950
not just our fields but this is a

261
00:12:01,000 --> 00:11:59,450
globular star cluster in Andromeda not

262
00:12:03,640 --> 00:12:01,010
in the Milky Way look at the kind of

263
00:12:08,440 --> 00:12:03,650

resolution Hubble can get but we can

264
00:12:12,340 --> 00:12:08,450
still do better because this image was

265
00:12:14,710 --> 00:12:12,350
taken way out here way far away from the

266
00:12:15,580 --> 00:12:14,720
disk of Andromeda this is out and called

267
00:12:18,400 --> 00:12:15,590
what we call

268
00:12:21,190 --> 00:12:18,410
Andromeda's halo studying the Stars and

269
00:12:24,340 --> 00:12:21,200
Andromeda's halo and so what we just

270
00:12:27,280 --> 00:12:24,350
completed is something called the fad

271
00:12:29,560 --> 00:12:27,290
survey the pan chromatic Hubble

272
00:12:33,450 --> 00:12:29,570
Andromeda Treasury program which has

273
00:12:35,940 --> 00:12:33,460
looked at the main disk of Andromeda in

274
00:12:39,760 --> 00:12:35,950
excruciating detail

275
00:12:41,230 --> 00:12:39,770
amazing detail incredible detail that

276
00:12:44,440 --> 00:12:41,240
looks like this

277
00:12:46,450 --> 00:12:44,450
okay so this is the Hubble image and you

278
00:12:48,010 --> 00:12:46,460
see the jaggies here these are the

279
00:12:49,360 --> 00:12:48,020
footprints of Hubble these are the

280
00:12:52,540 --> 00:12:49,370
pointings of Hubble

281
00:12:54,760 --> 00:12:52,550
- I'm Capri fully appreciate this scale

282
00:12:56,769 --> 00:12:54,770
of this image you recognize that this is

283
00:13:00,130 --> 00:12:56,779
a hunt over a hundred thousand pixels

284
00:13:03,490 --> 00:13:00,140
across here it's about thirty thousand

285
00:13:07,660 --> 00:13:03,500
pixels high it's several billion pixels

286
00:13:09,400 --> 00:13:07,670
total they did 411 different pointings

287
00:13:12,910 --> 00:13:09,410
of Hubble seven thousand three hundred

288
00:13:16,420 --> 00:13:12,920

ninety eight exposures over three years

289
00:13:18,190 --> 00:13:16,430
to cover basically half of the disk of

290
00:13:20,230 --> 00:13:18,200
Andromeda well actually it's about a

291
00:13:24,160 --> 00:13:20,240
third if you can consider the whole

292
00:13:27,490 --> 00:13:24,170
thing really the largest image composite

293
00:13:29,440 --> 00:13:27,500
image that Hubble has ever produced now

294
00:13:31,570 --> 00:13:29,450
I'm gonna take you in to show you some

295
00:13:36,190 --> 00:13:31,580
of the details of it and so this is

296
00:13:37,630 --> 00:13:36,200
gonna be at okay I can't do the full

297
00:13:39,550 --> 00:13:37,640
resolution it's too big an image for me

298
00:13:42,160 --> 00:13:39,560
you but this is gonna be at one-quarter

299
00:13:45,010 --> 00:13:42,170
resolution all right here so if we go

300
00:13:47,260 --> 00:13:45,020
into the center of the galaxy you can

301
00:13:49,480 --> 00:13:47,270
see this is the core of the galaxy and

302
00:13:51,519 --> 00:13:49,490
all the things and it's so blown out

303
00:13:52,900 --> 00:13:51,529
there are so many stars in here you

304
00:13:56,680 --> 00:13:52,910
can't really see them but if you see

305
00:13:59,199 --> 00:13:56,690
these white dots those are star clusters

306
00:14:02,170 --> 00:13:59,209
those aren't individual stars those are

307
00:14:04,690 --> 00:14:02,180
star clusters if we move a bit further

308
00:14:07,690 --> 00:14:04,700
out where we have the dark gas and dust

309
00:14:10,480 --> 00:14:07,700
you can see the dust lanes and things

310
00:14:13,000 --> 00:14:10,490
again these are star clusters and the

311
00:14:14,500 --> 00:14:13,010
individual stars are well at the

312
00:14:16,840 --> 00:14:14,510
resolution this projector they're still

313
00:14:17,290 --> 00:14:16,850

too small to see all right we'll get

314
00:14:19,449 --> 00:14:17,300
there

315
00:14:22,630 --> 00:14:19,459
I have something at the very end we get

316
00:14:25,060 --> 00:14:22,640
up to the star forming regions all the

317
00:14:28,390 --> 00:14:25,070
blue stars you see here these are

318
00:14:29,800 --> 00:14:28,400
newborn stars again the bigger ones are

319
00:14:33,190 --> 00:14:29,810
star clusters some of them might be

320
00:14:34,930 --> 00:14:33,200
stars in our own galaxy again seeing the

321
00:14:36,790 --> 00:14:34,940
the star clusters and if you get out to

322
00:14:39,340 --> 00:14:36,800
the really really edge well beyond

323
00:14:41,050 --> 00:14:39,350
almost the visible disc of it you can

324
00:14:44,190 --> 00:14:41,060
still see that there are still a

325
00:14:48,760 --> 00:14:44,200
tremendous number of stars out there

326
00:14:51,340 --> 00:14:48,770
viewing stars in Andromeda over 100

327
00:14:53,680 --> 00:14:51,350
million stars I believe the number that

328
00:14:56,140 --> 00:14:53,690
they quote is around 170 million hunt

329
00:14:59,310 --> 00:14:56,150
stars that they have cataloged here in

330
00:15:03,250 --> 00:14:59,320
this in this full image from Andromeda

331
00:15:04,750 --> 00:15:03,260
amazing detail to see so to show

332
00:15:06,790 --> 00:15:04,760
what you're looking at here we made it

333
00:15:08,350 --> 00:15:06,800
we made this image here to show okay

334
00:15:11,050 --> 00:15:08,360
we've got these dust lanes we've got

335
00:15:13,150 --> 00:15:11,060
these star clusters you can even see

336
00:15:15,370 --> 00:15:13,160
background galaxies through the disk of

337
00:15:18,910 --> 00:15:15,380
Andromeda some of the brighter stars

338
00:15:21,070 --> 00:15:18,920

will be Milky Way stars and over here we

339
00:15:23,080 --> 00:15:21,080
have a star for a region again more

340
00:15:24,840 --> 00:15:23,090
stellar clusters and dust lanes but you

341
00:15:27,130 --> 00:15:24,850
see those words star forming region

342
00:15:31,150 --> 00:15:27,140
we're going to go into those at full

343
00:15:33,220 --> 00:15:31,160
resolution and you can start finally

344
00:15:36,100 --> 00:15:33,230
start to see the stars this is the one

345
00:15:37,210 --> 00:15:36,110
that actually is full resolution at the

346
00:15:38,770 --> 00:15:37,220
full thing and not the quarter

347
00:15:40,960 --> 00:15:38,780
resolution I was able to show you in the

348
00:15:44,770 --> 00:15:40,970
previous images but the full resolution

349
00:15:48,250 --> 00:15:44,780
to see the amazing detail of the

350
00:15:50,200 --> 00:15:48,260
structure in Andromeda and if you didn't

351
00:15:53,230 --> 00:15:50,210
notice it on your way in if you go out

352
00:15:55,810 --> 00:15:53,240
that door we have the mosaic up there of

353
00:15:57,610 --> 00:15:55,820
the cropped image for you to look at and

354
00:16:00,250 --> 00:15:57,620
see the hundreds of hundred million

355
00:16:02,320 --> 00:16:00,260
stars in Andromeda for you just have a

356
00:16:05,320 --> 00:16:02,330
look at it's only gonna be here tonight

357
00:16:07,930 --> 00:16:05,330
okay that that mosaic isn't a permanent

358
00:16:09,520 --> 00:16:07,940
display here you just happen to come on

359
00:16:13,090 --> 00:16:09,530
the right night and when we get to see

360
00:16:15,310 --> 00:16:13,100
that okay all right so that is our news

361
00:16:17,050 --> 00:16:15,320
summary I went on a little bit long but

362
00:16:21,130 --> 00:16:17,060
you can see we had two really really

363
00:16:28,420 --> 00:16:21,140

cool things to talk about today all

364
00:16:30,760 --> 00:16:28,430
right so so our speaker tonight is dr.

365
00:16:34,090 --> 00:16:30,770
Jason Tomlinson also of the Space

366
00:16:40,120 --> 00:16:34,100
Telescope Science Institute I forgot to

367
00:16:42,430 --> 00:16:40,130
get his resume but I'd have a because

368
00:16:46,570 --> 00:16:42,440
they know you're fantastic and wonderful

369
00:16:53,170 --> 00:16:46,580
wonderful guy he's been here what ten

370
00:16:53,560 --> 00:16:53,180
years now and he was going to talk to us

371
00:16:56,260 --> 00:16:53,570
tonight

372
00:16:58,240 --> 00:16:56,270
about the future of space astronomy and

373
00:16:59,650 --> 00:16:58,250
the amazing new things that were going

374
00:17:02,080 --> 00:16:59,660
to be able to do over the next couple

375
00:17:31,530 --> 00:17:02,090
decades ladies and gentlemen dr. Jason

376
00:17:38,950 --> 00:17:36,370
alright I'm gonna try to make up in

377
00:17:42,270 --> 00:17:38,960
long-term vision what I lack in

378
00:17:45,760 --> 00:17:42,280
enthusiasm with respect to my color

379
00:17:49,390 --> 00:17:45,770
she's a tough act to follow but I want

380
00:17:53,410 --> 00:17:49,400
to spend about 45 minutes here telling

381
00:17:55,600 --> 00:17:53,420
you about something so it's the last 300

382
00:17:57,070 --> 00:17:55,610
years of astronomy and x-ray where we've

383
00:18:01,110 --> 00:17:57,080
been where are we going in terms of the

384
00:18:03,430 --> 00:18:01,120
biggest questions we can possibly ask

385
00:18:04,720 --> 00:18:03,440
well astronomy asking questions

386
00:18:07,330 --> 00:18:04,730
naturally we're thinking about the big

387
00:18:09,880 --> 00:18:07,340
things right asking big questions I'm

388
00:18:12,840 --> 00:18:09,890

going to talk about two particular where

389
00:18:16,240 --> 00:18:12,850
did it become from and are we alone now

390
00:18:20,230 --> 00:18:16,250
this is more general bigger than just

391
00:18:22,390 --> 00:18:20,240
how to galaxies form planets form these

392
00:18:23,920 --> 00:18:22,400
are really these our civilization will

393
00:18:26,650 --> 00:18:23,930
skate all questions these go back

394
00:18:30,370 --> 00:18:26,660
forever right and then probably go far

395
00:18:32,110 --> 00:18:30,380
into the future these are questions that

396
00:18:33,520 --> 00:18:32,120
were have been asked as long as people

397
00:18:35,920 --> 00:18:33,530
have been doing in astronomy

398
00:18:38,620 --> 00:18:35,930
of course naked-eye astronomy started as

399
00:18:41,020 --> 00:18:38,630
soon as the first caveman looked up into

400
00:18:43,660 --> 00:18:41,030
the sky but telescopic astronomy using

401
00:18:46,870 --> 00:18:43,670
actual telescopes and lessons began with

402
00:18:48,550 --> 00:18:46,880
galileo galilei officially in 1609 here

403
00:18:51,480 --> 00:18:48,560
he is demonstrating his little telescope

404
00:18:53,920 --> 00:18:51,490
for the dirty events in that year and

405
00:18:57,690 --> 00:18:53,930
one of the things that got away was

406
00:19:00,010 --> 00:18:57,700
famous for discovering among his many

407
00:19:01,460 --> 00:19:00,020
epic making discoveries was the

408
00:19:03,049 --> 00:19:01,470
satellites of the planet

409
00:19:08,649 --> 00:19:03,059
so there's Jupiter and their support

410
00:19:11,450 --> 00:19:08,659
Galilean satellites we call them and

411
00:19:14,810 --> 00:19:11,460
this was really neat piece of evidence

412
00:19:15,830 --> 00:19:14,820
that convinced people in Europe and the

413
00:19:17,659 --> 00:19:15,840

Renaissance and then eventually

414
00:19:20,720 --> 00:19:17,669
worldwide that there was a whole world

415
00:19:23,299 --> 00:19:20,730
out there and on the earth it was not

416
00:19:26,629 --> 00:19:23,309
merely terrestrial it wasn't just human

417
00:19:28,399 --> 00:19:26,639
it was this otherworldly universe out

418
00:19:31,399 --> 00:19:28,409
there that we could actually learn

419
00:19:34,549 --> 00:19:31,409
something about I told you this is going

420
00:19:37,730 --> 00:19:34,559
to be a fast issue skip ahead by more

421
00:19:40,639 --> 00:19:37,740
than 100 years now I chose to illustrate

422
00:19:42,289 --> 00:19:40,649
the next advance with a brother and

423
00:19:45,320 --> 00:19:42,299
sister team named the Herschel's William

424
00:19:46,759 --> 00:19:45,330
Caroline Herschel they fight by the time

425
00:19:50,119 --> 00:19:46,769
of rehearsals they were building

426
00:19:52,909 --> 00:19:50,129
reflecting telescopes actually meant to

427
00:19:54,980 --> 00:19:52,919
buy view but will universities

428
00:19:57,710 --> 00:19:54,990
supporting an aperture with this big

429
00:20:00,019 --> 00:19:57,720
rotating apparatus pointed it around

430
00:20:03,369 --> 00:20:00,029
with the sky the persons were famous for

431
00:20:09,169 --> 00:20:07,279
this is way too personal is drawing he

432
00:20:12,080 --> 00:20:09,179
thought the Milky Way must galaxy must

433
00:20:13,639 --> 00:20:12,090
look like from looking at the band of

434
00:20:14,990 --> 00:20:13,649
stars on the sky and trying to figure

435
00:20:17,480 --> 00:20:15,000
out how they would look if we weren't

436
00:20:19,730 --> 00:20:17,490
leaving excited it's not that bad I

437
00:20:22,460 --> 00:20:19,740
think you can compare personal image of

438
00:20:24,200 --> 00:20:22,470

disc galaxies with Hubble's image of a

439
00:20:25,399 --> 00:20:24,210
disc out see the lobby didn't see that

440
00:20:29,590 --> 00:20:25,409
you know he was doing pretty well for

441
00:20:34,340 --> 00:20:31,759
there's a whole lot of technique of

442
00:20:36,049 --> 00:20:34,350
astronomical observation which becomes

443
00:20:38,240 --> 00:20:36,059
absolutely critical a little bit later

444
00:20:40,820 --> 00:20:38,250
so I want to introduce it rather early

445
00:20:42,860 --> 00:20:40,830
that's called spectroscopy you can made

446
00:20:45,440 --> 00:20:42,870
me imagine what this is there's Newton

447
00:20:46,519 --> 00:20:45,450
with his president all right everybody's

448
00:20:48,590 --> 00:20:46,529
played with a prism when they were a kid

449
00:20:52,070 --> 00:20:48,600
or something yeah you hold a prism up to

450
00:20:54,019 --> 00:20:52,080
sunlight what do you get a rainbow right

451
00:20:57,440 --> 00:20:54,029
why'd you give red orange yellow on

452
00:20:59,840 --> 00:20:57,450
someone that is the fundamental

453
00:21:01,020 --> 00:20:59,850
technique that we still use today I use

454
00:21:02,640 --> 00:21:01,030
it in my daily life

455
00:21:04,830 --> 00:21:02,650
Shondra to figure out what stuff is made

456
00:21:06,840 --> 00:21:04,840
and the reason is if you take a spectrum

457
00:21:09,170 --> 00:21:06,850
like this this is essentially the same

458
00:21:11,610 --> 00:21:09,180
kind of measurement as Newton's prison

459
00:21:13,440 --> 00:21:11,620
if you take a spectrum like this or like

460
00:21:15,090 --> 00:21:13,450
this is one of the first that existed by

461
00:21:17,550 --> 00:21:15,100
the Germans trying out for a kickoff in

462
00:21:19,500 --> 00:21:17,560
the eighteen hundreds you can look for

463
00:21:20,790 --> 00:21:19,510

these lines see these lines this is a

464
00:21:21,600 --> 00:21:20,800
solar spectrum and if you see these

465
00:21:24,150 --> 00:21:21,610
lines

466
00:21:26,490 --> 00:21:24,160
that's absorption that's an atom of a

467
00:21:28,710 --> 00:21:26,500
particular kind in that environment

468
00:21:30,780 --> 00:21:28,720
absorbing light so the light doesn't get

469
00:21:32,640 --> 00:21:30,790
to you this is the light that comes out

470
00:21:35,820 --> 00:21:32,650
of the Sun that's the ultraviolet the

471
00:21:37,740 --> 00:21:35,830
blue the green yellow orange and red but

472
00:21:40,020 --> 00:21:37,750
where it's absorbed the spectrum goes

473
00:21:41,670 --> 00:21:40,030
black and that's the way that's for

474
00:21:43,470 --> 00:21:41,680
instance how we know that the Sun is

475
00:21:48,660 --> 00:21:43,480
made of hydrogen and helium has some

476
00:21:50,340 --> 00:21:48,670
higher carbon spectroscopy is the way

477
00:21:51,840 --> 00:21:50,350
that we do the physics side of

478
00:21:55,620 --> 00:21:51,850
astrophysics we figure out what stuff's

479
00:22:02,850 --> 00:21:55,630
made out with dynamics are from taking

480
00:22:07,770 --> 00:22:02,860
these okay forward into the 1920s this

481
00:22:09,570 --> 00:22:07,780
is Edwin Hubble himself and he use this

482
00:22:13,370 --> 00:22:09,580
hustle here at Mount Wilson which is a

483
00:22:16,230 --> 00:22:13,380
hundred to do what he's famous for which

484
00:22:17,670 --> 00:22:16,240
which Frank just mentioned which is to

485
00:22:20,250 --> 00:22:17,680
measure the expansion rate of the

486
00:22:22,470 --> 00:22:20,260
universe now he did that by observing

487
00:22:23,970 --> 00:22:22,480
exactly the stars some of the stars that

488
00:22:27,690 --> 00:22:23,980

Frank mentioned that the Hubble variable

489
00:22:30,060 --> 00:22:27,700
stars if he knew how fast and they

490
00:22:32,730 --> 00:22:30,070
brightened and Dimond he could work out

491
00:22:34,320 --> 00:22:32,740
the distance using spectroscopy he could

492
00:22:37,380 --> 00:22:34,330
work out their velocity by measuring

493
00:22:39,450 --> 00:22:37,390
what's called the redshift as an object

494
00:22:40,940 --> 00:22:39,460
recede from us it gets redder as it

495
00:22:43,470 --> 00:22:40,950
moves towards the sixth floor

496
00:22:45,120 --> 00:22:43,480
Hubble was able to take redshift and

497
00:22:47,700 --> 00:22:45,130
distance and work out that the entire

498
00:22:50,730 --> 00:22:47,710
universe was expanding that's why he's

499
00:22:55,080 --> 00:22:50,740
as famous as he is that's why we named

500
00:22:59,100 --> 00:22:55,090
our first stays tall so back here we are

501
00:23:00,600 --> 00:22:59,110
this is hung this is a outdated version

502
00:23:03,060 --> 00:23:00,610
of what you just saw it when I see a

503
00:23:06,900 --> 00:23:03,070
thunder but here's how about doing its

504
00:23:09,210 --> 00:23:06,910
thing this is the Ultra Deep Field taken

505
00:23:10,950 --> 00:23:09,220
with Hubble's advanced

506
00:23:12,690 --> 00:23:10,960
for surveys there's thousands of

507
00:23:14,220 --> 00:23:12,700
galaxies in there I think this one right

508
00:23:15,659 --> 00:23:14,230
here that's the only object in the field

509
00:23:19,080 --> 00:23:15,669
that's a star everything else is a

510
00:23:21,779 --> 00:23:19,090
galaxy this is today the deepest picture

511
00:23:26,760 --> 00:23:21,789
of the universe that's a and therefore

512
00:23:29,760 --> 00:23:26,770
anybody has ever taken so that brings us

513
00:23:32,520 --> 00:23:29,770

up to almost the present time we figured

514
00:23:33,899 --> 00:23:32,530
out how to we figured out first of all

515
00:23:35,340 --> 00:23:33,909
you know thanks to Galileo that there

516
00:23:38,190 --> 00:23:35,350
was a universe out there to learn about

517
00:23:41,100 --> 00:23:38,200
but what interests really we figured out

518
00:23:42,870 --> 00:23:41,110
that we could discover objects beyond

519
00:23:44,340 --> 00:23:42,880
what the naked eye or even small

520
00:23:46,590 --> 00:23:44,350
telescopes could see we can see the

521
00:23:49,500 --> 00:23:46,600
outer planets we could see parts of our

522
00:23:51,029 --> 00:23:49,510
own galaxy that we within Hubble showed

523
00:23:53,880 --> 00:23:51,039
us that the universe has a cosmology

524
00:23:56,460 --> 00:23:53,890
that it has a dynamic all of its own

525
00:23:58,169 --> 00:23:56,470
that it's expanding that there's there's

526
00:24:00,270 --> 00:23:58,179
a history to the universe that it had a

527
00:24:01,950 --> 00:24:00,280
beginning point it hasn't always been

528
00:24:03,960 --> 00:24:01,960
here all of those things flow from

529
00:24:07,590 --> 00:24:03,970
Hubble's discovery the expansion

530
00:24:09,779 --> 00:24:07,600
universe and probably the most epic

531
00:24:11,700 --> 00:24:09,789
making or significant from the

532
00:24:14,279 --> 00:24:11,710
historical point of view discovery in

533
00:24:16,049 --> 00:24:14,289
our lifetimes has been the discovery

534
00:24:19,440 --> 00:24:16,059
that there are planets orbiting other

535
00:24:22,260 --> 00:24:19,450
stars in our own galaxy this was came

536
00:24:24,090 --> 00:24:22,270
around 1995 or the first discovery of

537
00:24:27,570 --> 00:24:24,100
what's called an exoplanet a planet

538
00:24:34,909 --> 00:24:27,580

around another star by a Swiss group of

539
00:24:37,080 --> 00:24:34,919
astronomers using the telescope and

540
00:24:39,419 --> 00:24:37,090
what's really important about this is

541
00:24:41,430 --> 00:24:39,429
that they use this same technique that I

542
00:24:42,690 --> 00:24:41,440
introduce spectroscopy right so let's go

543
00:24:45,210 --> 00:24:42,700
through this a little bit of detail just

544
00:24:49,470 --> 00:24:45,220
to show you how it works here we have a

545
00:24:51,120 --> 00:24:49,480
star and a planet our planet and the

546
00:24:53,460 --> 00:24:51,130
starting to plan orbit their common

547
00:24:55,980 --> 00:24:53,470
center of gravity that's one of Newton's

548
00:24:58,680 --> 00:24:55,990
laws of gravitation is that any two

549
00:25:00,180 --> 00:24:58,690
objects orbiting will orbit at their

550
00:25:01,830 --> 00:25:00,190
common center of gravity that means the

551
00:25:03,659 --> 00:25:01,840
star even though you think you think

552
00:25:05,760 --> 00:25:03,669
we're nearly the planets or even star

553
00:25:07,950 --> 00:25:05,770
the Stars fixed and the planet moves but

554
00:25:10,169 --> 00:25:07,960
it's not quite that way the star has a

555
00:25:11,730 --> 00:25:10,179
reflex motion it moves a little bit in

556
00:25:13,830 --> 00:25:11,740
response to the gravitational force of

557
00:25:16,570 --> 00:25:13,840
the planet so the star wobbles back and

558
00:25:18,009 --> 00:25:16,580
forth just a little bit and

559
00:25:19,930 --> 00:25:18,019
illustrated here in the fact that there

560
00:25:21,310 --> 00:25:19,940
are two pictures of these stars when

561
00:25:22,779 --> 00:25:21,320
it's the stars are moving toward the

562
00:25:24,700 --> 00:25:22,789
earth just a little bit the light gets

563
00:25:26,230 --> 00:25:24,710

slightly blue shifted and when we start

564
00:25:28,060 --> 00:25:26,240
moving away from the earth just a little

565
00:25:29,860 --> 00:25:28,070
bit it gets slightly red shifted and so

566
00:25:32,590 --> 00:25:29,870
by watching the Stars wobble back and

567
00:25:33,759 --> 00:25:32,600
forth just like this these astronomers

568
00:25:35,710 --> 00:25:33,769
were able to prove that there was a

569
00:25:37,389 --> 00:25:35,720
planet there totally we couldn't we

570
00:25:39,100 --> 00:25:37,399
still can't see that planet we can't

571
00:25:41,110 --> 00:25:39,110
take a picture of that planet yet that's

572
00:25:42,399 --> 00:25:41,120
what we're trip driving in but you can

573
00:25:44,289 --> 00:25:42,409
prove that the planets there by

574
00:25:46,810 --> 00:25:44,299
measuring the motion of the star that's

575
00:25:50,320 --> 00:25:46,820
gravitationally introduced by a planet

576
00:25:53,080 --> 00:25:50,330
that was that that was a the greatest

577
00:25:55,240 --> 00:25:53,090
discovery astronomical discovery of my

578
00:25:56,590 --> 00:25:55,250
lifetime arguably people would tell you

579
00:25:58,330 --> 00:25:56,600
that the acceleration of the expansion

580
00:25:59,980 --> 00:25:58,340
of the universe is equally important

581
00:26:02,080 --> 00:25:59,990
there's a Nobel Prize for it up in

582
00:26:08,230 --> 00:26:02,090
lobbying but I think this one's you know

583
00:26:10,600 --> 00:26:08,240
right up there and this has kicked off a

584
00:26:13,509 --> 00:26:10,610
whole revolution in the way astronomers

585
00:26:14,950 --> 00:26:13,519
think about our field in the way I think

586
00:26:16,899 --> 00:26:14,960
the public thinks about our field

587
00:26:18,490 --> 00:26:16,909
because this is addressing some of the

588
00:26:25,000 --> 00:26:18,500

deepest questions that we can address

589
00:26:28,539 --> 00:26:25,010
like I said you know are we long so

590
00:26:30,340 --> 00:26:28,549
right now that was the last 300 years

591
00:26:32,350 --> 00:26:30,350
I'm going to talk a little bit about the

592
00:26:33,940 --> 00:26:32,360
presence in the next five to ten years

593
00:26:35,379 --> 00:26:33,950
and then I'm going to tell you what we

594
00:26:39,879 --> 00:26:35,389
see coming down twenty or thirty years

595
00:26:41,710 --> 00:26:39,889
from now it happens that we're all

596
00:26:44,980 --> 00:26:41,720
fortunate to live in what really is a

597
00:26:48,220 --> 00:26:44,990
Golden Age of astronomy and the reason

598
00:26:50,110 --> 00:26:48,230
for that is that that funding agencies

599
00:26:52,799 --> 00:26:50,120
and the public have bestowed on

600
00:26:55,779 --> 00:26:52,809
astronomers an incredibly rich array of

601
00:26:58,060 --> 00:26:55,789
frontline instrumentation you know the

602
00:26:59,039 --> 00:26:58,070
kinds of things that were far far beyond

603
00:27:01,499 --> 00:26:59,049
the imagination

604
00:27:03,570 --> 00:27:01,509
those early astronomers even even how

605
00:27:05,489 --> 00:27:03,580
who lived in the 20th century there's

606
00:27:07,320 --> 00:27:05,499
the giant space telescope named after

607
00:27:08,879 --> 00:27:07,330
him there's the kepler observatory that

608
00:27:11,669 --> 00:27:08,889
he looks for planets I'll say more about

609
00:27:13,560 --> 00:27:11,679
that later the Chandra x-ray Observatory

610
00:27:17,310 --> 00:27:13,570
this is a unique satellite called

611
00:27:20,279 --> 00:27:17,320
alright beauty gallops there's the

612
00:27:22,560 --> 00:27:20,289
spitzer space telescope which is still

613
00:27:24,149 --> 00:27:22,570

going after about 11 years as an

614
00:27:27,359 --> 00:27:24,159
infrared Space Telescope there's the

615
00:27:30,600 --> 00:27:27,369
European personal mission there's a huge

616
00:27:32,369 --> 00:27:30,610
number of 8 to 10 meter telescopes on

617
00:27:34,739 --> 00:27:32,379
the ground the Very Large Telescope the

618
00:27:36,239 --> 00:27:34,749
Keck Observatory we have lots of radio

619
00:27:38,629 --> 00:27:36,249
facilities like the Very Large Array

620
00:27:41,849 --> 00:27:38,639
when you add all these things together

621
00:27:44,129 --> 00:27:41,859
you can see you've probably seen since

622
00:27:46,229 --> 00:27:44,139
you're all probably you know hanging a

623
00:27:47,669 --> 00:27:46,239
bit of attention to this you can see the

624
00:27:50,099 --> 00:27:47,679
discoveries of these things come

625
00:27:52,669 --> 00:27:50,109
together and mix and teaches new things

626
00:27:55,049 --> 00:27:52,679
on a daily basis we really live in a

627
00:27:59,909 --> 00:27:55,059
real revolutionary period for astronomy

628
00:28:01,769 --> 00:27:59,919
and we're fortunate to do that I would

629
00:28:04,560 --> 00:28:01,779
like to be able to spend 10 or 15

630
00:28:07,049 --> 00:28:04,570
minutes telling you about why everything

631
00:28:08,580 --> 00:28:07,059
that Hubble has done that awesome it

632
00:28:11,099 --> 00:28:08,590
would take me a lot longer than 10 or 15

633
00:28:12,509 --> 00:28:11,109
minutes to get through all that but what

634
00:28:14,070 --> 00:28:12,519
I think I would do I will do instead of

635
00:28:16,139 --> 00:28:14,080
that is just point out the fact that

636
00:28:20,399 --> 00:28:16,149
Hubble is turning 25 years old this year

637
00:28:22,979 --> 00:28:20,409
and that's amazing for any space

638
00:28:24,359 --> 00:28:22,989

satellite of any kind the fact that

639
00:28:26,580 --> 00:28:24,369
we've managed to keep Hubble while

640
00:28:28,049 --> 00:28:26,590
operating as a an observatory for that

641
00:28:30,299 --> 00:28:28,059
long and not only that would make it

642
00:28:33,239 --> 00:28:30,309
better every five years thanks to the

643
00:28:35,879 --> 00:28:33,249
human servicing has made it by far the

644
00:28:37,320 --> 00:28:35,889
most productive astronomical observatory

645
00:28:38,999 --> 00:28:37,330
of all time and arguably the most

646
00:28:42,119 --> 00:28:39,009
productive scientific facility of all

647
00:28:43,379 --> 00:28:42,129
time because it is turning 25 everybody

648
00:28:45,269 --> 00:28:43,389
here in the building is going crazy

649
00:28:47,249 --> 00:28:45,279
planning all kinds of events and talks

650
00:28:49,529 --> 00:28:47,259
and presentations and we have a whole

651
00:28:50,849 --> 00:28:49,539
conference to vote up to this so instead

652
00:28:51,790 --> 00:28:50,859
of saying you know here's Hubble's

653
00:28:53,110 --> 00:28:51,800
greatest hits over the

654
00:28:55,090 --> 00:28:53,120
twenty-five years I think you should

655
00:28:57,160 --> 00:28:55,100
just follow this website and you'll see

656
00:28:59,140 --> 00:28:57,170
we have great video presentations coming

657
00:29:00,850 --> 00:28:59,150
out we're gonna have a big splash in

658
00:29:02,890 --> 00:29:00,860
April when the birthday actually rolls

659
00:29:05,260 --> 00:29:02,900
around it's gonna be fantastic

660
00:29:07,540 --> 00:29:05,270
so I'd rather spend more time talking

661
00:29:10,000 --> 00:29:07,550
about the future than the present so I'm

662
00:29:11,530 --> 00:29:10,010
going to move on to the immediate future

663
00:29:14,830 --> 00:29:11,540

for us

664
00:29:16,210 --> 00:29:14,840
the Hubble 2.0 so to speak which is what

665
00:29:22,630 --> 00:29:16,220
we call the James Webb Space Telescope

666
00:29:24,670 --> 00:29:22,640
now if you look at here it is and then

667
00:29:26,560 --> 00:29:24,680
you locate a to this T they don't look

668
00:29:30,180 --> 00:29:26,570
anything like each other nothing really

669
00:29:33,120 --> 00:29:30,190
I mean except there's a mirror there

670
00:29:37,630 --> 00:29:33,130
they're very very different pieces

671
00:29:39,640 --> 00:29:37,640
the reason is Hubble's not only 25 years

672
00:29:41,800 --> 00:29:39,650
old but it's a giant steel tube with a

673
00:29:43,960 --> 00:29:41,810
big piece of glass right if you go out

674
00:29:47,320 --> 00:29:43,970
in the lobby on your way out if you can

675
00:29:48,640 --> 00:29:47,330
make it past the Andromeda image back

676
00:29:50,020 --> 00:29:48,650
into the outer lobbying you can see

677
00:29:52,630 --> 00:29:50,030
there's these banners hanging from the

678
00:29:54,430 --> 00:29:52,640
walls and there are pictures of the

679
00:29:56,470 --> 00:29:54,440
Hubble and the web primary mirrors to

680
00:29:58,990 --> 00:29:56,480
scale so you'll see the hollow primary

681
00:30:02,110 --> 00:29:59,000
mirror about 2.4 meters across which is

682
00:30:03,670 --> 00:30:02,120
about like this and the web mirror just

683
00:30:05,560 --> 00:30:03,680
Dwarfs it it goes all the way to the

684
00:30:06,910 --> 00:30:05,570
ceiling and we it's so big that we can't

685
00:30:09,550 --> 00:30:06,920
actually print it on a banner it's just

686
00:30:13,780 --> 00:30:09,560
a piece of it so I I I suggest you check

687
00:30:15,610 --> 00:30:13,790
out all those designed to be a telescope

688
00:30:17,830 --> 00:30:15,620

is optimized for observations in the

689
00:30:19,450 --> 00:30:17,840
infrared wavelengths those are

690
00:30:22,060 --> 00:30:19,460
wavelengths beyond what you can see with

691
00:30:24,130 --> 00:30:22,070
your eyes you know white becomes blue

692
00:30:26,350 --> 00:30:24,140
and then and then green and then red and

693
00:30:27,970 --> 00:30:26,360
once it's passed red you can't see it

694
00:30:30,430 --> 00:30:27,980
with your iron more there's some insects

695
00:30:32,800 --> 00:30:30,440
that can some probably nocturnal animals

696
00:30:34,390 --> 00:30:32,810
that can but humans can the reason we're

697
00:30:36,010 --> 00:30:34,400
doing that is to pick up a bunch of

698
00:30:37,840 --> 00:30:36,020
stuff that we can only see at those

699
00:30:40,450 --> 00:30:37,850
wavelengths I'll go through a bit of a

700
00:30:42,100 --> 00:30:40,460
science case this is a zoom on the

701
00:30:44,380 --> 00:30:42,110
Hubble's deepest image that Ultra Deep

702
00:30:46,630 --> 00:30:44,390
Field that I showed you and then at the

703
00:30:47,270 --> 00:30:46,640
end here we're gonna try to re simulate

704
00:30:52,630 --> 00:30:47,280
that

705
00:30:55,130 --> 00:30:52,640
as it would appear for JWST so there is

706
00:30:56,630 --> 00:30:55,140
transitioning to what JWT sees you see

707
00:30:58,880 --> 00:30:56,640
it's a straight to sharper image that

708
00:31:01,490 --> 00:30:58,890
comes from having a larger telescope but

709
00:31:03,290 --> 00:31:01,500
not only that now I'm going to do our

710
00:31:05,990 --> 00:31:03,300
pictures of galaxy gets sharper because

711
00:31:08,720 --> 00:31:06,000
we have a learner Tulsa but we can

712
00:31:10,460 --> 00:31:08,730
suddenly do all kinds of science here

713
00:31:12,200 --> 00:31:10,470

that we couldn't do before these

714
00:31:14,300 --> 00:31:12,210
galaxies the red ones the old ones the

715
00:31:19,940 --> 00:31:14,310
really distant ones become much sharper

716
00:31:25,790 --> 00:31:19,950
and much more easy to detect uh just let

717
00:31:27,620 --> 00:31:25,800
them run again it's kind of cool o jqsu

718
00:31:30,620 --> 00:31:27,630
in the same time we'll be able to go

719
00:31:33,410 --> 00:31:30,630
almost a factor of 10 beeper so take

720
00:31:35,780 --> 00:31:33,420
images that are detecting objects about

721
00:31:38,120 --> 00:31:35,790
1/10 as bright as what Hubble can do at

722
00:31:41,600 --> 00:31:38,130
the same time it's gonna be pretty

723
00:31:43,520 --> 00:31:41,610
amazing my personal favorite science

724
00:31:45,800 --> 00:31:43,530
cases is something I actually plan to do

725
00:31:50,300 --> 00:31:45,810
with Jada misty once they hand over the

726
00:31:51,380 --> 00:31:50,310
keys is to look at very best illa feels

727
00:31:53,210 --> 00:31:51,390
these are what this is one of those

728
00:31:54,740 --> 00:31:53,220
globular clusters that Frank pointed out

729
00:31:55,880 --> 00:31:54,750
in the image of Andromeda this is the

730
00:32:00,140 --> 00:31:55,890
globular cluster in our own galaxy

731
00:32:04,550 --> 00:32:00,150
called target you see there's just this

732
00:32:07,580 --> 00:32:04,560
is a action not a Hubble image but close

733
00:32:09,350 --> 00:32:07,590
enough this is this is a halogen here

734
00:32:11,270 --> 00:32:09,360
and you see it breaks up into individual

735
00:32:13,790 --> 00:32:11,280
stars right blue star red star mu star

736
00:32:15,680 --> 00:32:13,800
red star JD boost keeps gonna have this

737
00:32:18,140 --> 00:32:15,690
amazing device on it called a micro

738
00:32:21,920 --> 00:32:18,150

shredder array which is this array of

739
00:32:23,570 --> 00:32:21,930
little electronic doors and we can open

740
00:32:26,320 --> 00:32:23,580
and close those doors at will and take

741
00:32:29,060 --> 00:32:26,330
observations of individual stars

742
00:32:30,860 --> 00:32:29,070
that's our coping that door taking

743
00:32:32,120 --> 00:32:30,870
observations that star and just leave

744
00:32:34,490 --> 00:32:32,130
the others close

745
00:32:36,170 --> 00:32:34,500
pick out stars Reserve in these fields

746
00:32:37,820 --> 00:32:36,180
we can work out their age you can work

747
00:32:39,620 --> 00:32:37,830
out the metal content you can work out

748
00:32:41,900 --> 00:32:39,630
what this cluster came from and where

749
00:32:44,930 --> 00:32:41,910
it's going all from taking spectroscopy

750
00:32:47,450 --> 00:32:44,940
of these very dense fields this is the

751
00:32:48,850 --> 00:32:47,460
the scale of those little electronic

752
00:32:51,400 --> 00:32:48,860
doors at the scale

753
00:32:53,530 --> 00:32:51,410
human hair so pluck out a hair hold it

754
00:32:55,150 --> 00:32:53,540
up and say they made quarter of a

755
00:32:57,070 --> 00:32:55,160
million oohs little doors smaller than

756
00:32:59,380 --> 00:32:57,080
human hair in the space of about three

757
00:33:03,160 --> 00:32:59,390
to three inches squared it's quite a

758
00:33:04,480 --> 00:33:03,170
device by the way it operates at three

759
00:33:08,860 --> 00:33:04,490
hundred and something degrees below zero

760
00:33:10,690 --> 00:33:08,870
to Gen even if she is an infrared

761
00:33:13,299 --> 00:33:10,700
optimized telescope is going to turn

762
00:33:15,010 --> 00:33:13,309
images that look like this one very much

763
00:33:17,080 --> 00:33:15,020

like the pillars of creation that Frank

764
00:33:21,090 --> 00:33:17,090
just went through into images that look

765
00:33:24,250 --> 00:33:21,100
like this one right in other words a

766
00:33:26,710 --> 00:33:24,260
peering through this obscuring dust to

767
00:33:28,510 --> 00:33:26,720
see the star forming regions the young

768
00:33:30,549 --> 00:33:28,520
stars right air in the Jets that they

769
00:33:32,350 --> 00:33:30,559
power we're going to start seeing

770
00:33:34,840 --> 00:33:32,360
hundreds of images and star forming

771
00:33:41,020 --> 00:33:34,850
regions that look just like this which

772
00:33:42,460 --> 00:33:41,030
is deep so once we have done that and I

773
00:33:44,230 --> 00:33:42,470
should just say that this is something

774
00:33:46,230 --> 00:33:44,240
that hasn't happened yet right Jada

775
00:33:48,970 --> 00:33:46,240
misty is supposed to launch in about

776
00:33:52,120 --> 00:33:48,980
three and a half years at the end 2018

777
00:33:52,659 --> 00:33:52,130
we expect it to operate we hope for ten

778
00:33:54,820 --> 00:33:52,669
years

779
00:33:58,090 --> 00:33:54,830
so that'll carry us through almost the

780
00:34:02,440 --> 00:33:58,100
end of the next decade 20 28 2013

781
00:34:03,659 --> 00:34:02,450
perhaps Jada misty like any telescope

782
00:34:06,130 --> 00:34:03,669
that's come before it

783
00:34:07,780 --> 00:34:06,140
it's intended to revolutionize things

784
00:34:10,180 --> 00:34:07,790
it's intended to bring us knowledge that

785
00:34:11,980 --> 00:34:10,190
we never had before and more than that

786
00:34:13,419 --> 00:34:11,990
if it's anything like Hubble it's going

787
00:34:15,369 --> 00:34:13,429
to teach us to ask questions that we

788
00:34:17,710 --> 00:34:15,379

never thought in other words the thing

789
00:34:18,639 --> 00:34:17,720
we build it to do is actually a little

790
00:34:20,530 --> 00:34:18,649
bit of what it does

791
00:34:22,149 --> 00:34:20,540
most of what Hubble's famous for are

792
00:34:23,770 --> 00:34:22,159
things that its its designers never

793
00:34:25,840 --> 00:34:23,780
imagined their questions they never

794
00:34:27,820 --> 00:34:25,850
thought to ask and that's because the

795
00:34:28,990 --> 00:34:27,830
science moves along you come up with new

796
00:34:31,990 --> 00:34:29,000
discoveries and every new discovery

797
00:34:33,940 --> 00:34:32,000
raises a new question so it's very hard

798
00:34:36,669 --> 00:34:33,950
for us to predict where our field is

799
00:34:41,169 --> 00:34:36,679
going to be in 2028 at least when it

800
00:34:44,470 --> 00:34:41,179
comes to deep infrared observations of

801
00:34:44,980 --> 00:34:44,480
the universe so where do we go from

802
00:34:47,919 --> 00:34:44,990
there

803
00:34:50,109 --> 00:34:47,929
right where once we got David misty and

804
00:34:55,060 --> 00:34:50,119
we definitely will get it where do we go

805
00:34:55,580 --> 00:34:55,070
in well I like to motivate our work with

806
00:34:56,960 --> 00:34:55,590
this

807
00:34:59,900 --> 00:34:56,970
really fantastic quote not from

808
00:35:01,970 --> 00:34:59,910
astronomers a biologist rather famous

809
00:35:05,300 --> 00:35:01,980
biologists at Harvard uh and we'll see

810
00:35:07,280 --> 00:35:05,310
things for hands he's rated a lot of

811
00:35:09,560 --> 00:35:07,290
wonderful books about science generally

812
00:35:11,060 --> 00:35:09,570
and his life as a naturalist and his

813
00:35:13,910 --> 00:35:11,070

library recently was that the most

814
00:35:15,980 --> 00:35:13,920
important experiment in biology is the

815
00:35:18,140 --> 00:35:15,990
search for extraterrestrial life think

816
00:35:20,440 --> 00:35:18,150
of this this is a world-famous file that

817
00:35:23,330 --> 00:35:20,450
is telling us that the most important

818
00:35:26,540 --> 00:35:23,340
experiment in modern biology is an

819
00:35:28,250 --> 00:35:26,550
astronomy operation right that tells you

820
00:35:31,660 --> 00:35:28,260
something very important about where our

821
00:35:34,730 --> 00:35:31,670
field is going in the next decade and

822
00:35:38,060 --> 00:35:34,740
it's not just Hubble it's not just JWST

823
00:35:40,310 --> 00:35:38,070
NASA has deployed and will employ a

824
00:35:42,140 --> 00:35:40,320
whole array of missions at a smaller

825
00:35:45,080 --> 00:35:42,150
scale these are not the giant you know

826
00:35:47,150 --> 00:35:45,090
multibillion-dollar flagships but it has

827
00:35:48,590 --> 00:35:47,160
deployed the Kepler mission and there

828
00:35:50,960 --> 00:35:48,600
are two coming down the pike Old

829
00:35:53,750 --> 00:35:50,970
Testament after that I'll speak about

830
00:35:55,940 --> 00:35:53,760
three in a month which are designed to

831
00:35:58,850 --> 00:35:55,950
address this problem that Wilson has

832
00:36:00,410 --> 00:35:58,860
posed how can we find planets how can we

833
00:36:02,420 --> 00:36:00,420
find planets that might be bearing life

834
00:36:06,700 --> 00:36:02,430
and how can we find out a claim is

835
00:36:11,530 --> 00:36:06,710
actually there so we're on a pattern

836
00:36:14,240 --> 00:36:11,540
Kepler's great discovery has been of

837
00:36:15,890 --> 00:36:14,250
earth-sized planets capital is very good

838
00:36:17,320 --> 00:36:15,900

at finding all kinds of planets but it's

839
00:36:20,990 --> 00:36:17,330
especially good at finding earth-like

840
00:36:24,020 --> 00:36:21,000
planets and it's done that with exactly

841
00:36:26,180 --> 00:36:24,030
the same with it with it so that with an

842
00:36:30,170 --> 00:36:26,190
observing technique that I'll describe a

843
00:36:32,570 --> 00:36:30,180
moment called transits but the real

844
00:36:34,790 --> 00:36:32,580
important observation is that one out of

845
00:36:38,900 --> 00:36:34,800
every five sun-like stars has an

846
00:36:40,580 --> 00:36:38,910
earth-like planet one out of every five

847
00:36:42,920 --> 00:36:40,590
sun-like stars has an earth-like planet

848
00:36:45,560 --> 00:36:42,930
if you go back after the Andromeda in it

849
00:36:48,590 --> 00:36:45,570
you're going to see millions of sun-like

850
00:36:50,210 --> 00:36:48,600
stars that suggest that there are

851
00:36:52,230 --> 00:36:50,220
probably millions to hundreds of

852
00:36:54,990 --> 00:36:52,240
thousands of stars on earth life

853
00:36:57,440 --> 00:36:55,000
in that image right just statistically

854
00:37:01,140 --> 00:36:57,450
and our galaxy there are probably

855
00:37:03,690 --> 00:37:01,150
millions tens of millions of stars with

856
00:37:07,290 --> 00:37:03,700
earth-like cats that is a discovery that

857
00:37:09,390 --> 00:37:07,300
even those even those astronomers who

858
00:37:11,550 --> 00:37:09,400
discover the first exoplanets couldn't

859
00:37:16,890 --> 00:37:11,560
really imagine this is a very new result

860
00:37:18,810 --> 00:37:16,900
this is a 2014 well we're not only

861
00:37:24,660 --> 00:37:18,820
looking for earth-like planets if we

862
00:37:26,370 --> 00:37:24,670
want to solve wilson's puzzle we're

863
00:37:29,430 --> 00:37:26,380

looking for earth-like planets in what

864
00:37:30,750 --> 00:37:29,440
we call the habitable zone right you

865
00:37:33,839 --> 00:37:30,760
might think of this as a bit of a

866
00:37:36,030 --> 00:37:33,849
Goldilocks problem if a planet like the

867
00:37:38,339 --> 00:37:36,040
earth let's say is that the position of

868
00:37:41,690 --> 00:37:38,349
Venus in our own solar system or even

869
00:37:44,099 --> 00:37:41,700
worse mercury it's not a comfortable

870
00:37:45,240 --> 00:37:44,109
place where you might want to go to the

871
00:37:47,490 --> 00:37:45,250
beach or play golf

872
00:37:50,400 --> 00:37:47,500
it's like mercury where it's you know

873
00:37:52,829 --> 00:37:50,410
700 degrees during the daytime and 700

874
00:37:56,070 --> 00:37:52,839
degrees below or 4 degrees below zero at

875
00:37:58,070 --> 00:37:56,080
night it's not out of it's too hot while

876
00:38:02,040 --> 00:37:58,080
if you're at the distance of Mars or

877
00:38:05,910 --> 00:38:02,050
beyond also not good for going to the

878
00:38:08,040 --> 00:38:05,920
beach and golfing it's too cold so the

879
00:38:11,400 --> 00:38:08,050
habitable zone is it's more or less

880
00:38:14,700 --> 00:38:11,410
defined as where the radiation from the

881
00:38:16,410 --> 00:38:14,710
Sun is just right so that water is in

882
00:38:18,690 --> 00:38:16,420
liquid form at the surface temperature

883
00:38:22,320 --> 00:38:18,700
because water is the key ingredient of

884
00:38:25,500 --> 00:38:22,330
life at 70% of all of our bodies it's a

885
00:38:29,010 --> 00:38:25,510
bummer if the 7% of your body that's

886
00:38:30,780 --> 00:38:29,020
water freezes so in order for a planet

887
00:38:32,130 --> 00:38:30,790
called habitable by the astronomical

888
00:38:34,710 --> 00:38:32,140

standard it has to be in that region

889
00:38:36,690 --> 00:38:34,720
with us not too close to get to hot oil

890
00:38:39,240 --> 00:38:36,700
all the water not too far away to get

891
00:38:41,280 --> 00:38:39,250
too cold freeze all the water it has to

892
00:38:46,530 --> 00:38:41,290
be in this happening habitable something

893
00:38:48,450 --> 00:38:46,540
the htc so we have missions that can

894
00:38:52,140 --> 00:38:48,460
find earth-like planets Kepler has done

895
00:38:53,670 --> 00:38:52,150
it we have a definition we understand

896
00:38:56,460 --> 00:38:53,680
where those planets should be around

897
00:38:58,380 --> 00:38:56,470
their stars to be habitable once we

898
00:38:59,410 --> 00:38:58,390
found them how will we answer this

899
00:39:00,819 --> 00:38:59,420
question is there

900
00:39:03,819 --> 00:39:00,829
but living there is their life they're

901
00:39:06,460 --> 00:39:03,829
on that planet and it turns out this is

902
00:39:07,839 --> 00:39:06,470
a pretty straightforward problem when

903
00:39:09,069 --> 00:39:07,849
you think about it it's a challenging

904
00:39:10,809 --> 00:39:09,079
observation but it's a pretty

905
00:39:12,789 --> 00:39:10,819
straightforward problem and that's

906
00:39:14,500 --> 00:39:12,799
because if you take a spectrum

907
00:39:16,660 --> 00:39:14,510
just like news he's better than the Sun

908
00:39:18,960 --> 00:39:16,670
with the prism he's like front-of-house

909
00:39:21,609 --> 00:39:18,970
respected in the Sun with his scrape

910
00:39:24,940 --> 00:39:21,619
there are features in the spectrum of

911
00:39:28,150 --> 00:39:24,950
the earth that betray the presence of

912
00:39:30,700 --> 00:39:28,160
what on the earth there called me

913
00:39:34,329 --> 00:39:30,710

calling out biomarkers it's a marker for

914
00:39:36,370 --> 00:39:34,339
a biosphere a biomarker molecule the

915
00:39:39,220 --> 00:39:36,380
easiest one to pick out if you have the

916
00:39:42,970 --> 00:39:39,230
correct wavelength range covered is the

917
00:39:48,400 --> 00:39:42,980
water these big divots in the spectrum

918
00:39:49,809 --> 00:39:48,410
here are from water okay these big

919
00:39:53,130 --> 00:39:49,819
things in the spectrum here are from

920
00:39:56,380 --> 00:39:53,140
water light hits the Earth's atmosphere

921
00:39:58,240 --> 00:39:56,390
some of those photons from the Sun get

922
00:40:00,010 --> 00:39:58,250
trapped by water molecule and never go

923
00:40:02,559 --> 00:40:00,020
anywhere again and it reradiating to the

924
00:40:04,329 --> 00:40:02,569
infrared so those like those photons

925
00:40:05,620 --> 00:40:04,339
that light drops out it's a spectrum and

926
00:40:11,980 --> 00:40:05,630
it shows up just like that

927
00:40:14,770 --> 00:40:11,990
there's also here the effect of the dust

928
00:40:16,329 --> 00:40:14,780
in the atmosphere and then the ozone in

929
00:40:17,589 --> 00:40:16,339
the atmosphere which is what protects us

930
00:40:20,829 --> 00:40:17,599
from the ultraviolet radiation that

931
00:40:24,370 --> 00:40:20,839
introduces a very clear-cut drop of the

932
00:40:26,349 --> 00:40:24,380
spectrum there's oxygen the molecule

933
00:40:29,020 --> 00:40:26,359
we're all breathing to live has these

934
00:40:31,660 --> 00:40:29,030
little signs right in there

935
00:40:33,670 --> 00:40:31,670
ozone is itself a very important

936
00:40:35,500 --> 00:40:33,680
biomarker because it doesn't exist with

937
00:40:40,539 --> 00:40:35,510
these other molecules in the absence of

938
00:40:44,339 --> 00:40:40,549

life ozone is a very clear signature

939
00:40:47,079 --> 00:40:44,349
that you have biochemistry going on and

940
00:40:48,440 --> 00:40:47,089
then finally these other things carbon

941
00:40:51,160 --> 00:40:48,450
dioxide and methane

942
00:40:53,630 --> 00:40:51,170
which should produce carbon dioxide

943
00:40:57,560 --> 00:40:53,640
maintained by living people and then

944
00:41:01,490 --> 00:40:57,570
consumed by sorry by plants and then

945
00:41:05,329 --> 00:41:01,500
consumed oxygen is consumed by us

946
00:41:10,490 --> 00:41:05,339
methane is another case where it's

947
00:41:13,310 --> 00:41:10,500
either emitted by bacteria or by my

948
00:41:15,710 --> 00:41:13,320
hands so if you can detect all of these

949
00:41:17,780 --> 00:41:15,720
biomarkers in the spectrum of an

950
00:41:20,630 --> 00:41:17,790
earth-like planet in its habitable zone

951
00:41:23,540 --> 00:41:20,640
you have the answer that tells you that

952
00:41:24,890 --> 00:41:23,550
on that planet at least there's strong

953
00:41:27,170 --> 00:41:24,900
evidence that there's life there

954
00:41:29,089 --> 00:41:27,180
creating these signatures which

955
00:41:31,250 --> 00:41:29,099
otherwise would not exist

956
00:41:33,230 --> 00:41:31,260
this is not what Mars looks like this is

957
00:41:34,849 --> 00:41:33,240
not what Venus looks like the

958
00:41:36,980 --> 00:41:34,859
uninhabited planets in our solar system

959
00:41:39,589 --> 00:41:36,990
don't look anything like this the earth

960
00:41:44,000 --> 00:41:39,599
does because we live here along with a

961
00:41:45,950 --> 00:41:44,010
lot of plants so one way to detect a

962
00:41:48,650 --> 00:41:45,960
biomarker is to use the method that

963
00:41:51,140 --> 00:41:48,660

Kepler has used to detect planets and

964
00:41:54,200 --> 00:41:51,150
that's the so called transitive this is

965
00:41:55,990 --> 00:41:54,210
an illustration actually to see if you

966
00:42:00,530 --> 00:41:56,000
have a star a planet orbiting that star

967
00:42:02,780 --> 00:42:00,540
if it's oriented just right right if the

968
00:42:04,910 --> 00:42:02,790
orbit of the planet is more or less in

969
00:42:06,950 --> 00:42:04,920
the plane that you're looking in that

970
00:42:08,569 --> 00:42:06,960
startled that planet will pass in front

971
00:42:10,220 --> 00:42:08,579
of start will make it even to the star

972
00:42:12,920 --> 00:42:10,230
just a little tiny bit brighter like

973
00:42:15,020 --> 00:42:12,930
it'll take 110 thousand of the photons

974
00:42:16,700 --> 00:42:15,030
out of the image so you have to you know

975
00:42:19,790 --> 00:42:16,710
if you can measure one part in 10,000

976
00:42:22,670 --> 00:42:19,800
you can detect us and you can then

977
00:42:24,410 --> 00:42:22,680
measure the planet's atmosphere if the

978
00:42:27,170 --> 00:42:24,420
planet passes in front of the star of

979
00:42:29,809 --> 00:42:27,180
the star by looking for these spectral

980
00:42:31,220 --> 00:42:29,819
features in the light that passes from

981
00:42:35,059 --> 00:42:31,230
the star through the planet's atmosphere

982
00:42:37,250 --> 00:42:35,069
into our telescopes so this is one way

983
00:42:39,800 --> 00:42:37,260
to detect these biomarker molecules but

984
00:42:42,230 --> 00:42:39,810
it only works if the planet transits

985
00:42:44,140 --> 00:42:42,240
right it only works if this happens if

986
00:42:46,420 --> 00:42:44,150
the star and the planet is or

987
00:42:48,040 --> 00:42:46,430
- just so it just planet every

988
00:42:50,350 --> 00:42:48,050

once-in-a-while passes in from the start

989
00:42:51,850 --> 00:42:50,360
if it's oriented a different way where

990
00:42:54,100 --> 00:42:51,860
you say you have to star and the planets

991
00:42:55,840 --> 00:42:54,110
going around it like this it never

992
00:42:57,010 --> 00:42:55,850
actually passes in front of the start it

993
00:43:00,370 --> 00:42:57,020
doesn't work and that's actually the

994
00:43:01,960 --> 00:43:00,380
case most of the time because of the

995
00:43:03,610 --> 00:43:01,970
orbits are just random you know they

996
00:43:05,770 --> 00:43:03,620
have you have to be lucky for them to

997
00:43:07,390 --> 00:43:05,780
translate this so that's probably not

998
00:43:09,490 --> 00:43:07,400
going to be the way that we figure out

999
00:43:13,290 --> 00:43:09,500
at least for lots of nearby planets

1000
00:43:16,120 --> 00:43:13,300
whether they have is five miles right

1001
00:43:19,150 --> 00:43:16,130
but anyway this is a technique that we

1002
00:43:23,590 --> 00:43:19,160
will use with JWST going back to that

1003
00:43:25,180 --> 00:43:23,600
fantastic observatory it Jake jr. yes he

1004
00:43:28,570 --> 00:43:25,190
may be able to use this transit

1005
00:43:30,730 --> 00:43:28,580
technique to detect some biomarker

1006
00:43:33,910 --> 00:43:30,740
molecules especially water and methane

1007
00:43:35,710 --> 00:43:33,920
what are called super water worlds so

1008
00:43:37,990 --> 00:43:35,720
something that's two times or three or

1009
00:43:41,050 --> 00:43:38,000
four times the Earth's mass rocky in the

1010
00:43:43,000 --> 00:43:41,060
core but surrounded by a big ocean the

1011
00:43:45,970 --> 00:43:43,010
university might be able to detect water

1012
00:43:47,230 --> 00:43:45,980
and methane on those planets the

1013
00:43:49,990 --> 00:43:47,240

spectrum of look like this and I know

1014
00:43:51,790 --> 00:43:50,000
this appears to be a total mess but it's

1015
00:43:53,590 --> 00:43:51,800
a simulated spectrum by the way this is

1016
00:43:55,330 --> 00:43:53,600
not real data one reason you know that

1017
00:43:59,650 --> 00:43:55,340
the telescope is still in part some

1018
00:44:03,520 --> 00:43:59,660
ground and number two it looks a little

1019
00:44:05,200 --> 00:44:03,530
better than real data actually but this

1020
00:44:06,790 --> 00:44:05,210
is a simulated spectrum with jegos T

1021
00:44:08,230 --> 00:44:06,800
because believe me all the astronomers

1022
00:44:09,910 --> 00:44:08,240
are ramped up we're thinking about it

1023
00:44:11,050 --> 00:44:09,920
you know this even though it's a park on

1024
00:44:13,360 --> 00:44:11,060
the ground we're launching in three

1025
00:44:14,560 --> 00:44:13,370
years and we're ready to go right so we

1026
00:44:16,930 --> 00:44:14,570
have to start thinking about what we're

1027
00:44:18,700 --> 00:44:16,940
going to find so generous you may be

1028
00:44:20,440 --> 00:44:18,710
able to reach these water world planets

1029
00:44:22,240 --> 00:44:20,450
but it's not going to be able to get to

1030
00:44:24,480 --> 00:44:22,250
genuine earth-like planets you know just

1031
00:44:27,150 --> 00:44:24,490
like the earth one so one person asked

1032
00:44:30,360 --> 00:44:27,160
and it's certainly not going to do that

1033
00:44:32,910 --> 00:44:30,370
for a large number of plants so it's a

1034
00:44:34,860 --> 00:44:32,920
step in the right direction it's a way

1035
00:44:36,330 --> 00:44:34,870
to prove that the techniques work it's

1036
00:44:37,710 --> 00:44:36,340
maybe a way to make an important

1037
00:44:40,890 --> 00:44:37,720
discovery there's a water world out

1038
00:44:45,110 --> 00:44:40,900

there with something look at but it's

1039
00:44:47,880 --> 00:44:45,120
not really the answer to Wilson's claim

1040
00:44:50,670 --> 00:44:47,890
so what is the answer what is going to

1041
00:44:52,410 --> 00:44:50,680
get us this evidence that there's a

1042
00:44:53,850 --> 00:44:52,420
separate evolutionary pathway for life

1043
00:44:56,420 --> 00:44:53,860
that's been in separate origin of life

1044
00:44:59,070 --> 00:44:56,430
on another planet in our house

1045
00:45:02,790 --> 00:44:59,080
the ultimate goal really is another

1046
00:45:04,140 --> 00:45:02,800
living earth like our own we already

1047
00:45:05,580 --> 00:45:04,150
know school children on earth already

1048
00:45:07,740 --> 00:45:05,590
learned that there are these worlds

1049
00:45:09,810 --> 00:45:07,750
orbiting other stars and what we like is

1050
00:45:11,310 --> 00:45:09,820
for the future generations and I don't

1051
00:45:13,260 --> 00:45:11,320
mean the distant future I don't need a

1052
00:45:16,170 --> 00:45:13,270
thousand years from now I mean my

1053
00:45:19,140 --> 00:45:16,180
children right possibly get children but

1054
00:45:21,180 --> 00:45:19,150
probably my own right next generation

1055
00:45:23,910 --> 00:45:21,190
school trailers to fight to know with

1056
00:45:25,170 --> 00:45:23,920
the same certainty would know this right

1057
00:45:29,460 --> 00:45:25,180
that there's life on some of those

1058
00:45:31,260 --> 00:45:29,470
worlds a increasingly large number of

1059
00:45:33,090 --> 00:45:31,270
genres myself included that's why I'm

1060
00:45:35,070 --> 00:45:33,100
here but you know a large part of our

1061
00:45:36,330 --> 00:45:35,080
community is confident of you that we

1062
00:45:40,110 --> 00:45:36,340
can actually do this

1063
00:45:41,520 --> 00:45:40,120

within two decades because we're

1064
00:45:43,740 --> 00:45:41,530
starting to see you have the technology

1065
00:45:47,720 --> 00:45:43,750
we have the ability to build a telescope

1066
00:45:50,370 --> 00:45:47,730
that can do this so how are you doing

1067
00:45:52,830 --> 00:45:50,380
well it's much different from what I

1068
00:45:55,230 --> 00:45:52,840
said Kepler does and what Jacob is he

1069
00:45:57,720 --> 00:45:55,240
will do because what we want to do is

1070
00:45:59,490 --> 00:45:57,730
break open this this restriction of

1071
00:46:01,590 --> 00:45:59,500
having to have the planet pass in front

1072
00:46:04,550 --> 00:46:01,600
of the star as well that doesn't happen

1073
00:46:06,900 --> 00:46:04,560
very often for typical stars

1074
00:46:09,750 --> 00:46:06,910
statistically we've worked out that 20%

1075
00:46:11,490 --> 00:46:09,760
of sun-like stars have planets but

1076
00:46:13,370 --> 00:46:11,500
that's by extrapolating from a much

1077
00:46:17,220 --> 00:46:13,380
smaller number of millions with category

1078
00:46:19,380 --> 00:46:17,230
so the way to really prove this works is

1079
00:46:21,930 --> 00:46:19,390
to just figure out a way to take a

1080
00:46:24,990 --> 00:46:21,940
picture of the planet go out to the

1081
00:46:25,490 --> 00:46:25,000
thousand nearest stars find the planets

1082
00:46:27,110 --> 00:46:25,500
there

1083
00:46:30,770 --> 00:46:27,120
take your picture right that's worth a

1084
00:46:32,060 --> 00:46:30,780
thousand words so every minute you try

1085
00:46:33,980 --> 00:46:32,070
to use is an instrument called a

1086
00:46:35,750 --> 00:46:33,990
coronagraph I want to get all until the

1087
00:46:38,840 --> 00:46:35,760
technical and an optical jargon that's

1088
00:46:40,640 --> 00:46:38,850

involved here but basically what you do

1089
00:46:43,280 --> 00:46:40,650
is when you point your telescope you put

1090
00:46:46,160 --> 00:46:43,290
something in the way that blocks the

1091
00:46:48,770 --> 00:46:46,170
Starlight so you can see the planet now

1092
00:46:51,230 --> 00:46:48,780
I have here an illustration using a star

1093
00:46:52,880 --> 00:46:51,240
a bunch of planets in the habitable zone

1094
00:46:55,100 --> 00:46:52,890
around that star it wouldn't have that

1095
00:46:57,980 --> 00:46:55,110
many they could all gravitationally

1096
00:47:00,470 --> 00:46:57,990
eject each other but that's just a model

1097
00:47:02,420 --> 00:47:00,480
and the idea is to have the coronagraph

1098
00:47:04,100 --> 00:47:02,430
brought block the Starlight for reasons

1099
00:47:05,710 --> 00:47:04,110
I'll explain in a minute so that you can

1100
00:47:07,190 --> 00:47:05,720
see the planet now we already do

1101
00:47:07,910 --> 00:47:07,200
measurements with things like

1102
00:47:10,220 --> 00:47:07,920
chronographs

1103
00:47:12,410 --> 00:47:10,230
in fact they were invented to study the

1104
00:47:15,260 --> 00:47:12,420
Sun if you want to study anything here

1105
00:47:17,300 --> 00:47:15,270
the Sun like the Kirk the the corona of

1106
00:47:19,370 --> 00:47:17,310
the Sun or a comment that happens to be

1107
00:47:21,560 --> 00:47:19,380
a comment right there since from a NASA

1108
00:47:23,210 --> 00:47:21,570
solar mission you have to block the Sun

1109
00:47:24,320 --> 00:47:23,220
because the Sun is the brightest thing

1110
00:47:25,880 --> 00:47:24,330
in the sky right you wouldn't see

1111
00:47:27,740 --> 00:47:25,890
anything near it if you didn't block it

1112
00:47:29,570 --> 00:47:27,750
out so people have figured out a way to

1113
00:47:32,690 --> 00:47:29,580

block out starlight to see stuff nearby

1114
00:47:34,280 --> 00:47:32,700
and that's what we intend to do the idea

1115
00:47:38,690 --> 00:47:34,290
is to build up the Stars so you can see

1116
00:47:43,250 --> 00:47:38,700
the planets there right but it's really

1117
00:47:46,430 --> 00:47:43,260
really really really hard right because

1118
00:47:48,560 --> 00:47:46,440
the planet is 10 billion times fainter

1119
00:47:50,000 --> 00:47:48,570
than the star I'm looking at now the

1120
00:47:51,680 --> 00:47:50,010
kinds of stars we're talking about are

1121
00:47:53,540 --> 00:47:51,690
literally the kinds of stars you can see

1122
00:47:55,190 --> 00:47:53,550
if you walk out into the streets and

1123
00:47:57,800 --> 00:47:55,200
Martin here and look up there that

1124
00:47:59,450 --> 00:47:57,810
bright they're bright stars they're not

1125
00:48:01,100 --> 00:47:59,460
the 28th magnitude stars that you're

1126
00:48:03,080 --> 00:48:01,110
seeing in the Andromeda image in the

1127
00:48:05,330 --> 00:48:03,090
lobby these are bright stars but the

1128
00:48:06,980 --> 00:48:05,340
planet because it doesn't emit any light

1129
00:48:09,170 --> 00:48:06,990
of its own it's only picking up the

1130
00:48:12,500 --> 00:48:09,180
light that the star shines on right it's

1131
00:48:14,660 --> 00:48:12,510
picking up earth shine right it's 10

1132
00:48:16,310 --> 00:48:14,670
billion times fans in the host star so

1133
00:48:18,260 --> 00:48:16,320
how in the world are you going to take a

1134
00:48:20,450 --> 00:48:18,270
spectrum of the thing that's sitting

1135
00:48:21,650 --> 00:48:20,460
right next to something that's we then

1136
00:48:24,570 --> 00:48:21,660
you know at end of the arc second or

1137
00:48:28,240 --> 00:48:24,580
something that's a 10 billion

1138
00:48:28,480 --> 00:48:28,250

this is a real engineering job you all

1139
00:48:31,000 --> 00:48:28,490
right

1140
00:48:32,890 --> 00:48:31,010
in fact this problem detecting an

1141
00:48:34,630 --> 00:48:32,900
earth-like planet in its habitable zone

1142
00:48:35,860 --> 00:48:34,640
a tenth of an arcsecond way from a

1143
00:48:39,100 --> 00:48:35,870
bright star at ten billion times

1144
00:48:41,050 --> 00:48:39,110
brighter it's actually no harder than

1145
00:48:42,610 --> 00:48:41,060
this guy so if you figure out how to

1146
00:48:44,770 --> 00:48:42,620
solve this problem you can figure out

1147
00:48:47,080 --> 00:48:44,780
the plan right it's this problem let's

1148
00:48:48,640 --> 00:48:47,090
put a telescope in Baltimore and let's

1149
00:48:51,850 --> 00:48:48,650
put a searchlight in Los Angeles

1150
00:48:56,560 --> 00:48:51,860
and then let's put a firefly next to

1151
00:48:58,990 --> 00:48:56,570
that searchlight solve the problem and

1152
00:49:01,480 --> 00:48:59,000
final Firefly for all the searchlights

1153
00:49:03,190 --> 00:49:01,490
in Los Angeles from Baltimore you got it

1154
00:49:05,350 --> 00:49:03,200
fixed it works

1155
00:49:07,150 --> 00:49:05,360
that's how challenging this problem is

1156
00:49:09,460 --> 00:49:07,160
yeah I don't want I don't want to

1157
00:49:11,380 --> 00:49:09,470
minimize the challenge of altering this

1158
00:49:13,660 --> 00:49:11,390
is why it's going to take us 20 years to

1159
00:49:16,180 --> 00:49:13,670
get to this point but it's actually

1160
00:49:18,010 --> 00:49:16,190
something that that people who build

1161
00:49:19,900 --> 00:49:18,020
instruments and work with telescopes on

1162
00:49:21,430 --> 00:49:19,910
the ground in space are spending their

1163
00:49:23,290 --> 00:49:21,440

careers trying to figure out we have a

1164
00:49:25,060 --> 00:49:23,300
whole group of people here in what's

1165
00:49:27,160 --> 00:49:25,070
called high contrast imaging believe me

1166
00:49:29,740 --> 00:49:27,170
this is a high contrast fainting and a

1167
00:49:33,450 --> 00:49:29,750
really bright thing they're looking for

1168
00:49:40,210 --> 00:49:33,460
the fireflies in searchlights so I think

1169
00:49:41,710 --> 00:49:40,220
okay well the mission I've been teasing

1170
00:49:42,940 --> 00:49:41,720
all along is something that we've

1171
00:49:46,060 --> 00:49:42,950
started to call the High Definition

1172
00:49:50,670 --> 00:49:46,070
Space Telescope it would be a new Space

1173
00:49:53,320 --> 00:49:50,680
Telescope following on JWST it would

1174
00:49:54,730 --> 00:49:53,330
orbit at the earth style two points in

1175
00:49:56,440 --> 00:49:54,740
the same place Jamie guessed he is going

1176
00:49:59,740 --> 00:49:56,450
and sort of a gravitationally happy spot

1177
00:50:01,780 --> 00:49:59,750
million miles beyond the moon we'd like

1178
00:50:04,030 --> 00:50:01,790
to see an aperture for the telescope of

1179
00:50:06,490 --> 00:50:04,040
10 to 12 meters which is about the same

1180
00:50:08,020 --> 00:50:06,500
size as the room here so you know not

1181
00:50:13,120 --> 00:50:08,030
small more like the room in this

1182
00:50:14,620 --> 00:50:13,130
direction but still it's big it has to

1183
00:50:16,930 --> 00:50:14,630
be deployable mirror just like jadibooti

1184
00:50:20,320 --> 00:50:16,940
so it'll all fold up origami style and

1185
00:50:22,930 --> 00:50:20,330
fit in rocket cars ultraviolet in your

1186
00:50:24,760 --> 00:50:22,940
throat wavelengths we'd really like for

1187
00:50:26,470 --> 00:50:24,770
it to be more like Hubble and less like

1188
00:50:27,190 --> 00:50:26,480

you to do is T so that robots or

1189
00:50:28,630 --> 00:50:27,200
astronauts

1190
00:50:30,579 --> 00:50:28,640
go in there and replace the instruments

1191
00:50:32,530 --> 00:50:30,589
that's been the reason that Hubble has

1192
00:50:34,690 --> 00:50:32,540
been so successful over 25 years that's

1193
00:50:36,819 --> 00:50:34,700
a reason to live that long so that's

1194
00:50:38,290 --> 00:50:36,829
what we'd like and of course these

1195
00:50:40,930 --> 00:50:38,300
things take time so we're looking into

1196
00:50:42,640 --> 00:50:40,940
decades or so before this is a

1197
00:50:44,319 --> 00:50:42,650
comparative mirror sizes there's the

1198
00:50:45,760 --> 00:50:44,329
humble mirror if you go out and lobby as

1199
00:50:47,620 --> 00:50:45,770
I said you can see that banner that

1200
00:50:50,140 --> 00:50:47,630
tells you how big it really is that's

1201
00:50:52,690 --> 00:50:50,150
rated to see the scale and our High

1202
00:50:55,410 --> 00:50:52,700
Definition space also this is your thing

1203
00:50:58,120 --> 00:50:55,420
it's pretty big

1204
00:51:00,550 --> 00:50:58,130
okay so why does it need to be serviced

1205
00:51:03,510 --> 00:51:00,560
let's take the stars within 200

1206
00:51:06,460 --> 00:51:03,520
light-years which is about 17 parsecs

1207
00:51:07,839 --> 00:51:06,470
that's all the stars but that from the

1208
00:51:10,329 --> 00:51:07,849
list of actual stars at that distance

1209
00:51:14,349 --> 00:51:10,339
okay that's our galactic neighborhood in

1210
00:51:17,500 --> 00:51:14,359
the side of the center okay let's now

1211
00:51:18,819 --> 00:51:17,510
say well we know that about 20% of those

1212
00:51:20,680 --> 00:51:18,829
have worked like planets we don't know

1213
00:51:23,589 --> 00:51:20,690

which ones but let's just randomly pick

1214
00:51:26,349 --> 00:51:23,599
20% if you only go up 5 meter telescope

1215
00:51:27,790 --> 00:51:26,359
you only got a few right but if you go

1216
00:51:30,490 --> 00:51:27,800
to 10 meters now you're starting to talk

1217
00:51:33,700 --> 00:51:30,500
about real numbers and the reason that

1218
00:51:35,829 --> 00:51:33,710
matters is that you know we don't have

1219
00:51:37,630 --> 00:51:35,839
to be lucky it's possible that all of

1220
00:51:39,609 --> 00:51:37,640
all we are like planets you know if

1221
00:51:41,500 --> 00:51:39,619
every sun-like star has an earth-like

1222
00:51:43,150 --> 00:51:41,510
planet it might be there only one

1223
00:51:45,640 --> 00:51:43,160
percent of those have just the right

1224
00:51:48,400 --> 00:51:45,650
conditions to have developed life to

1225
00:51:51,790 --> 00:51:48,410
have these biomarkers to have bacteria

1226
00:51:53,890 --> 00:51:51,800
and bipeds right so we don't want to

1227
00:51:55,780 --> 00:51:53,900
gamble it too much right if you're gonna

1228
00:51:58,210 --> 00:51:55,790
build a big telescope and launch it into

1229
00:52:00,089 --> 00:51:58,220
space and really you know spend a lot of

1230
00:52:02,440 --> 00:52:00,099
money and waste a lot of people's time

1231
00:52:04,450 --> 00:52:02,450
you don't want to gamble on just doing

1232
00:52:06,010 --> 00:52:04,460
it with 10 planets because it would say

1233
00:52:07,569 --> 00:52:06,020
if only 1% of those planets have life

1234
00:52:10,329 --> 00:52:07,579
and you only roll the dice in time

1235
00:52:11,710 --> 00:52:10,339
you're not going to win right so what we

1236
00:52:13,150 --> 00:52:11,720
want to do is we roll the dice enough

1237
00:52:15,370 --> 00:52:13,160
times that we know we're going to come

1238
00:52:15,950 --> 00:52:15,380

up or we can really predict confidently

1239
00:52:18,560 --> 00:52:15,960
we're going to come

1240
00:52:21,140 --> 00:52:18,570
winters even if people die someone

1241
00:52:23,329 --> 00:52:21,150
guesses so turns out the number you

1242
00:52:26,359 --> 00:52:23,339
really eat is more like 50 to 70 we'd

1243
00:52:27,859 --> 00:52:26,369
really like 100 planets and that forces

1244
00:52:29,480 --> 00:52:27,869
us to these very warm temperatures

1245
00:52:31,609 --> 00:52:29,490
because we have to use stars that are

1246
00:52:33,530 --> 00:52:31,619
progressively further away and planets

1247
00:52:35,240 --> 00:52:33,540
that are progressively fan so that

1248
00:52:39,170 --> 00:52:35,250
forces us to be in this region between

1249
00:52:42,250 --> 00:52:39,180
10 and 12 meters to pick up 70 50 70 100

1250
00:52:44,750 --> 00:52:42,260
plants that's a 10 millimeter Tulsa

1251
00:52:46,910 --> 00:52:44,760
that's as I said that's critical because

1252
00:52:48,980 --> 00:52:46,920
we don't know the actual rate of wyeth

1253
00:52:53,750 --> 00:52:48,990
on these earth-like planets and we have

1254
00:52:55,160 --> 00:52:53,760
to improve our odds by aiming high okay

1255
00:52:57,680 --> 00:52:55,170
so it's a simple equation between a

1256
00:52:59,690 --> 00:52:57,690
large telescope and 50 years for a lot

1257
00:53:01,640 --> 00:52:59,700
of planets maybe life we don't know we

1258
00:53:03,500 --> 00:53:01,650
have to take we have the first find

1259
00:53:05,270 --> 00:53:03,510
these by going to the star calling out

1260
00:53:07,730 --> 00:53:05,280
the star light imaging the earth-like

1261
00:53:10,490 --> 00:53:07,740
planet taking a spectrum and hoping that

1262
00:53:14,000 --> 00:53:10,500
get this expect right with the water or

1263
00:53:15,349 --> 00:53:14,010

the oxygen and the ozone and that would

1264
00:53:16,820 --> 00:53:15,359
be the ramp loss that would be the

1265
00:53:19,070 --> 00:53:16,830
spectrum of earth-like planet and

1266
00:53:21,079 --> 00:53:19,080
habitable zone of the star showing

1267
00:53:28,120 --> 00:53:21,089
biological molecules and that's going to

1268
00:53:30,680 --> 00:53:28,130
be you know in the newspaper right 35

1269
00:53:32,630 --> 00:53:30,690
discoveries announced I guarantee you

1270
00:53:34,490 --> 00:53:32,640
will never see a spectrum like that

1271
00:53:35,660 --> 00:53:34,500
they'll show some artist's conception of

1272
00:53:38,510 --> 00:53:35,670
the plan because they never show

1273
00:53:45,950 --> 00:53:38,520
spectroscopy in the newspaper presumably

1274
00:53:46,910 --> 00:53:45,960
bob was not going to have any but that's

1275
00:53:49,310 --> 00:53:46,920
not all

1276
00:53:51,230 --> 00:53:49,320
you're not only discovering earth-like

1277
00:53:52,370 --> 00:53:51,240
planets with potentially life on them

1278
00:53:54,200 --> 00:53:52,380
but you're going to completely

1279
00:53:56,420 --> 00:53:54,210
revolutionize the rest of the stronger

1280
00:53:58,099 --> 00:53:56,430
right 10 meter telescope in space at 12

1281
00:54:00,589 --> 00:53:58,109
meter telescope in space this is a big

1282
00:54:02,180 --> 00:54:00,599
deal and it tells us all kinds of things

1283
00:54:05,150 --> 00:54:02,190
we didn't know before about galaxies

1284
00:54:06,950 --> 00:54:05,160
stars everything even think of and what

1285
00:54:08,630 --> 00:54:06,960
it really does is follow through this

1286
00:54:11,040 --> 00:54:08,640
promised I were part of the akane who

1287
00:54:13,860 --> 00:54:11,050
won the Nobel Prize in Physics in 2002

1288
00:54:15,180 --> 00:54:13,870

and x-ray astronomy he was also the

1289
00:54:18,000 --> 00:54:15,190
first director of the Space Telescope

1290
00:54:19,590 --> 00:54:18,010
Science Institute 21st century

1291
00:54:21,450 --> 00:54:19,600
astronomers are uniquely positioned to

1292
00:54:24,180 --> 00:54:21,460
study evolution of the universe in order

1293
00:54:26,130 --> 00:54:24,190
to relate causally related cause elite

1294
00:54:27,900 --> 00:54:26,140
would fit the chain of causes the

1295
00:54:30,000 --> 00:54:27,910
physical conditions during a Big Bang to

1296
00:54:32,700 --> 00:54:30,010
the development of our Navy and our team

1297
00:54:34,350 --> 00:54:32,710
at mature and there really is an actual

1298
00:54:36,180 --> 00:54:34,360
link between those two things in the way

1299
00:54:37,860 --> 00:54:36,190
that they are so the frontier for

1300
00:54:39,240 --> 00:54:37,870
astronomy is not only to discover these

1301
00:54:41,790 --> 00:54:39,250
earth-like planets improvements like

1302
00:54:44,040 --> 00:54:41,800
their but to figure out how we got right

1303
00:54:47,400 --> 00:54:44,050
which is the same way that we got here

1304
00:54:50,130 --> 00:54:47,410
and I like to illustrate this profound

1305
00:54:52,020 --> 00:54:50,140
fact with the answer to a question that

1306
00:54:54,000 --> 00:54:52,030
Neil Tyson was asked I think on a radio

1307
00:54:56,130 --> 00:54:54,010
show it's actually a pretty cool YouTube

1308
00:54:57,840 --> 00:54:56,140
video if you dig it out what is the most

1309
00:55:02,490 --> 00:54:57,850
astounding fact you could share with us

1310
00:55:04,110 --> 00:55:02,500
about the universe it wasn't his vest it

1311
00:55:06,120 --> 00:55:04,120
was the knowledge that the atoms

1312
00:55:07,890 --> 00:55:06,130
comprise life on Earth the atoms that

1313
00:55:09,240 --> 00:55:07,900

make up the human body are traceable to

1314
00:55:11,580 --> 00:55:09,250
the crucibles that cooked light elements

1315
00:55:13,380 --> 00:55:11,590
into heavier elements and all the

1316
00:55:15,000 --> 00:55:13,390
fundamental ingredients of life itself

1317
00:55:17,550 --> 00:55:15,010
that's the fusion of hydrogen to helium

1318
00:55:20,040 --> 00:55:17,560
to carbon nitrogen to oxygen in the

1319
00:55:22,050 --> 00:55:20,050
interiors of stars these ingredients

1320
00:55:23,790 --> 00:55:22,060
become part of glass count glass gas

1321
00:55:25,260 --> 00:55:23,800
clouds that form the next generation of

1322
00:55:26,550 --> 00:55:25,270
solar system stars with orbiting planets

1323
00:55:28,740 --> 00:55:26,560
and those planets now have the

1324
00:55:30,270 --> 00:55:28,750
ingredients for what so that when I woke

1325
00:55:31,710 --> 00:55:30,280
up at the night sky and I know that we

1326
00:55:32,160 --> 00:55:31,720
are artists universe we are in this

1327
00:55:34,380 --> 00:55:32,170
universe

1328
00:55:37,110 --> 00:55:34,390
but perhaps more important than that is

1329
00:55:38,520 --> 00:55:37,120
the fact that the universe is in us you

1330
00:55:40,560 --> 00:55:38,530
may have heard me our star stuff and

1331
00:55:41,520 --> 00:55:40,570
that is literally true all the carbon

1332
00:55:43,590 --> 00:55:41,530
all the nitrogen all

1333
00:55:46,470 --> 00:55:43,600
and all magnesium iron everything can

1334
00:55:48,200 --> 00:55:46,480
think of here your body the room came

1335
00:55:50,670 --> 00:55:48,210
out of the star that's pretty profound

1336
00:55:53,160 --> 00:55:50,680
it's so profound that it has t-shirt

1337
00:55:55,620 --> 00:55:53,170
right you are here right what we're

1338
00:55:57,060 --> 00:55:55,630

really saying it's not you are here

1339
00:56:03,150 --> 00:55:57,070
that's true you know we're here very

1340
00:56:05,400 --> 00:56:03,160
galaxy it's wrong we're here right the

1341
00:56:07,500 --> 00:56:05,410
stuff in you used to be in a star used

1342
00:56:09,840 --> 00:56:07,510
to be in the interstellar gas some of it

1343
00:56:12,360 --> 00:56:09,850
used to be in intergalactic space

1344
00:56:16,020 --> 00:56:12,370
because galaxies like to eject material

1345
00:56:19,250 --> 00:56:16,030
out of intergalactic space over time so

1346
00:56:21,480 --> 00:56:19,260
this whole story of the origin of life

1347
00:56:23,300 --> 00:56:21,490
goes through the intergalactic medium

1348
00:56:25,830 --> 00:56:23,310
galaxies the interstellar medium

1349
00:56:29,400 --> 00:56:25,840
supernovae right you used to be part of

1350
00:56:31,440 --> 00:56:29,410
a supernova explosion at some point this

1351
00:56:33,840 --> 00:56:31,450
is the whole story of cosmic birth of

1352
00:56:37,020 --> 00:56:33,850
living earth so what I very briefly go

1353
00:56:38,610 --> 00:56:37,030
through this this evolution from from

1354
00:56:40,590 --> 00:56:38,620
the black exceeds through the birth of

1355
00:56:43,470 --> 00:56:40,600
galaxies through star clusters through

1356
00:56:45,780 --> 00:56:43,480
planet forming into the solar system to

1357
00:56:47,130 --> 00:56:45,790
tell you how this telescope the same

1358
00:56:49,080 --> 00:56:47,140
telescope that's potentially going to

1359
00:56:51,480 --> 00:56:49,090
discover life into the world is going to

1360
00:56:53,910 --> 00:56:51,490
blow open this whole story of how that

1361
00:56:55,800 --> 00:56:53,920
life got there and ourselves right it's

1362
00:56:58,650 --> 00:56:55,810
actually pretty amazing to think that

1363
00:57:00,840 --> 00:56:58,660

even if the life we were to discover

1364
00:57:03,150 --> 00:57:00,850
were to have you know seven heads and to

1365
00:57:06,120 --> 00:57:03,160
drive on the other side of roads we

1366
00:57:08,490 --> 00:57:06,130
would still have this in common right we

1367
00:57:11,000 --> 00:57:08,500
all came out of the same basic common

1368
00:57:13,380 --> 00:57:11,010
origins stars galaxies and planets

1369
00:57:16,200 --> 00:57:13,390
however you know whatever language they

1370
00:57:18,630 --> 00:57:16,210
speak even if they're just unicellular

1371
00:57:23,550 --> 00:57:18,640
bacteria we at least have that talk

1372
00:57:25,590 --> 00:57:23,560
about what we're calling this h TST does

1373
00:57:27,420 --> 00:57:25,600
an amazing thing it improves the

1374
00:57:29,340 --> 00:57:27,430
resolution with which we can observe the

1375
00:57:31,530 --> 00:57:29,350
universe by more than a factor of five

1376
00:57:34,410 --> 00:57:31,540
in one dimension or 25 in another

1377
00:57:37,740 --> 00:57:34,420
dimension over huh it allows us to

1378
00:57:39,480 --> 00:57:37,750
resolve very important thresholds and I

1379
00:57:42,570 --> 00:57:39,490
like to illustrate this with a very

1380
00:57:44,250 --> 00:57:42,580
simple analogy right the gaming image

1381
00:57:45,480 --> 00:57:44,260
sharpness between Hubble which we've all

1382
00:57:47,370 --> 00:57:45,490
been marveling about

1383
00:57:49,830 --> 00:57:47,380
right why look at the end Rafa galaxy

1384
00:57:52,650 --> 00:57:49,840
the image sharpness between Hubble and

1385
00:57:54,930 --> 00:57:52,660
this HGST is exactly the same as between

1386
00:57:56,340 --> 00:57:54,940
the standard definition TVs and in the

1387
00:58:02,640 --> 00:57:56,350
eighties were encased in wooden boxes

1388
00:58:05,100 --> 00:58:02,650

right and the new ultra 4k HD TVs and

1389
00:58:07,530 --> 00:58:05,110
can still barely afford right it's a

1390
00:58:09,570 --> 00:58:07,540
factor of 25 and image sharpness and

1391
00:58:12,570 --> 00:58:09,580
that's going to totally revolutionize

1392
00:58:15,960 --> 00:58:12,580
the vision we have of galaxies stars and

1393
00:58:17,940 --> 00:58:15,970
everything else what I want to make this

1394
00:58:19,650 --> 00:58:17,950
very concrete so you're the great

1395
00:58:20,940 --> 00:58:19,660
postdoc here who likes to make fake

1396
00:58:22,530 --> 00:58:20,950
galaxies and compare them to real

1397
00:58:24,660 --> 00:58:22,540
galaxies and figure out what galaxies

1398
00:58:28,200 --> 00:58:24,670
are doing and he's helped me to simulate

1399
00:58:29,970 --> 00:58:28,210
a galaxy a trench of 2 so this is 10

1400
00:58:31,620 --> 00:58:29,980
billion light years away it's 10 years

1401
00:58:34,770 --> 00:58:31,630
10 million years back in time this

1402
00:58:36,810 --> 00:58:34,780
galaxies Hubble has taken pictures of

1403
00:58:38,970 --> 00:58:36,820
thousands of galaxies that look just

1404
00:58:39,720 --> 00:58:38,980
like this right this is looks like real

1405
00:58:45,330 --> 00:58:39,730
holiday

1406
00:58:47,970 --> 00:58:45,340
it's a discount see at this area if we

1407
00:58:50,750 --> 00:58:47,980
zoom in to it start forming discs you

1408
00:58:53,400 --> 00:58:50,760
really can't see much right it's a more

1409
00:58:57,210 --> 00:58:53,410
even Hubble them which is only you know

1410
00:58:59,880 --> 00:58:57,220
7 8 feet across can't make out all the

1411
00:59:01,980 --> 00:58:59,890
detail well I said janitors he's gonna

1412
00:59:04,530 --> 00:59:01,990
fly that's true I'm gonna do better it's

1413
00:59:06,390 --> 00:59:04,540

vision is sharper but it only observes

1414
00:59:07,980 --> 00:59:06,400
in the infrared it's so it's going to

1415
00:59:10,770 --> 00:59:07,990
miss a lot of the important light

1416
00:59:12,420 --> 00:59:10,780
especially the youngest stars the blue

1417
00:59:14,430 --> 00:59:12,430
starting the drama is out there those

1418
00:59:18,359 --> 00:59:14,440
are the youngest stars they can really

1419
00:59:20,580 --> 00:59:18,369
show up in the JWST image that's like

1420
00:59:22,380 --> 00:59:20,590
this so it's still even though it's a

1421
00:59:26,280 --> 00:59:22,390
sharper picture it's not capturing the

1422
00:59:28,680 --> 00:59:26,290
whole range of what there is to see but

1423
00:59:32,190 --> 00:59:28,690
this look at that compare that to this

1424
00:59:34,470 --> 00:59:32,200
right night and day that's a 12 meter

1425
00:59:39,660 --> 00:59:34,480
telescope observing the same wavelength

1426
00:59:41,520 --> 00:59:39,670
ranges so right now you're seeing

1427
00:59:43,500 --> 00:59:41,530
individual star forming regions all

1428
00:59:44,849 --> 00:59:43,510
these little blobs what used to be just

1429
00:59:46,440 --> 00:59:44,859
a blur breaks up into

1430
00:59:48,380 --> 00:59:46,450
individual star forming regions can

1431
00:59:51,450 --> 00:59:48,390
actually see what's going on there right

1432
00:59:54,210 --> 00:59:51,460
this is these are the building blocks of

1433
00:59:56,549 --> 00:59:54,220
galaxies there's another see you guys on

1434
01:00:04,819 --> 00:59:56,559
satellite galaxies pretty much gone

1435
01:00:04,829 --> 01:00:08,450
you

1436
01:00:14,570 --> 01:00:11,000
and the images from the telethia mitosis

1437
01:00:16,250 --> 01:00:14,580
so this unique spatial resolution from

1438
01:00:18,530 --> 01:00:16,260

having this enormous telescope that's 12

1439
01:00:21,080 --> 01:00:18,540
meter tall so allows us to resolve

1440
01:00:24,350 --> 01:00:21,090
things at a hundred parsecs which is 300

1441
01:00:26,840 --> 01:00:24,360
light-years everywhere in the observable

1442
01:00:33,770 --> 01:00:26,850
universe something you've never been

1443
01:00:35,420 --> 01:00:33,780
able to do before and that's not only

1444
01:00:37,370 --> 01:00:35,430
that but actually I just lied to you

1445
01:00:39,920 --> 01:00:37,380
because I said that was galaxies that's

1446
01:00:41,510 --> 01:00:39,930
true that's part of a galaxy but the

1447
01:00:44,690 --> 01:00:41,520
luminous parts of galaxies the part you

1448
01:00:47,590 --> 01:00:44,700
can see are really only a bit of the

1449
01:00:50,600 --> 01:00:47,600
story let's skip ahead there's a galaxy

1450
01:00:56,030 --> 01:00:50,610
but in fact galaxies are surrounded by

1451
01:00:57,890 --> 01:00:56,040
this very diffuse gaseous medium which

1452
01:00:59,780 --> 01:00:57,900
you can't see in images it's just it

1453
01:01:01,910 --> 01:00:59,790
just doesn't light up in star light the

1454
01:01:04,640 --> 01:01:01,920
stars aren't there but this is the fuel

1455
01:01:05,990 --> 01:01:04,650
that creates galaxies and in fact some

1456
01:01:07,190 --> 01:01:06,000
of those heavy elements the carbon

1457
01:01:09,470 --> 01:01:07,200
nitrogen and other stuff that I

1458
01:01:11,780 --> 01:01:09,480
mentioned earlier used to be out here in

1459
01:01:14,300 --> 01:01:11,790
this so-called circum galactic medium

1460
01:01:17,720 --> 01:01:14,310
and which found its way into a galaxy

1461
01:01:20,480 --> 01:01:17,730
form stars planets people told you know

1462
01:01:22,790 --> 01:01:20,490
toes and everything else and we've never

1463
01:01:25,310 --> 01:01:22,800

seen this stuff right we know it's there

1464
01:01:26,870 --> 01:01:25,320
because you can see it absorbing light

1465
01:01:29,420 --> 01:01:26,880
from the background but we can't take a

1466
01:01:31,160 --> 01:01:29,430
picture of it this Observatory will be

1467
01:01:32,600 --> 01:01:31,170
able to do that and so we'll be able to

1468
01:01:35,240 --> 01:01:32,610
see that galaxies are actually

1469
01:01:38,000 --> 01:01:35,250
surrounded by this rich medium of gas

1470
01:01:40,130 --> 01:01:38,010
that's feeding them that's receiving the

1471
01:01:42,230 --> 01:01:40,140
products of their output and moreover

1472
01:01:44,390 --> 01:01:42,240
this stuff recycles over billions of

1473
01:01:46,190 --> 01:01:44,400
years this gas goes in a galaxy forms of

1474
01:01:49,100 --> 01:01:46,200
star gets kicked out again comes back in

1475
01:01:54,950 --> 01:01:49,110
on this great recycling process and we

1476
01:01:57,200 --> 01:01:54,960
can watch that happen if we not only

1477
01:02:01,130 --> 01:01:57,210
that if that's not enough like the knife

1478
01:02:03,590 --> 01:02:01,140
salesman says but wait there's more at

1479
01:02:06,230 --> 01:02:03,600
the at the resolution that this observer

1480
01:02:10,370 --> 01:02:06,240
can achieve virtually every star in the

1481
01:02:12,790 --> 01:02:10,380
Milky Way moves okay so if you watch a

1482
01:02:16,910 --> 01:02:12,800
star and find a star to wait 10 years

1483
01:02:18,620 --> 01:02:16,920
it'll move right the the velocities we

1484
01:02:20,900 --> 01:02:18,630
can resolve with the tariff

1485
01:02:22,970 --> 01:02:20,910
are actually just kind of my ball right

1486
01:02:24,529 --> 01:02:22,980
out to the nearest stars you can detect

1487
01:02:28,339 --> 01:02:24,539
motion that's as fast as a giant

1488
01:02:30,410 --> 01:02:28,349

tortoise right 0.2 miles per hour so go

1489
01:02:32,029 --> 01:02:30,420
to the zoo like a giant for them if you

1490
01:02:34,069 --> 01:02:32,039
wait if he walked for 10 years without

1491
01:02:42,079 --> 01:02:34,079
stopping and you put it out of 10

1492
01:02:44,599 --> 01:02:42,089
parsecs and then you live them up it's a

1493
01:02:47,509 --> 01:02:44,609
really slow motion right virtually every

1494
01:02:49,700 --> 01:02:47,519
star is moving faster than that out to

1495
01:02:52,640 --> 01:02:49,710
100 parsecs up to 10 kiloparsecs which

1496
01:02:55,160 --> 01:02:52,650
encompasses the entire entire disk of

1497
01:02:58,220 --> 01:02:55,170
the Milky Way we can text up it's moving

1498
01:02:59,539 --> 01:02:58,230
as fast as a Formula one racer out to

1499
01:03:01,849 --> 01:02:59,549
the Earth's galaxy like the Andromeda

1500
01:03:03,440 --> 01:03:01,859
galaxy anything that's moving about as

1501
01:03:06,079 --> 01:03:03,450
fast as the Space Shuttle or spacecraft

1502
01:03:08,870 --> 01:03:06,089
does in orbit also detectable motion and

1503
01:03:11,509 --> 01:03:08,880
and this is amazing because it turns the

1504
01:03:13,609 --> 01:03:11,519
entire galaxy into a movie right

1505
01:03:15,950 --> 01:03:13,619
you can now study not only the static

1506
01:03:18,230 --> 01:03:15,960
universe what stuff looks like when you

1507
01:03:20,120 --> 01:03:18,240
take its picture but watch its motion

1508
01:03:22,700 --> 01:03:20,130
over time so imagine taking that

1509
01:03:24,890 --> 01:03:22,710
Andromeda image in the lobby there and

1510
01:03:27,259 --> 01:03:24,900
seeing it and seeing all the motions of

1511
01:03:29,779 --> 01:03:27,269
the stars and watching all the dynamics

1512
01:03:32,240 --> 01:03:29,789
of the stars and moving and forming over

1513
01:03:38,390 --> 01:03:32,250

time it will be possible to do all of

1514
01:03:40,430 --> 01:03:38,400
this will not only be able to do that

1515
01:03:42,620 --> 01:03:40,440
we'll be able to measure the masses of

1516
01:03:44,420 --> 01:03:42,630
stars individual masses of individual

1517
01:03:46,849 --> 01:03:44,430
stars all the way out past Andromeda

1518
01:03:48,349 --> 01:03:46,859
will be able to see stars forming in

1519
01:03:49,849 --> 01:03:48,359
environments where they currently can't

1520
01:03:52,490 --> 01:03:49,859
this is a Hubble image of the star

1521
01:03:54,200 --> 01:03:52,500
forming region called 32oz it's in our

1522
01:03:55,190 --> 01:03:54,210
one of our own satellite galaxies called

1523
01:03:58,849 --> 01:03:55,200
Magellanic Clouds

1524
01:04:00,440 --> 01:03:58,859
and Hubble sees doesn't were there Frank

1525
01:04:02,329 --> 01:04:00,450
was showing you earlier a lot of those

1526
01:04:04,759 --> 01:04:02,339
star clusters in Andromeda or just did

1527
01:04:05,720 --> 01:04:04,769
they just become a continuous blur in

1528
01:04:08,539 --> 01:04:05,730
the center because we don't have the

1529
01:04:10,099 --> 01:04:08,549
resolution to pick it out it's just he's

1530
01:04:12,470 --> 01:04:10,109
going to be able to see that breaking

1531
01:04:14,539 --> 01:04:12,480
the individual stars count them and work

1532
01:04:16,539 --> 01:04:14,549
out how they got what their masses are

1533
01:04:19,339 --> 01:04:16,549
at having either

1534
01:04:21,230 --> 01:04:19,349
finally one of my favorite products is

1535
01:04:22,560 --> 01:04:21,240
the solar system we went all the way to

1536
01:04:24,750 --> 01:04:22,570
the ends of the universe and now

1537
01:04:26,940 --> 01:04:24,760
that but this is just as much part

1538
01:04:29,370 --> 01:04:26,950

origins as anything else a lot of these

1539
01:04:30,510 --> 01:04:29,380
out of soldiers some objects when we

1540
01:04:32,310 --> 01:04:30,520
figure out what they're made of they

1541
01:04:33,780 --> 01:04:32,320
tell us what some of the oldest

1542
01:04:35,010 --> 01:04:33,790
components of the solar system are they

1543
01:04:36,690 --> 01:04:35,020
tell us how much carbon and nitrogen

1544
01:04:38,820 --> 01:04:36,700
option there was in the early solar

1545
01:04:41,070 --> 01:04:38,830
system when the earth won and they tell

1546
01:04:44,850 --> 01:04:41,080
us much about the history of our own

1547
01:04:47,940 --> 01:04:44,860
planetary system you know if you take an

1548
01:04:49,980 --> 01:04:47,950
image of Pluto with Hubble it looks like

1549
01:04:51,810 --> 01:04:49,990
that not so great

1550
01:04:54,030 --> 01:04:51,820
you can barely make out the fact that

1551
01:04:55,440 --> 01:04:54,040
it's not even a form service but if you

1552
01:04:56,760 --> 01:04:55,450
were to do it with this father you tell

1553
01:05:00,480 --> 01:04:56,770
us so suddenly you can actually see

1554
01:05:02,100 --> 01:05:00,490
service features we can resolve features

1555
01:05:04,470 --> 01:05:02,110
in the outer solar system and have the

1556
01:05:06,870 --> 01:05:04,480
orbit of Jupiter that are as large as

1557
01:05:09,510 --> 01:05:06,880
the island of Manhattan say right which

1558
01:05:11,580 --> 01:05:09,520
is pretty small twenty one of the

1559
01:05:14,280 --> 01:05:11,590
coolest things you can do is watch stuff

1560
01:05:16,410 --> 01:05:14,290
happen on the other planets so this is a

1561
01:05:18,420 --> 01:05:16,420
Hubble observation of the disk of the

1562
01:05:20,250 --> 01:05:18,430
Galilean satellite we're not going all

1563
01:05:24,120 --> 01:05:20,260

the way back to Galileo he discovered

1564
01:05:27,270 --> 01:05:24,130
this it's the ice world probably seen it

1565
01:05:29,250 --> 01:05:27,280
in how the pictures how also discovered

1566
01:05:31,890 --> 01:05:29,260
that it has divers right so those giant

1567
01:05:34,500 --> 01:05:31,900
ice plates crack open in and Jets of

1568
01:05:37,560 --> 01:05:34,510
water vapour come out this one is

1569
01:05:39,540 --> 01:05:37,570
probably about 200 kilometers tall what

1570
01:05:42,420 --> 01:05:39,550
is that 120 miles that's a pretty tall

1571
01:05:44,160 --> 01:05:42,430
geyser but we can't actually say exactly

1572
01:05:46,200 --> 01:05:44,170
how tall it is because Hubble just sees

1573
01:05:48,030 --> 01:05:46,210
a little bit of an indistinct word right

1574
01:05:50,310 --> 01:05:48,040
again it's a problem resolution you have

1575
01:05:53,100 --> 01:05:50,320
a bigger telescope so that you can see

1576
01:05:54,690 --> 01:05:53,110
the structure of those objects follow

1577
01:05:56,670 --> 01:05:54,700
over there evolution over time and learn

1578
01:05:59,160 --> 01:05:56,680
a lot about our solar system even

1579
01:06:00,660 --> 01:05:59,170
without sending the spacecraft which we

1580
01:06:03,180 --> 01:06:00,670
automate right it's great we sent

1581
01:06:05,100 --> 01:06:03,190
spacecraft out there to slip any outer

1582
01:06:06,600 --> 01:06:05,110
planets for years but you can't do that

1583
01:06:08,490 --> 01:06:06,610
for every planet you can't do it at all

1584
01:06:10,560 --> 01:06:08,500
times we have telescopes here were

1585
01:06:13,200 --> 01:06:10,570
pretty competitive with the image

1586
01:06:15,390 --> 01:06:13,210
quality so there's a lot of amazing

1587
01:06:17,940 --> 01:06:15,400
stuff you can do with this telescope

1588
01:06:21,210 --> 01:06:17,950

apart from finding life if that's not

1589
01:06:22,440 --> 01:06:21,220
enough what can I do particularly why

1590
01:06:23,050 --> 01:06:22,450
should involve other galaxies in the

1591
01:06:25,660 --> 01:06:23,060
universe

1592
01:06:27,400 --> 01:06:25,670
Kotzur better that's 300 layers can

1593
01:06:29,050 --> 01:06:27,410
detect virtually every galaxy that's

1594
01:06:30,400 --> 01:06:29,060
former stars at the epoch when our own

1595
01:06:31,690 --> 01:06:30,410
Milky Way point which means you're going

1596
01:06:34,420 --> 01:06:31,700
to see all the Milky Way these building

1597
01:06:35,590 --> 01:06:34,430
blocks and the entire history of

1598
01:06:37,540 --> 01:06:35,600
galaxies like it up through the

1599
01:06:39,010 --> 01:06:37,550
president we can observe individual

1600
01:06:40,930 --> 01:06:39,020
supernovae all the way back to the

1601
01:06:42,640 --> 01:06:40,940
beginning of the universe we can see

1602
01:06:44,890 --> 01:06:42,650
this nearly invisible gas feeding

1603
01:06:46,900 --> 01:06:44,900
galaxies and receiving their products

1604
01:06:48,730 --> 01:06:46,910
and recycling can watch the motion of

1605
01:06:54,210 --> 01:06:48,740
virtually any star we choose and a local

1606
01:07:01,450 --> 01:06:59,800
including those big models which is

1607
01:07:09,460 --> 01:07:01,460
older than it allows us to draw this

1608
01:07:10,900 --> 01:07:09,470
whole picture of cosmic birth so I just

1609
01:07:13,930 --> 01:07:10,910
want to leave you with the thought that

1610
01:07:16,710 --> 01:07:13,940
we're building on 400 years of

1611
01:07:19,090 --> 01:07:16,720
astronomical history right sorry

1612
01:07:20,860 --> 01:07:19,100
Galileo's first attempt to put a

1613
01:07:24,370 --> 01:07:20,870

telescope on the sky and figure out what

1614
01:07:25,840 --> 01:07:24,380
was there and his historical and

1615
01:07:27,610 --> 01:07:25,850
revolutionary discovery that there was a

1616
01:07:30,220 --> 01:07:27,620
world out there to know that wasn't

1617
01:07:32,380 --> 01:07:30,230
terrestrial all the way through the

1618
01:07:34,630 --> 01:07:32,390
astronomical pioneers of the last two

1619
01:07:36,790 --> 01:07:34,640
centuries through our present when we

1620
01:07:39,790 --> 01:07:36,800
started to grasp the idea that there may

1621
01:07:42,040 --> 01:07:39,800
be living planets out there and to think

1622
01:07:44,830 --> 01:07:42,050
that we're you know with 400 years of

1623
01:07:47,740 --> 01:07:44,840
this history behind us possibly only 20

1624
01:07:52,420 --> 01:07:47,750
years from discovering that life is a

1625
01:07:54,490 --> 01:07:52,430
really amazing idea to contemplate so

1626
01:07:56,800 --> 01:07:54,500
I'm excited about this I hope I've got

1627
01:07:59,050 --> 01:07:56,810
you a little bit excited about this I'd

1628
01:08:01,540 --> 01:07:59,060
like you to try and follow our progress

1629
01:08:03,130 --> 01:08:01,550
as we go along the particularly the

1630
01:08:05,020 --> 01:08:03,140
institute has a site called search for

1631
01:08:08,410 --> 01:08:05,030
life net where we post a lot of these

1632
01:08:10,120 --> 01:08:08,420
developments in this field as well as

1633
01:08:12,340 --> 01:08:10,130
some more in-depth material about this

1634
01:08:15,040 --> 01:08:12,350
particular telescope and there's the

1635
01:08:18,760 --> 01:08:15,050
usual websites for tracking what the

1636
01:08:20,110 --> 01:08:18,770
institute here is doing I hope that was

1637
01:08:47,150 --> 01:08:20,120
enjoyable and

1638
01:08:54,390 --> 01:08:52,260

I almost hide this seemed to assume but

1639
01:08:56,940 --> 01:08:54,400
we need to be in the range of where

1640
01:09:03,390 --> 01:08:56,950
there's water and so on that's right

1641
01:09:06,900 --> 01:09:03,400
even if so that we need the liquid co2

1642
01:09:08,849 --> 01:09:06,910
yeah it's true so we are making a big

1643
01:09:11,459 --> 01:09:08,859
assumption when we talk this way it's

1644
01:09:13,050 --> 01:09:11,469
you could almost you could remove that

1645
01:09:13,620 --> 01:09:13,060
assumption or you could explain that

1646
01:09:15,479 --> 01:09:13,630
assumption

1647
01:09:19,070 --> 01:09:15,489
I just taking basically everything that

1648
01:09:22,829 --> 01:09:19,080
I said when I said why I would say like

1649
01:09:29,670 --> 01:09:22,839
as we understand carbon-based water

1650
01:09:32,340 --> 01:09:29,680
dependence and person giving I'll prove

1651
01:09:34,170 --> 01:09:32,350
it it's entirely possible people who

1652
01:09:36,260 --> 01:09:34,180
studied the origins of life here on

1653
01:09:38,579 --> 01:09:36,270
earth in these very extreme environments

1654
01:09:42,050 --> 01:09:38,589
speculate that there may be independent

1655
01:09:44,400 --> 01:09:42,060
strings like that here and elsewhere so

1656
01:09:46,610 --> 01:09:44,410
it's a very good point and what I'm

1657
01:09:49,079 --> 01:09:46,620
talking about is is life that we would

1658
01:09:58,170 --> 01:09:49,089
we have at least enough in common that

1659
01:10:01,290 --> 01:09:58,180
as farmer Mason so could you two get out

1660
01:10:12,520 --> 01:10:01,300
there with this and find this life then

1661
01:10:21,490 --> 01:10:18,840
I think a pic of the song yeah right

1662
01:10:24,580 --> 01:10:21,500
you know these are these are what we

1663
01:10:30,580 --> 01:10:24,590

call flagship missions help love the

1664
01:10:33,340 --> 01:10:30,590
flagship mission and mind you they only

1665
01:10:35,710 --> 01:10:33,350
exist because stronger members and the

1666
01:10:37,690 --> 01:10:35,720
general public and Congress and every

1667
01:10:39,580 --> 01:10:37,700
administration all came to the same

1668
01:10:42,430 --> 01:10:39,590
conclusion which is to make the great

1669
01:10:44,140 --> 01:10:42,440
discoveries you have to have big gains

1670
01:10:46,330 --> 01:10:44,150
in capability and to have a good case of

1671
01:10:51,400 --> 01:10:46,340
capability you have to keep pushing the

1672
01:10:56,410 --> 01:10:51,410
technology we're variable we all are

1673
01:10:58,900 --> 01:10:56,420
that our country and our government and

1674
01:11:00,280 --> 01:10:58,910
ourselves have agreed to support clients

1675
01:11:02,320 --> 01:11:00,290
at this scale for decades

1676
01:11:06,880 --> 01:11:02,330
okay so we're talking about over its

1677
01:11:08,590 --> 01:11:06,890
lifetime the grand scheme of things that

1678
01:11:10,390 --> 01:11:08,600
doesn't add up to much when you're

1679
01:11:14,370 --> 01:11:10,400
comparing it to other things that the

1680
01:11:16,480 --> 01:11:14,380
government spends its money on right but

1681
01:11:24,100 --> 01:11:16,490
what I think you're getting out of that

1682
01:11:25,720 --> 01:11:24,110
is Nobel laureate who discovered the

1683
01:11:29,050 --> 01:11:25,730
cosmic background radiation same as

1684
01:11:30,880 --> 01:11:29,060
marbles and the 1970s he was testifying

1685
01:11:33,070 --> 01:11:30,890
before Congress he is asked by one of

1686
01:11:35,770 --> 01:11:33,080
the budget skeptics mr. Wilson in what

1687
01:11:38,290 --> 01:11:35,780
sense does your proposal zurna Tory

1688
01:11:42,280 --> 01:11:38,300

defend the country and says sorry that's

1689
01:11:47,040 --> 01:11:42,290
not what makes it work that's something

1690
01:11:57,700 --> 01:11:50,740
it's illuminating all of us all all of

1691
01:12:02,410 --> 01:11:57,710
our citizens all of you man I think and

1692
01:12:06,580 --> 01:12:02,420
you say repair that telescope it helped

1693
01:12:10,420 --> 01:12:06,590
to raise that robotic or yeah it could

1694
01:12:13,000 --> 01:12:10,430
be either it's not very well known

1695
01:12:14,710 --> 01:12:13,010
really but nASA has brought this robotic

1696
01:12:29,880 --> 01:12:14,720
servicing capability to a pretty high

1697
01:13:33,070 --> 01:13:19,000
so they on the other hand tomorrow thing

1698
01:14:00,000 --> 01:13:33,080
is unique so oxygen mask you come from

1699
01:14:04,180 --> 01:14:00,010
from a source isn't life but oxygen 13

1700
01:14:14,650 --> 01:14:04,190
both like that were little lengthy we

1701
01:14:18,770 --> 01:14:14,660
have we 10% of you know we know how many

1702
01:14:24,170 --> 01:14:21,140
as are in their own habitable zones what

1703
01:14:27,290 --> 01:14:24,180
we don't know is given the start of age

1704
01:14:29,300 --> 01:14:27,300
the energy of this planet the mass of

1705
01:14:32,570 --> 01:14:29,310
the planet the after guys we don't know

1706
01:14:35,270 --> 01:14:32,580
how a very this is control the incidence

1707
01:14:37,220 --> 01:14:35,280
of life we know that on our own earth it

1708
01:14:40,370 --> 01:14:37,230
took billions of years to get where you

1709
01:14:43,250 --> 01:14:40,380
are now right if we had observed you

1710
01:14:47,480 --> 01:14:43,260
know if you observe the earth 500

1711
01:14:51,170 --> 01:14:47,490
million years ago where the sea is so

1712
01:14:53,510 --> 01:14:51,180
it's a very subtle problem and we have

1713
01:14:56,420 --> 01:14:53,520

to be open to the fact that most of the

1714
01:15:05,030 --> 01:14:56,430
times we look at what show us see it's

1715
01:15:07,520 --> 01:15:05,040
possible to always keeping with the

1716
01:15:09,620 --> 01:15:07,530
theme of big general questions in the

1717
01:15:12,080 --> 01:15:09,630
near in the hopefully near future when

1718
01:15:13,310 --> 01:15:12,090
we have a catalogue of planets that have

1719
01:15:14,810 --> 01:15:13,320
life as we know it

1720
01:15:16,850 --> 01:15:14,820
what do you envision we might do with

1721
01:15:18,920 --> 01:15:16,860
that information for example would there

1722
01:15:21,860 --> 01:15:18,930
be a way to communicate with as planters

1723
01:15:24,050 --> 01:15:21,870
so one of the nice side benefits of

1724
01:15:26,930 --> 01:15:24,060
observing planets and find life this way

1725
01:15:28,310 --> 01:15:26,940
would be startled really close they're

1726
01:15:32,120 --> 01:15:28,320
all within about fifty to a hundred

1727
01:15:34,040 --> 01:15:32,130
parsecs which is about 150 300 light

1728
01:15:36,440 --> 01:15:34,050
years now

1729
01:15:38,180 --> 01:15:36,450
light travels at a finite velocity which

1730
01:15:40,910 --> 01:15:38,190
means that if you send the radio signal

1731
01:15:45,590 --> 01:15:40,920
it takes fifty to a hundred years to get

1732
01:15:50,250 --> 01:15:48,120
but you know it's theoretically possible

1733
01:15:52,770 --> 01:15:50,260
that you could maintain a conversation

1734
01:15:54,060 --> 01:15:52,780
over such a long time so that that's

1735
01:15:55,820 --> 01:15:54,070
talking to ETS

1736
01:15:57,450 --> 01:15:55,830
I should point out I should not be

1737
01:16:00,150 --> 01:15:57,460
over-promising and I should point out

1738
01:16:02,310 --> 01:16:00,160

you know you can find life with these by

1739
01:16:04,230 --> 01:16:02,320
numbers awesome and ozone methane and it

1740
01:16:06,330 --> 01:16:04,240
doesn't have to be you know people

1741
01:16:08,280 --> 01:16:06,340
walking on thread doesn't have to be man

1742
01:16:09,750 --> 01:16:08,290
it could be bacteria but we at least

1743
01:16:12,060 --> 01:16:09,760
know that there has been an independent

1744
01:16:16,490 --> 01:16:12,070
origin of something living on that

1745
01:16:18,960 --> 01:16:16,500
planet they could be far ahead of us

1746
01:16:21,240 --> 01:16:18,970
another thing you can do is any more

1747
01:16:22,980 --> 01:16:21,250
scientific sense is you can take the

1748
01:16:24,360 --> 01:16:22,990
plants where you see the biomarkers in

1749
01:16:26,430 --> 01:16:24,370
and then everything else you know about

1750
01:16:29,370 --> 01:16:26,440
that content in that star and you can

1751
01:16:30,930 --> 01:16:29,380
start to work out if I if I see life

1752
01:16:32,850 --> 01:16:30,940
it's a star that's older than five

1753
01:16:34,050 --> 01:16:32,860
million years and the planets so and so

1754
01:16:35,610 --> 01:16:34,060
in this orbit and it's good an

1755
01:16:37,710 --> 01:16:35,620
opportunity to start to work out the

1756
01:16:39,810 --> 01:16:37,720
factors that actually may be possible

1757
01:16:47,670 --> 01:16:39,820
and that's going to nail down they say

1758
01:16:50,400 --> 01:16:47,680
we don't know now is it conceivable that

1759
01:16:54,360 --> 01:16:50,410
there could be life like things based on

1760
01:17:07,620 --> 01:16:54,370
something other than car as I understand

1761
01:17:15,390 --> 01:17:07,630
it that is chemical that's outside but I

1762
01:17:17,850 --> 01:17:15,400
understand that is really as you look at

1763
01:17:20,040 --> 01:17:17,860

the structures you see as far out as you

1764
01:17:22,650 --> 01:17:20,050
can see and then you look at like

1765
01:17:24,630 --> 01:17:22,660
certain high-energy particle Prime's is

1766
01:17:28,950 --> 01:17:24,640
there any like relationship between the

1767
01:17:31,950 --> 01:17:28,960
two ends of the you know there's an area

1768
01:17:33,990 --> 01:17:31,960
in between where people think about the

1769
01:17:35,400 --> 01:17:34,000
cosmological consequences of particle

1770
01:17:39,180 --> 01:17:35,410
physics that the energy scales that

1771
01:17:41,460 --> 01:17:39,190
certain pros you know there are some

1772
01:17:42,640 --> 01:17:41,470
high-energy there there are theories

1773
01:17:44,530 --> 01:17:42,650
based on high-energy

1774
01:17:50,680 --> 01:17:44,540
that explained the acceleration of

1775
01:17:52,360 --> 01:17:50,690
universe there's not much bearing of

1776
01:17:56,200 --> 01:17:52,370
high-energy physics directly on the

1777
01:18:01,110 --> 01:17:56,210
question of life and so to the extent

1778
01:18:03,030 --> 01:18:01,120
that universe has to make sense of all

1779
01:18:05,950 --> 01:18:03,040
right any other questions

1780
01:18:08,860 --> 01:18:05,960
all right well Mossman does different

1781
01:18:10,990 --> 01:18:08,870
question I apologize for it but I'm so

1782
01:18:15,010 --> 01:18:11,000
interested you should have picture of

1783
01:18:18,729 --> 01:18:15,020
the Andromeda galaxy taken in 1905 yes

1784
01:18:22,540 --> 01:18:18,739
and of course the whole able to make

1785
01:18:25,030 --> 01:18:22,550
representations to be no astronomer okay

1786
01:18:30,970 --> 01:18:25,040
that was a beautiful picture would you

1787
01:18:33,580 --> 01:18:30,980
mind telling us how do you still thanks

1788
01:18:36,189 --> 01:18:33,590

to the internet I found it there is you

1789
01:18:38,620 --> 01:18:36,199
go to what the Project Gutenberg I

1790
01:18:41,439 --> 01:18:38,630
believe is where I found it it was a

1791
01:18:43,060 --> 01:18:41,449
book that was published before copyright

1792
01:18:46,840 --> 01:18:43,070
was instituted in the United States and

1793
01:18:52,899 --> 01:18:46,850
it had so it was a 1915 or something

1794
01:18:55,450 --> 01:18:52,909
book book on Natural History and it had

1795
01:19:07,120 --> 01:18:55,460
all sorts of illustrations and it did

1796
01:19:10,630 --> 01:19:07,130
have that 1901 year keys observer so I

1797
01:19:12,880 --> 01:19:10,640
just I literally do a lot of searching

1798
01:19:14,500 --> 01:19:12,890
on the internet to find find my imagery

1799
01:19:16,300 --> 01:19:14,510
and that was what I happened to find

1800
01:19:18,340 --> 01:19:16,310
because finding those old photographs

1801
01:19:20,800 --> 01:19:18,350
too compared to today's photographs is

1802
01:19:23,950 --> 01:19:20,810
very important also to show the state of

1803
01:19:29,770 --> 01:19:23,960
photography a hundred years ago 114

1804
01:19:31,959 --> 01:19:29,780
years ago was still pretty good yes bio

1805
01:19:34,149 --> 01:19:31,969
signature you're searching for right now

1806
01:19:37,510 --> 01:19:34,159
what's the level of technology we got it

1807
01:19:40,060 --> 01:19:37,520
get to is James Webb yeah Tandi closer

1808
01:19:41,709 --> 01:19:40,070
to that goal ah it does it doesn't infer

1809
01:19:43,030 --> 01:19:41,719
some fairly significant ways so the

1810
01:19:44,620 --> 01:19:43,040
thing we're learning to do with web

1811
01:19:47,020 --> 01:19:44,630
which we cross our fingers and hope

1812
01:19:48,970 --> 01:19:47,030
works is to build the telescope that's

1813
01:19:51,240 --> 01:19:48,980

larger than what fits into rockets to

1814
01:19:54,310 --> 01:19:51,250
monkeys the deployables

1815
01:19:57,310 --> 01:19:54,320
anything that big enlarger has to be

1816
01:20:00,160 --> 01:19:57,320
launched folded up and then hold itself

1817
01:20:02,140 --> 01:20:00,170
upon us so that's one thing we're

1818
01:20:04,060 --> 01:20:02,150
approving what we're projecting see

1819
01:20:06,459 --> 01:20:04,070
that's called Technology Development and

1820
01:20:06,970 --> 01:20:06,469
housing heritage that look into the next

1821
01:20:09,609 --> 01:20:06,980
day

1822
01:20:12,250 --> 01:20:09,619
but the real challenge is this 10

1823
01:20:15,010 --> 01:20:12,260
billion Bakula it's getting the star leg

1824
01:20:17,109 --> 01:20:15,020
to go away to throw okay well let's just

1825
01:20:19,180 --> 01:20:17,119
take an example right do you want we

1826
01:20:20,709 --> 01:20:19,190
want to throw out the 10 billion photons

1827
01:20:22,629 --> 01:20:20,719
the particles of light coming from the

1828
01:20:26,560 --> 01:20:22,639
star and detect the one coming from the

1829
01:20:28,030 --> 01:20:26,570
planet these planets by the way when you

1830
01:20:30,729 --> 01:20:28,040
go over token your variable in one of

1831
01:20:32,080 --> 01:20:30,739
these planets one particle one photon

1832
01:20:33,819 --> 01:20:32,090
from that planet is going to hit that

1833
01:20:37,060 --> 01:20:33,829
giant mirror as we go around every

1834
01:20:38,649 --> 01:20:37,070
second that's up there so the

1835
01:20:40,600 --> 01:20:38,659
technological challenges to be able to

1836
01:20:43,089 --> 01:20:40,610
know about the Starlight it's like

1837
01:20:45,399 --> 01:20:43,099
finding one person if you took everybody

1838
01:20:48,910 --> 01:20:45,409

on earth and trying to find one person

1839
01:20:57,370 --> 01:20:48,920
right cosmic game will Where's Waldo

1840
01:20:59,740 --> 01:20:57,380
yeah the high contrast imaging is a very

1841
01:21:02,260 --> 01:20:59,750
demanding game where you have to throw

1842
01:21:03,910 --> 01:21:02,270
out that many photons and the ones you

1843
01:21:07,479 --> 01:21:03,920
don't want these people as you want and

1844
01:21:09,069 --> 01:21:07,489
requires very exquisite thermal and

1845
01:21:12,399 --> 01:21:09,079
mechanical stability like this thing has

1846
01:21:15,220 --> 01:21:12,409
to be totally still quiet

1847
01:21:23,800 --> 01:21:15,230
and it requires optical manipulation of

1848
01:21:29,109 --> 01:21:23,810
language that actually projecting out

1849
01:21:30,790 --> 01:21:29,119
saying yeah it's working okay it's

1850
01:21:42,969 --> 01:21:30,800
nine-thirty and we usually cut off at

1851
01:21:48,850 --> 01:21:46,479
new year next month March third

1852
01:21:50,799 --> 01:21:48,860
darío Robledo a wonderful conversation