

1
00:00:00,089 --> 00:00:04,529
unless you delve into the details so I

2
00:00:02,669 --> 00:00:06,778
wasn't able to delve into the details in

3
00:00:04,528 --> 00:00:09,809
my talk last month I'll do it this month

4
00:00:06,778 --> 00:00:11,250
in the news summary so here is a let me

5
00:00:09,808 --> 00:00:13,048
go back here I'm we're gonna go into

6
00:00:11,250 --> 00:00:15,629
this region right here on the left

7
00:00:13,048 --> 00:00:17,969
pillar okay about two-thirds of the way

8
00:00:15,630 --> 00:00:21,510
down the left pillar and on the left you

9
00:00:17,969 --> 00:00:24,750
see the 1995 image and on the right you

10
00:00:21,510 --> 00:00:26,880
see the 2015 image and you can see that

11
00:00:24,750 --> 00:00:29,429
the 2015 image has twice the resolution

12
00:00:26,879 --> 00:00:32,278
we had tenth of an arcsecond resolution

13
00:00:29,428 --> 00:00:35,070
in 1995 we have a 20th of an arcsecond

14
00:00:32,279 --> 00:00:38,550
resolution in 2015 and you see it's just

15
00:00:35,070 --> 00:00:42,689
that much crisper all right one of the

16
00:00:38,549 --> 00:00:45,288
results of the 1995 scientific papers

17
00:00:42,689 --> 00:00:49,619
was that these yellow regions this

18
00:00:45,289 --> 00:00:51,780
ionization front where as thin as Hubble

19
00:00:49,619 --> 00:00:55,140
could resolve you know one of the

20
00:00:51,780 --> 00:00:57,960
results from 2015 is they are still as

21
00:00:55,140 --> 00:01:00,058
thin as Hubble can resolve these

22
00:00:57,960 --> 00:01:03,719
ionization fronts are the regions where

23
00:01:00,058 --> 00:01:06,000
the dense molecular gas turns into the

24
00:01:03,719 --> 00:01:08,129
rarefied ionized gas okay

25
00:01:06,000 --> 00:01:10,709
ionization the process where high-energy

26
00:01:08,129 --> 00:01:11,310
hits the atom and the electrons are

27
00:01:10,709 --> 00:01:13,319
removed

28
00:01:11,310 --> 00:01:15,210
that's the ionization process well you

29

00:01:13,319 --> 00:01:17,489
can see that ionization front is really

30
00:01:15,209 --> 00:01:19,739
as thin as Hubble can resolve it it's

31
00:01:17,489 --> 00:01:21,629
still below the resolution and I got to

32
00:01:19,739 --> 00:01:23,280
say in graduate school you learn that

33
00:01:21,629 --> 00:01:26,039
the transition region is really really

34
00:01:23,280 --> 00:01:28,560
thin but to see it visually is really

35
00:01:26,040 --> 00:01:32,210
kind of cool now if we look at the

36
00:01:28,560 --> 00:01:35,400
Senate that sense the central pillar in

37
00:01:32,209 --> 00:01:37,679
1995 that was done with the PC chip the

38
00:01:35,400 --> 00:01:39,960
planetary camera chip which actually had

39
00:01:37,680 --> 00:01:42,750
one twentieth of an arcsecond resolution

40
00:01:39,959 --> 00:01:44,459
all right the wif pictu had three chips

41
00:01:42,750 --> 00:01:46,618
that had tenth of an arc second

42
00:01:44,459 --> 00:01:48,569
resolution and then one ship that had

43
00:01:46,618 --> 00:01:51,780

20th of our executive resolution pixels

44

00:01:48,569 --> 00:01:54,048

were all down a smaller angle so you can

45

00:01:51,780 --> 00:01:57,118

see that some of the detail here is

46

00:01:54,049 --> 00:01:59,310

reflected here but you can see that the

47

00:01:57,118 --> 00:02:01,769

signal-to-noise the improvement in the

48

00:01:59,310 --> 00:02:04,170

detectors is a lot you can see there's a

49

00:02:01,769 --> 00:02:06,780

lot of ups let's go back a lot of noise

50

00:02:04,170 --> 00:02:08,640

in here that you just don't see in here

51

00:02:06,780 --> 00:02:11,370

so the structure that you

52

00:02:08,639 --> 00:02:14,039

is improved not just by an improvement

53

00:02:11,370 --> 00:02:16,409

in resolution but by an improvement in

54

00:02:14,039 --> 00:02:19,289

the detectors and the efficiency of

55

00:02:16,409 --> 00:02:21,719

those detectors in getting and getting

56

00:02:19,289 --> 00:02:23,699

the light from distant cosmic objects I

57

00:02:21,719 --> 00:02:35,039

also like this little object up here you

58
00:02:23,699 --> 00:02:36,750
see this top of the left pillar and the

59
00:02:35,039 --> 00:02:40,079
place where all these stars are forming

60
00:02:36,750 --> 00:02:44,009
and again on the left is 1995 on the

61
00:02:40,080 --> 00:02:46,620
right is 2015 and again just that much

62
00:02:44,009 --> 00:02:50,099
more detail looking at the structures

63
00:02:46,620 --> 00:02:52,560
that are forming so in which stars are

64
00:02:50,099 --> 00:02:55,799
forming these little fingers here these

65
00:02:52,560 --> 00:02:57,360
are places where dense objects and stars

66
00:02:55,800 --> 00:03:00,180
may be forming inside them

67
00:02:57,360 --> 00:03:02,810
now down bottom here you see this jet

68
00:03:00,180 --> 00:03:05,580
here and that is a signature of

69
00:03:02,810 --> 00:03:08,370
starvation now to call this a birth

70
00:03:05,580 --> 00:03:11,100
announcement because as a star forms

71
00:03:08,370 --> 00:03:14,430
material is flowing on streaming on to

72
00:03:11,099 --> 00:03:16,439
that star from a disc and other material

73
00:03:14,430 --> 00:03:19,530
is then flung off in these oppositely

74
00:03:16,439 --> 00:03:21,449
directed by polar Jets and you can see

75
00:03:19,530 --> 00:03:23,789
the Jets streaming out from a newborn

76
00:03:21,449 --> 00:03:25,078
star but here's where you can really see

77
00:03:23,789 --> 00:03:27,560
because I've blown this up a lot

78
00:03:25,079 --> 00:03:31,560
the resolution difference between 1995

79
00:03:27,560 --> 00:03:34,620
versus 2015 in the resolution of that

80
00:03:31,560 --> 00:03:38,239
jet the other cool thing about that jet

81
00:03:34,620 --> 00:03:40,560
is we actually saw it move the jets

82
00:03:38,239 --> 00:03:44,610
material flowing away from that newborn

83
00:03:40,560 --> 00:03:47,519
star was here in 1995 and moved to here

84
00:03:44,610 --> 00:03:49,470
in 2014 when the picture was imaging I'm

85
00:03:47,519 --> 00:03:51,689
calling it the 2015 image because we

86

00:03:49,469 --> 00:03:55,620
released it in 2015 but of course we

87
00:03:51,689 --> 00:03:59,159
took the data in 2014 so in the 19 years

88
00:03:55,620 --> 00:04:05,509
you can actually measure motion of that

89
00:03:59,159 --> 00:04:07,949
material flowing across the nebula cool

90
00:04:05,509 --> 00:04:09,750
so there are some other things of course

91
00:04:07,949 --> 00:04:11,129
that's just a comparison between those

92
00:04:09,750 --> 00:04:12,539
two images there are other things that

93
00:04:11,129 --> 00:04:15,560
are peer in this image that of course

94
00:04:12,539 --> 00:04:17,659
don't appear in the other image

95
00:04:15,560 --> 00:04:19,160
you see what the bottom of the pillars

96
00:04:17,660 --> 00:04:22,580
look like and you can see that they

97
00:04:19,160 --> 00:04:25,280
actually flow out that we talk about the

98
00:04:22,579 --> 00:04:27,859
Stars way way up here that their

99
00:04:25,279 --> 00:04:30,138
material their amazing region and winds

100
00:04:27,860 --> 00:04:33,139

are streaming down streaming across

101

00:04:30,139 --> 00:04:34,910

these pillars creating these these

102

00:04:33,139 --> 00:04:37,250

pillars but here you can see the

103

00:04:34,910 --> 00:04:39,340

material streaming down matter of fact a

104

00:04:37,250 --> 00:04:41,689

friend of mine who likes science fiction

105

00:04:39,339 --> 00:04:43,909

looked at this and said oh I know what

106

00:04:41,689 --> 00:04:49,490

that is this pillar it looks like the

107

00:04:43,910 --> 00:04:51,139

Dementors from Harry Potter gaseous

108

00:04:49,490 --> 00:04:53,930

effect that they used for the Dementors

109

00:04:51,139 --> 00:04:57,100

in Harry Potter also at the bottom you

110

00:04:53,930 --> 00:04:59,660

can see an amazing art of yellow

111

00:04:57,100 --> 00:05:00,919

ionizing emission which usually expect

112

00:04:59,660 --> 00:05:03,620

the ionizing mission to be along the

113

00:05:00,918 --> 00:05:05,359

ionization fronts I'm not exactly sure

114

00:05:03,620 --> 00:05:07,100

what this is I'm not a specialist in

115
00:05:05,360 --> 00:05:09,860
star formation but it really caught my

116
00:05:07,100 --> 00:05:12,320
eye is something cool as well as these

117
00:05:09,860 --> 00:05:15,530
tiny little pillars off in the lower

118
00:05:12,319 --> 00:05:17,769
right corner of the image our image

119
00:05:15,529 --> 00:05:20,209
processes result of a calls this mini-me

120
00:05:17,769 --> 00:05:22,430
because it looks very much like it's

121
00:05:20,209 --> 00:05:26,180
these tiny little pillars these pillars

122
00:05:22,430 --> 00:05:28,009
and things appear on all scales the

123
00:05:26,180 --> 00:05:30,500
other thing we got to do with the 2015

124
00:05:28,009 --> 00:05:33,430
image is not just do visible light but

125
00:05:30,500 --> 00:05:35,418
also do an infrared version of it

126
00:05:33,430 --> 00:05:40,430
they're kind of cool let me go back

127
00:05:35,418 --> 00:05:42,769
visible infrared all right with Y Field

128
00:05:40,430 --> 00:05:44,689
Camera 3 we have we can go into the

129
00:05:42,769 --> 00:05:46,969
infrared I put the two of them up next

130
00:05:44,689 --> 00:05:49,550
to each other you can see that there's a

131
00:05:46,970 --> 00:05:51,979
lot of correlation but a lot of

132
00:05:49,550 --> 00:05:53,509
differences between them so let's jump

133
00:05:51,978 --> 00:05:56,689
through some of those features again

134
00:05:53,509 --> 00:05:59,870
here is the visible light 2015 here is

135
00:05:56,689 --> 00:06:02,269
the infrared all right and looking at

136
00:05:59,870 --> 00:06:05,418
the detail you can still see the

137
00:06:02,269 --> 00:06:08,089
structure infrared light is longer

138
00:06:05,418 --> 00:06:10,159
wavelength it can penetrate through much

139
00:06:08,089 --> 00:06:12,199
of the gas and dust and see details

140
00:06:10,160 --> 00:06:13,910
inside but of course where you see it

141
00:06:12,199 --> 00:06:18,139
dark in the infrared that means where it

142
00:06:13,910 --> 00:06:20,960
really is these dark dense clouds go to

143

00:06:18,139 --> 00:06:23,900
the top of the central pillar here is

144
00:06:20,959 --> 00:06:26,629
that that jellyfish here you can almost

145
00:06:23,899 --> 00:06:28,219
see a little bit of it here that doesn't

146
00:06:26,629 --> 00:06:30,709
look like it's got a star forming

147
00:06:28,220 --> 00:06:33,590
inside it okay it's not a really dense

148
00:06:30,709 --> 00:06:35,419
piece but you can see some star

149
00:06:33,589 --> 00:06:37,429
formation going on in here looking down

150
00:06:35,420 --> 00:06:39,949
into the gas you can see star formation

151
00:06:37,430 --> 00:06:41,660
here which is only hinted at you can see

152
00:06:39,949 --> 00:06:46,009
one of the stars here but it's hinted at

153
00:06:41,660 --> 00:06:48,530
here on the in the visible light also if

154
00:06:46,009 --> 00:06:51,349
you go up to the upper region of the up

155
00:06:48,529 --> 00:06:54,019
top of the left pillar you can see the

156
00:06:51,350 --> 00:06:56,480
the the fingers here well the fingers

157
00:06:54,019 --> 00:06:59,629

aren't so prominent but if you look you

158

00:06:56,480 --> 00:07:02,450

can see up there you go this star

159

00:06:59,629 --> 00:07:05,269

forming place here which is not shown

160

00:07:02,449 --> 00:07:06,680

here you see the red here looking inside

161

00:07:05,269 --> 00:07:13,549

the gas you can start to see what's

162

00:07:06,680 --> 00:07:16,009

happening inside these pillars the most

163

00:07:13,550 --> 00:07:18,620

more telling views is from the larger

164

00:07:16,009 --> 00:07:20,659

point of view this is that left pillar

165

00:07:18,620 --> 00:07:23,720

which we tend to sort of think of as

166

00:07:20,660 --> 00:07:26,840

being this tall solid pillar but we

167

00:07:23,720 --> 00:07:31,490

often say it's not necessarily well look

168

00:07:26,839 --> 00:07:33,379

in the infrared what do you see here you

169

00:07:31,490 --> 00:07:35,389

can see oh you can see through the

170

00:07:33,379 --> 00:07:37,219

pillar what you're really seeing is

171

00:07:35,389 --> 00:07:39,918

you're seeing this dense gas cloud up

172
00:07:37,220 --> 00:07:41,930
here and then the shadow through here

173
00:07:39,918 --> 00:07:44,930
all of this in here is the shadow of

174
00:07:41,930 --> 00:07:47,030
this dense cloud the ionizing radiation

175
00:07:44,930 --> 00:07:50,180
isn't hitting that region so it looks

176
00:07:47,029 --> 00:07:51,918
dark when we see it an optical but when

177
00:07:50,180 --> 00:07:54,680
you look at an infrared you can see that

178
00:07:51,918 --> 00:07:57,849
the emperor has no clothes that it

179
00:07:54,680 --> 00:08:00,860
really is transparent in the infrared

180
00:07:57,850 --> 00:08:03,020
one other cool thing is that here is a

181
00:08:00,860 --> 00:08:05,780
region in optical take a look at these

182
00:08:03,019 --> 00:08:09,079
four stars here because this is the very

183
00:08:05,779 --> 00:08:12,649
same region okay and it looks like that

184
00:08:09,079 --> 00:08:15,740
and infrared okay

185
00:08:12,649 --> 00:08:18,019
these four stars here the four stars

186
00:08:15,740 --> 00:08:20,180
that you that match and these four stars

187
00:08:18,019 --> 00:08:23,000
suddenly appear out of nowhere really

188
00:08:20,180 --> 00:08:24,978
what they are is they're behind the gas

189
00:08:23,000 --> 00:08:27,769
you're seeing through the gas to see

190
00:08:24,978 --> 00:08:30,740
these you can see a lot more stars and

191
00:08:27,769 --> 00:08:32,088
stars that glow in the infrared are

192
00:08:30,740 --> 00:08:33,979
different than stars that glow and

193
00:08:32,089 --> 00:08:36,320
visible light visible light you need

194
00:08:33,979 --> 00:08:38,150
tens of thousands of degrees thousands

195
00:08:36,320 --> 00:08:40,490
to tens of thousands only a couple

196
00:08:38,149 --> 00:08:41,718
thousand degrees and stars that are like

197
00:08:40,490 --> 00:08:43,938
two thousand three thousand

198
00:08:41,719 --> 00:08:47,028
these actually glow more in the infrared

199
00:08:43,938 --> 00:08:49,759
than they do with the optical all right

200

00:08:47,028 --> 00:08:51,889
so here we had three cool images of the

201
00:08:49,759 --> 00:08:54,019
pillars of creation and just a nice

202
00:08:51,889 --> 00:08:58,879
little exploration to take a look at it

203
00:08:54,019 --> 00:09:01,730
okay so this pillar here is about three

204
00:08:58,879 --> 00:09:03,740
light years long so we take that three

205
00:09:01,730 --> 00:09:06,459
call about 6 light years top to bottom

206
00:09:03,740 --> 00:09:09,919
at the distance of the Eagle Nebula okay

207
00:09:06,458 --> 00:09:12,169
yeah kind of cool all right we got one

208
00:09:09,919 --> 00:09:14,360
more story for you which has sort of

209
00:09:12,169 --> 00:09:18,469
been preempted by our lobby display but

210
00:09:14,360 --> 00:09:21,139
I call it in your dreams Hubble okay so

211
00:09:18,470 --> 00:09:23,810
this is a picture of the great nebula in

212
00:09:21,139 --> 00:09:27,709
Andromeda I found it in a book published

213
00:09:23,809 --> 00:09:31,609
in 1915 from the Yerkes Observatory this

214
00:09:27,708 --> 00:09:35,719

was taken a September 1901 this is the

215

00:09:31,610 --> 00:09:38,930

nebula in Andromeda because we didn't

216

00:09:35,720 --> 00:09:42,050

know what it was for sure until Hubble

217

00:09:38,929 --> 00:09:46,669

came along in the 1920s so here is

218

00:09:42,049 --> 00:09:49,669

Hubble's 1923 discovery observation of a

219

00:09:46,669 --> 00:09:51,349

variable star in the Andromeda nebula as

220

00:09:49,669 --> 00:09:54,500

you can see he's got these end marks

221

00:09:51,350 --> 00:09:56,300

here looking for nove you know in in

222

00:09:54,500 --> 00:09:59,028

this in this nebula to see what he could

223

00:09:56,299 --> 00:10:01,219

see he had one mark that he thought was

224

00:09:59,028 --> 00:10:04,639

a nova and then found out no it's a

225

00:10:01,220 --> 00:10:07,790

variable star and the variable stars are

226

00:10:04,639 --> 00:10:09,799

really cool because if it's a specific

227

00:10:07,789 --> 00:10:12,828

type of variable star called a Cepheid

228

00:10:09,799 --> 00:10:15,558

variable star the period which it

229
00:10:12,828 --> 00:10:19,308
brightens and dims brightens and dims

230
00:10:15,558 --> 00:10:22,100
that timescale is proportional to its

231
00:10:19,308 --> 00:10:24,078
absolute magnitude so you can measure

232
00:10:22,100 --> 00:10:26,659
the brightening and dimming timescale

233
00:10:24,078 --> 00:10:29,028
and then know how bright that star

234
00:10:26,659 --> 00:10:31,100
really is and then once you know how

235
00:10:29,028 --> 00:10:35,299
bright it is you can measure how far

236
00:10:31,100 --> 00:10:35,960
away Andromeda is at how it will do this

237
00:10:35,299 --> 00:10:39,259
in 19

238
00:10:35,960 --> 00:10:41,840
three and set the stage that it is not a

239
00:10:39,259 --> 00:10:44,569
nebula but it is a galaxy unto itself

240
00:10:41,840 --> 00:10:45,889
that this nebula is definitely outside

241
00:10:44,570 --> 00:10:49,610
of our galaxy

242
00:10:45,889 --> 00:10:52,069
well Hubble's namesake telescope looked

243
00:10:49,610 --> 00:10:54,740
at that exact same star we called it

244
00:10:52,070 --> 00:10:59,360
Hubble variable one and got images like

245
00:10:54,740 --> 00:11:01,930
this so these are four images of HV one

246
00:10:59,360 --> 00:11:05,990
over the course of December to January

247
00:11:01,929 --> 00:11:09,129
2010 2011 and if we put these in motion

248
00:11:05,990 --> 00:11:16,009
this is an animated gif you can see it

249
00:11:09,129 --> 00:11:19,149
brightening and dimming so the star that

250
00:11:16,009 --> 00:11:23,360
changed the universe but you can see

251
00:11:19,149 --> 00:11:30,319
that Hubble can see what Hubble could

252
00:11:23,360 --> 00:11:32,300
only dream of called the stellar Deep

253
00:11:30,320 --> 00:11:34,670
Field when the advanced camera for

254
00:11:32,299 --> 00:11:38,209
surveys was was brand-new on Hubble you

255
00:11:34,669 --> 00:11:41,149
can see this amazing image and if i zoom

256
00:11:38,210 --> 00:11:44,180
into it to show you the detail that star

257

00:11:41,149 --> 00:11:48,730
is in our Milky Way galaxy and every

258
00:11:44,179 --> 00:11:52,519
other star is in the Andromeda galaxy

259
00:11:48,730 --> 00:11:54,950
examining star field in another galaxy

260
00:11:52,519 --> 00:11:59,449
not just our fields but this is a

261
00:11:54,950 --> 00:12:01,009
globular star cluster in Andromeda not

262
00:11:59,450 --> 00:12:03,650
in the Milky Way look at the kind of

263
00:12:01,009 --> 00:12:08,450
resolution Hubble can get but we can

264
00:12:03,649 --> 00:12:12,350
still do better because this image was

265
00:12:08,450 --> 00:12:14,720
taken way out here way far away from the

266
00:12:12,350 --> 00:12:15,590
disk of Andromeda this is out and called

267
00:12:14,720 --> 00:12:18,410
what we call

268
00:12:15,590 --> 00:12:21,200
Andromeda's halo studying the Stars and

269
00:12:18,409 --> 00:12:24,350
Andromeda's halo and so what we just

270
00:12:21,200 --> 00:12:27,290
completed is something called the fad

271
00:12:24,350 --> 00:12:29,570

survey the pan chromatic Hubble

272

00:12:27,289 --> 00:12:33,459

Andromeda Treasury program which has

273

00:12:29,570 --> 00:12:35,950

looked at the main disk of Andromeda in

274

00:12:33,460 --> 00:12:39,769

excruciating detail

275

00:12:35,950 --> 00:12:41,240

amazing detail incredible detail that

276

00:12:39,769 --> 00:12:44,449

looks like this

277

00:12:41,240 --> 00:12:46,460

okay so this is the Hubble image and you

278

00:12:44,450 --> 00:12:48,020

see the jaggies here these are the

279

00:12:46,460 --> 00:12:49,370

footprints of Hubble these are the

280

00:12:48,019 --> 00:12:52,549

pointings of Hubble

281

00:12:49,370 --> 00:12:54,769

- I'm Capri fully appreciate this scale

282

00:12:52,549 --> 00:12:56,778

of this image you recognize that this is

283

00:12:54,769 --> 00:13:00,139

a hunt over a hundred thousand pixels

284

00:12:56,778 --> 00:13:03,500

across here it's about thirty thousand

285

00:13:00,139 --> 00:13:07,669

pixels high it's several billion pixels

286
00:13:03,500 --> 00:13:09,409
total they did 411 different pointings

287
00:13:07,669 --> 00:13:12,919
of Hubble seven thousand three hundred

288
00:13:09,409 --> 00:13:16,429
ninety eight exposures over three years

289
00:13:12,919 --> 00:13:18,199
to cover basically half of the disk of

290
00:13:16,429 --> 00:13:20,239
Andromeda well actually it's about a

291
00:13:18,200 --> 00:13:24,170
third if you can consider the whole

292
00:13:20,240 --> 00:13:27,500
thing really the largest image composite

293
00:13:24,169 --> 00:13:29,449
image that Hubble has ever produced now

294
00:13:27,500 --> 00:13:31,580
I'm gonna take you in to show you some

295
00:13:29,450 --> 00:13:36,200
of the details of it and so this is

296
00:13:31,580 --> 00:13:37,639
gonna be at okay I can't do the full

297
00:13:36,200 --> 00:13:39,560
resolution it's too big an image for me

298
00:13:37,639 --> 00:13:42,169
you but this is gonna be at one-quarter

299
00:13:39,559 --> 00:13:45,019
resolution all right here so if we go

300
00:13:42,169 --> 00:13:47,269
into the center of the galaxy you can

301
00:13:45,019 --> 00:13:49,490
see this is the core of the galaxy and

302
00:13:47,269 --> 00:13:51,528
all the things and it's so blown out

303
00:13:49,490 --> 00:13:52,909
there are so many stars in here you

304
00:13:51,528 --> 00:13:56,689
can't really see them but if you see

305
00:13:52,909 --> 00:13:59,208
these white dots those are star clusters

306
00:13:56,690 --> 00:14:02,180
those aren't individual stars those are

307
00:13:59,208 --> 00:14:04,699
star clusters if we move a bit further

308
00:14:02,179 --> 00:14:07,699
out where we have the dark gas and dust

309
00:14:04,700 --> 00:14:10,490
you can see the dust lanes and things

310
00:14:07,700 --> 00:14:13,009
again these are star clusters and the

311
00:14:10,490 --> 00:14:14,509
individual stars are well at the

312
00:14:13,009 --> 00:14:16,850
resolution this projector they're still

313
00:14:14,509 --> 00:14:17,299
too small to see all right we'll get

314

00:14:16,850 --> 00:14:19,459
there

315
00:14:17,299 --> 00:14:22,639
I have something at the very end we get

316
00:14:19,458 --> 00:14:25,069
up to the star forming regions all the

317
00:14:22,639 --> 00:14:28,399
blue stars you see here these are

318
00:14:25,070 --> 00:14:29,810
newborn stars again the bigger ones are

319
00:14:28,399 --> 00:14:33,199
star clusters some of them might be

320
00:14:29,809 --> 00:14:34,939
stars in our own galaxy again seeing the

321
00:14:33,200 --> 00:14:36,800
the star clusters and if you get out to

322
00:14:34,940 --> 00:14:39,350
the really really edge well beyond

323
00:14:36,799 --> 00:14:41,059
almost the visible disc of it you can

324
00:14:39,350 --> 00:14:44,200
still see that there are still a

325
00:14:41,059 --> 00:14:48,769
tremendous number of stars out there

326
00:14:44,200 --> 00:14:51,350
viewing stars in Andromeda over 100

327
00:14:48,769 --> 00:14:53,689
million stars I believe the number that

328
00:14:51,350 --> 00:14:56,149

they quote is around 170 million hunt

329

00:14:53,690 --> 00:14:59,320

stars that they have cataloged here in

330

00:14:56,149 --> 00:15:03,259

this in this full image from Andromeda

331

00:14:59,320 --> 00:15:04,760

amazing detail to see so to show

332

00:15:03,259 --> 00:15:06,799

what you're looking at here we made it

333

00:15:04,759 --> 00:15:08,360

we made this image here to show okay

334

00:15:06,799 --> 00:15:11,059

we've got these dust lanes we've got

335

00:15:08,360 --> 00:15:13,159

these star clusters you can even see

336

00:15:11,059 --> 00:15:15,379

background galaxies through the disk of

337

00:15:13,159 --> 00:15:18,919

Andromeda some of the brighter stars

338

00:15:15,379 --> 00:15:21,080

will be Milky Way stars and over here we

339

00:15:18,919 --> 00:15:23,089

have a star for a region again more

340

00:15:21,080 --> 00:15:24,850

stellar clusters and dust lanes but you

341

00:15:23,090 --> 00:15:27,139

see those words star forming region

342

00:15:24,850 --> 00:15:31,159

we're going to go into those at full

343
00:15:27,139 --> 00:15:33,230
resolution and you can start finally

344
00:15:31,159 --> 00:15:36,110
start to see the stars this is the one

345
00:15:33,230 --> 00:15:37,220
that actually is full resolution at the

346
00:15:36,110 --> 00:15:38,779
full thing and not the quarter

347
00:15:37,220 --> 00:15:40,970
resolution I was able to show you in the

348
00:15:38,779 --> 00:15:44,779
previous images but the full resolution

349
00:15:40,970 --> 00:15:48,259
to see the amazing detail of the

350
00:15:44,779 --> 00:15:50,209
structure in Andromeda and if you didn't

351
00:15:48,259 --> 00:15:53,240
notice it on your way in if you go out

352
00:15:50,210 --> 00:15:55,820
that door we have the mosaic up there of

353
00:15:53,240 --> 00:15:57,620
the cropped image for you to look at and

354
00:15:55,820 --> 00:16:00,260
see the hundreds of hundred million

355
00:15:57,620 --> 00:16:02,330
stars in Andromeda for you just have a

356
00:16:00,259 --> 00:16:05,330
look at it's only gonna be here tonight

357
00:16:02,330 --> 00:16:07,940
okay that that mosaic isn't a permanent

358
00:16:05,330 --> 00:16:09,530
display here you just happen to come on

359
00:16:07,940 --> 00:16:13,100
the right night and when we get to see

360
00:16:09,529 --> 00:16:15,319
that okay all right so that is our news

361
00:16:13,100 --> 00:16:17,060
summary I went on a little bit long but

362
00:16:15,320 --> 00:16:21,140
you can see we had two really really

363
00:16:17,059 --> 00:16:28,429
cool things to talk about today all

364
00:16:21,139 --> 00:16:30,769
right so so our speaker tonight is dr.

365
00:16:28,429 --> 00:16:34,099
Jason Tomlinson also of the Space

366
00:16:30,769 --> 00:16:40,129
Telescope Science Institute I forgot to

367
00:16:34,100 --> 00:16:42,440
get his resume but I'd have a because

368
00:16:40,129 --> 00:16:46,580
they know you're fantastic and wonderful

369
00:16:42,440 --> 00:16:53,180
wonderful guy he's been here what ten

370
00:16:46,580 --> 00:16:53,570
years now and he was going to talk to us

371

00:16:53,179 --> 00:16:56,269
tonight

372
00:16:53,570 --> 00:16:58,250
about the future of space astronomy and

373
00:16:56,269 --> 00:16:59,659
the amazing new things that were going

374
00:16:58,250 --> 00:17:02,090
to be able to do over the next couple

375
00:16:59,659 --> 00:17:04,569
decades ladies and gentlemen dr. Jason

376
00:17:02,090 --> 00:17:04,569
Tomlinson

377
00:17:31,539 --> 00:17:38,960
alright I'm gonna try to make up in

378
00:17:36,380 --> 00:17:42,280
long-term vision what I lack in

379
00:17:38,960 --> 00:17:45,769
enthusiasm with respect to my color

380
00:17:42,279 --> 00:17:49,399
she's a tough act to follow but I want

381
00:17:45,769 --> 00:17:53,420
to spend about 45 minutes here telling

382
00:17:49,400 --> 00:17:55,610
you about something so it's the last 300

383
00:17:53,420 --> 00:17:57,080
years of astronomy and x-ray where we've

384
00:17:55,609 --> 00:18:01,119
been where are we going in terms of the

385
00:17:57,079 --> 00:18:03,439

biggest questions we can possibly ask

386

00:18:01,119 --> 00:18:04,729

well astronomy asking questions

387

00:18:03,440 --> 00:18:07,340

naturally we're thinking about the big

388

00:18:04,730 --> 00:18:09,890

things right asking big questions I'm

389

00:18:07,339 --> 00:18:12,849

going to talk about two particular where

390

00:18:09,890 --> 00:18:16,250

did it become from and are we alone now

391

00:18:12,849 --> 00:18:20,240

this is more general bigger than just

392

00:18:16,250 --> 00:18:22,400

how to galaxies form planets form these

393

00:18:20,240 --> 00:18:23,930

are really these our civilization will

394

00:18:22,400 --> 00:18:26,660

skate all questions these go back

395

00:18:23,930 --> 00:18:30,380

forever right and then probably go far

396

00:18:26,660 --> 00:18:32,120

into the future these are questions that

397

00:18:30,380 --> 00:18:33,530

were have been asked as long as people

398

00:18:32,119 --> 00:18:35,929

have been doing in astronomy

399

00:18:33,529 --> 00:18:38,629

of course naked-eye astronomy started as

400
00:18:35,930 --> 00:18:41,029
soon as the first caveman looked up into

401
00:18:38,630 --> 00:18:43,670
the sky but telescopic astronomy using

402
00:18:41,029 --> 00:18:46,879
actual telescopes and lessons began with

403
00:18:43,670 --> 00:18:48,560
galileo galilei officially in 1609 here

404
00:18:46,880 --> 00:18:51,490
he is demonstrating his little telescope

405
00:18:48,559 --> 00:18:53,929
for the dirty events in that year and

406
00:18:51,490 --> 00:18:57,700
one of the things that got away was

407
00:18:53,930 --> 00:19:00,019
famous for discovering among his many

408
00:18:57,700 --> 00:19:01,470
epic making discoveries was the

409
00:19:00,019 --> 00:19:03,058
satellites of the planet

410
00:19:01,470 --> 00:19:08,659
so there's Jupiter and their support

411
00:19:03,058 --> 00:19:11,460
Galilean satellites we call them and

412
00:19:08,659 --> 00:19:14,820
this was really neat piece of evidence

413
00:19:11,460 --> 00:19:15,840
that convinced people in Europe and the

414
00:19:14,819 --> 00:19:17,668
Renaissance and then eventually

415
00:19:15,839 --> 00:19:20,730
worldwide that there was a whole world

416
00:19:17,669 --> 00:19:23,309
out there and on the earth it was not

417
00:19:20,730 --> 00:19:26,639
merely terrestrial it wasn't just human

418
00:19:23,308 --> 00:19:28,408
it was this otherworldly universe out

419
00:19:26,638 --> 00:19:31,408
there that we could actually learn

420
00:19:28,409 --> 00:19:34,559
something about I told you this is going

421
00:19:31,409 --> 00:19:37,740
to be a fast issue skip ahead by more

422
00:19:34,558 --> 00:19:40,648
than 100 years now I chose to illustrate

423
00:19:37,740 --> 00:19:42,298
the next advance with a brother and

424
00:19:40,648 --> 00:19:45,329
sister team named the Herschel's William

425
00:19:42,298 --> 00:19:46,769
Caroline Herschel they fight by the time

426
00:19:45,329 --> 00:19:50,128
of rehearsals they were building

427
00:19:46,769 --> 00:19:52,919
reflecting telescopes actually meant to

428

00:19:50,128 --> 00:19:54,990
buy view but will universities

429
00:19:52,919 --> 00:19:57,720
supporting an aperture with this big

430
00:19:54,990 --> 00:20:00,028
rotating apparatus pointed it around

431
00:19:57,720 --> 00:20:03,319
with the sky the persons were famous for

432
00:20:00,028 --> 00:20:03,319
having discovered the planet Neptune

433
00:20:03,378 --> 00:20:09,178
this is way too personal is drawing he

434
00:20:07,288 --> 00:20:12,089
thought the Milky Way must galaxy must

435
00:20:09,179 --> 00:20:13,649
look like from looking at the band of

436
00:20:12,089 --> 00:20:15,000
stars on the sky and trying to figure

437
00:20:13,648 --> 00:20:17,489
out how they would look if we weren't

438
00:20:15,000 --> 00:20:19,740
leaving excited it's not that bad I

439
00:20:17,490 --> 00:20:22,470
think you can compare personal image of

440
00:20:19,740 --> 00:20:24,210
disc galaxies with Hubble's image of a

441
00:20:22,470 --> 00:20:25,409
disc out see the lobby didn't see that

442
00:20:24,210 --> 00:20:28,879

you know he was doing pretty well for

443

00:20:25,409 --> 00:20:28,879

his time but he can do much better

444

00:20:29,599 --> 00:20:34,349

there's a whole lot of technique of

445

00:20:31,769 --> 00:20:36,058

astronomical observation which becomes

446

00:20:34,349 --> 00:20:38,250

absolutely critical a little bit later

447

00:20:36,058 --> 00:20:40,829

so I want to introduce it rather early

448

00:20:38,250 --> 00:20:42,869

that's called spectroscopy you can made

449

00:20:40,829 --> 00:20:45,449

me imagine what this is there's Newton

450

00:20:42,869 --> 00:20:46,528

with his president all right everybody's

451

00:20:45,450 --> 00:20:48,600

played with a prism when they were a kid

452

00:20:46,528 --> 00:20:52,079

or something yeah you hold a prism up to

453

00:20:48,599 --> 00:20:54,028

sunlight what do you get a rainbow right

454

00:20:52,079 --> 00:20:57,449

why'd you give red orange yellow on

455

00:20:54,028 --> 00:20:59,849

someone that is the fundamental

456

00:20:57,450 --> 00:21:01,029

technique that we still use today I use

457
00:20:59,849 --> 00:21:02,649
it in my daily life

458
00:21:01,029 --> 00:21:04,839
Shondra to figure out what stuff is made

459
00:21:02,650 --> 00:21:06,850
and the reason is if you take a spectrum

460
00:21:04,839 --> 00:21:09,179
like this this is essentially the same

461
00:21:06,849 --> 00:21:11,619
kind of measurement as Newton's prism

462
00:21:09,180 --> 00:21:13,450
if you take a spectrum like this or like

463
00:21:11,619 --> 00:21:15,099
this is one of the first that existed by

464
00:21:13,450 --> 00:21:17,559
the Germans trying out for a kickoff in

465
00:21:15,099 --> 00:21:19,509
the eighteen hundreds you can look for

466
00:21:17,559 --> 00:21:20,799
these lines see these lines this is a

467
00:21:19,509 --> 00:21:21,609
solar spectrum and if you see these

468
00:21:20,799 --> 00:21:24,159
lines

469
00:21:21,609 --> 00:21:26,500
that's absorption that's an atom of a

470
00:21:24,160 --> 00:21:28,720
particular kind in that environment

471
00:21:26,500 --> 00:21:30,789
absorbing light so the light doesn't get

472
00:21:28,720 --> 00:21:32,650
to you this is the light that comes out

473
00:21:30,789 --> 00:21:35,829
of the Sun that's the ultraviolet the

474
00:21:32,650 --> 00:21:37,750
blue the green yellow orange and red but

475
00:21:35,829 --> 00:21:40,029
where it's absorbed the spectrum goes

476
00:21:37,750 --> 00:21:41,680
black and that's the way that's for

477
00:21:40,029 --> 00:21:43,480
instance how we know that the Sun is

478
00:21:41,680 --> 00:21:48,670
made of hydrogen and helium has some

479
00:21:43,480 --> 00:21:50,349
higher carbon spectroscopy is the way

480
00:21:48,670 --> 00:21:51,850
that we do the physics side of

481
00:21:50,349 --> 00:21:55,629
astrophysics we figure out what stuff's

482
00:21:51,849 --> 00:22:02,859
made out with dynamics are from taking

483
00:21:55,630 --> 00:22:07,780
these okay forward into the 1920s this

484
00:22:02,859 --> 00:22:09,579
is Edwin Hubble himself and he use this

485

00:22:07,779 --> 00:22:13,379
hustle here at Mount Wilson which is a

486
00:22:09,579 --> 00:22:16,240
hundred to do what he's famous for which

487
00:22:13,380 --> 00:22:17,680
which Frank just mentioned which is to

488
00:22:16,240 --> 00:22:20,259
measure the expansion rate of the

489
00:22:17,680 --> 00:22:22,480
universe now he did that by observing

490
00:22:20,259 --> 00:22:23,980
exactly the stars some of the stars that

491
00:22:22,480 --> 00:22:27,700
Frank mentioned that the Hubble variable

492
00:22:23,980 --> 00:22:30,069
stars if he knew how fast and they

493
00:22:27,700 --> 00:22:32,740
brightened and Dimond he could work out

494
00:22:30,069 --> 00:22:34,329
the distance using spectroscopy he could

495
00:22:32,740 --> 00:22:37,390
work out their velocity by measuring

496
00:22:34,329 --> 00:22:39,460
what's called the redshift as an object

497
00:22:37,390 --> 00:22:40,950
recede from us it gets redder as it

498
00:22:39,460 --> 00:22:43,480
moves towards the sixth floor

499
00:22:40,950 --> 00:22:45,130

Hubble was able to take redshift and

500

00:22:43,480 --> 00:22:47,710

distance and work out that the entire

501

00:22:45,130 --> 00:22:50,740

universe was expanding that's why he's

502

00:22:47,710 --> 00:22:55,090

as famous as he is that's why we named

503

00:22:50,740 --> 00:22:59,109

our first stays tall so back here we are

504

00:22:55,089 --> 00:23:00,609

this is hung this is a outdated version

505

00:22:59,109 --> 00:23:03,069

of what you just saw it when I see a

506

00:23:00,609 --> 00:23:06,909

thunder but here's how about doing its

507

00:23:03,069 --> 00:23:09,220

thing this is the Ultra Deep Field taken

508

00:23:06,910 --> 00:23:10,960

with Hubble's advanced

509

00:23:09,220 --> 00:23:12,700

for surveys there's thousands of

510

00:23:10,960 --> 00:23:14,230

galaxies in there I think this one right

511

00:23:12,700 --> 00:23:15,669

here that's the only object in the field

512

00:23:14,230 --> 00:23:19,089

that's a star everything else is a

513

00:23:15,669 --> 00:23:21,788

galaxy this is today the deepest picture

514
00:23:19,089 --> 00:23:26,769
of the universe that's a and therefore

515
00:23:21,788 --> 00:23:29,769
anybody has ever taken so that brings us

516
00:23:26,769 --> 00:23:32,529
up to almost the present time we figured

517
00:23:29,769 --> 00:23:33,908
out how to we figured out first of all

518
00:23:32,529 --> 00:23:35,349
you know thanks to Galileo that there

519
00:23:33,909 --> 00:23:38,200
was a universe out there to learn about

520
00:23:35,349 --> 00:23:41,109
but what interests really we figured out

521
00:23:38,200 --> 00:23:42,880
that we could discover objects beyond

522
00:23:41,109 --> 00:23:44,349
what the naked eye or even small

523
00:23:42,880 --> 00:23:46,600
telescopes could see we can see the

524
00:23:44,349 --> 00:23:49,509
outer planets we could see parts of our

525
00:23:46,599 --> 00:23:51,038
own galaxy that we within Hubble showed

526
00:23:49,509 --> 00:23:53,890
us that the universe has a cosmology

527
00:23:51,038 --> 00:23:56,470
that it has a dynamic all of its own

528
00:23:53,890 --> 00:23:58,179
that it's expanding that there's there's

529
00:23:56,470 --> 00:24:00,279
a history to the universe that it had a

530
00:23:58,179 --> 00:24:01,960
beginning point it hasn't always been

531
00:24:00,279 --> 00:24:03,970
here all of those things flow from

532
00:24:01,960 --> 00:24:07,600
Hubble's discovery the expansion

533
00:24:03,970 --> 00:24:09,788
universe and probably the most epic

534
00:24:07,599 --> 00:24:11,709
making or significant from the

535
00:24:09,788 --> 00:24:14,288
historical point of view discovery in

536
00:24:11,710 --> 00:24:16,058
our lifetimes has been the discovery

537
00:24:14,288 --> 00:24:19,450
that there are planets orbiting other

538
00:24:16,058 --> 00:24:22,269
stars in our own galaxy this was came

539
00:24:19,450 --> 00:24:24,100
around 1995 or the first discovery of

540
00:24:22,269 --> 00:24:27,579
what's called an exoplanet a planet

541
00:24:24,099 --> 00:24:34,918
around another star by a Swiss group of

542

00:24:27,579 --> 00:24:37,089
astronomers using the telescope and

543
00:24:34,919 --> 00:24:39,429
what's really important about this is

544
00:24:37,089 --> 00:24:41,439
that they use this same technique that I

545
00:24:39,429 --> 00:24:42,700
introduce spectroscopy right so let's go

546
00:24:41,440 --> 00:24:45,220
through this a little bit of detail just

547
00:24:42,700 --> 00:24:49,480
to show you how it works here we have a

548
00:24:45,220 --> 00:24:51,130
star and a planet our planet and the

549
00:24:49,480 --> 00:24:53,470
starting to plan orbit their common

550
00:24:51,130 --> 00:24:55,990
center of gravity that's one of Newton's

551
00:24:53,470 --> 00:24:58,690
laws of gravitation is that any two

552
00:24:55,990 --> 00:25:00,190
objects orbiting will orbit at their

553
00:24:58,690 --> 00:25:01,840
common center of gravity that means the

554
00:25:00,190 --> 00:25:03,669
star even though you think you think

555
00:25:01,839 --> 00:25:05,769
we're nearly the planets or even star

556
00:25:03,669 --> 00:25:07,960

the Stars fixed and the planet moves but

557

00:25:05,769 --> 00:25:10,179

it's not quite that way the star has a

558

00:25:07,960 --> 00:25:11,740

reflex motion it moves a little bit in

559

00:25:10,179 --> 00:25:13,840

response to the gravitational force of

560

00:25:11,740 --> 00:25:16,579

the planet so the star wobbles back and

561

00:25:13,839 --> 00:25:18,019

forth just a little bit and

562

00:25:16,579 --> 00:25:19,939

illustrated here in the fact that there

563

00:25:18,019 --> 00:25:21,319

are two pictures of these stars when

564

00:25:19,940 --> 00:25:22,788

it's the stars are moving toward the

565

00:25:21,319 --> 00:25:24,710

earth just a little bit the light gets

566

00:25:22,788 --> 00:25:26,240

slightly blue shifted and when we start

567

00:25:24,710 --> 00:25:28,069

moving away from the earth just a little

568

00:25:26,240 --> 00:25:29,870

bit it gets slightly red shifted and so

569

00:25:28,069 --> 00:25:32,599

by watching the Stars wobble back and

570

00:25:29,869 --> 00:25:33,768

forth just like this these astronomers

571
00:25:32,599 --> 00:25:35,719
were able to prove that there was a

572
00:25:33,769 --> 00:25:37,399
planet there totally we couldn't we

573
00:25:35,720 --> 00:25:39,110
still can't see that planet we can't

574
00:25:37,398 --> 00:25:41,119
take a picture of that planet yet that's

575
00:25:39,109 --> 00:25:42,408
what we're trip driving in but you can

576
00:25:41,119 --> 00:25:44,298
prove that the planets there by

577
00:25:42,409 --> 00:25:46,820
measuring the motion of the star that's

578
00:25:44,298 --> 00:25:50,329
gravitationally introduced by a planet

579
00:25:46,819 --> 00:25:53,089
that was that that was a the greatest

580
00:25:50,329 --> 00:25:55,250
discovery astronomical discovery of my

581
00:25:53,089 --> 00:25:56,599
lifetime arguably people would tell you

582
00:25:55,250 --> 00:25:58,339
that the acceleration of the expansion

583
00:25:56,599 --> 00:25:59,990
of the universe is equally important

584
00:25:58,339 --> 00:26:02,089
there's a Nobel Prize for it up in

585
00:25:59,990 --> 00:26:08,240
lobbying but I think this one's you know

586
00:26:02,089 --> 00:26:10,609
right up there and this has kicked off a

587
00:26:08,240 --> 00:26:13,519
whole revolution in the way astronomers

588
00:26:10,609 --> 00:26:14,959
think about our field in the way I think

589
00:26:13,519 --> 00:26:16,909
the public thinks about our field

590
00:26:14,960 --> 00:26:18,500
because this is addressing some of the

591
00:26:16,909 --> 00:26:25,010
deepest questions that we can address

592
00:26:18,500 --> 00:26:28,548
like I said you know are we long so

593
00:26:25,009 --> 00:26:30,349
right now that was the last 300 years

594
00:26:28,548 --> 00:26:32,359
I'm going to talk a little bit about the

595
00:26:30,349 --> 00:26:33,949
presence in the next five to ten years

596
00:26:32,359 --> 00:26:35,388
and then I'm going to tell you what we

597
00:26:33,950 --> 00:26:39,889
see coming down twenty or thirty years

598
00:26:35,388 --> 00:26:41,719
from now it happens that we're all

599

00:26:39,888 --> 00:26:44,990
fortunate to live in what really is a

600
00:26:41,720 --> 00:26:48,230
Golden Age of astronomy and the reason

601
00:26:44,990 --> 00:26:50,120
for that is that that funding agencies

602
00:26:48,230 --> 00:26:52,808
and the public have bestowed on

603
00:26:50,119 --> 00:26:55,788
astronomers an incredibly rich array of

604
00:26:52,808 --> 00:26:58,069
frontline instrumentation you know the

605
00:26:55,788 --> 00:26:59,048
kinds of things that were far far beyond

606
00:26:58,069 --> 00:27:01,509
the imagination

607
00:26:59,048 --> 00:27:03,579
those early astronomers even even how

608
00:27:01,509 --> 00:27:05,499
who lived in the 20th century there's

609
00:27:03,579 --> 00:27:07,329
the giant space telescope named after

610
00:27:05,499 --> 00:27:08,889
him there's the kepler observatory that

611
00:27:07,329 --> 00:27:11,678
he looks for planets I'll say more about

612
00:27:08,888 --> 00:27:13,569
that later the Chandra x-ray Observatory

613
00:27:11,679 --> 00:27:17,320

this is a unique satellite called

614

00:27:13,569 --> 00:27:20,288
alright beauty gallops there's the

615

00:27:17,319 --> 00:27:22,569
spitzer space telescope which is still

616

00:27:20,288 --> 00:27:24,158
going after about 11 years as an

617

00:27:22,569 --> 00:27:27,368
infrared Space Telescope there's the

618

00:27:24,159 --> 00:27:30,610
European personal mission there's a huge

619

00:27:27,368 --> 00:27:32,378
number of 8 to 10 meter telescopes on

620

00:27:30,609 --> 00:27:34,748
the ground the Very Large Telescope the

621

00:27:32,378 --> 00:27:36,248
Keck Observatory we have lots of radio

622

00:27:34,749 --> 00:27:38,639
facilities like the Very Large Array

623

00:27:36,249 --> 00:27:41,858
when you add all these things together

624

00:27:38,638 --> 00:27:44,138
you can see you've probably seen since

625

00:27:41,858 --> 00:27:46,239
you're all probably you know hanging a

626

00:27:44,138 --> 00:27:47,678
bit of attention to this you can see the

627

00:27:46,239 --> 00:27:50,108
discoveries of these things come

628
00:27:47,679 --> 00:27:52,679
together and mix and teaches new things

629
00:27:50,108 --> 00:27:55,058
on a daily basis we really live in a

630
00:27:52,679 --> 00:27:59,919
real revolutionary period for astronomy

631
00:27:55,058 --> 00:28:01,778
and we're fortunate to do that I would

632
00:27:59,919 --> 00:28:04,570
like to be able to spend 10 or 15

633
00:28:01,778 --> 00:28:07,058
minutes telling you about why everything

634
00:28:04,569 --> 00:28:08,589
that Hubble has done that awesome it

635
00:28:07,058 --> 00:28:11,108
would take me a lot longer than 10 or 15

636
00:28:08,589 --> 00:28:12,519
minutes to get through all that but what

637
00:28:11,108 --> 00:28:14,079
I think I would do I will do instead of

638
00:28:12,519 --> 00:28:16,149
that is just point out the fact that

639
00:28:14,079 --> 00:28:20,408
Hubble is turning 25 years old this year

640
00:28:16,148 --> 00:28:22,988
and that's amazing for any space

641
00:28:20,409 --> 00:28:24,369
satellite of any kind the fact that

642
00:28:22,989 --> 00:28:26,590
we've managed to keep Hubble while

643
00:28:24,368 --> 00:28:28,058
operating as a an observatory for that

644
00:28:26,589 --> 00:28:30,308
long and not only that would make it

645
00:28:28,058 --> 00:28:33,249
better every five years thanks to the

646
00:28:30,308 --> 00:28:35,888
human servicing has made it by far the

647
00:28:33,249 --> 00:28:37,329
most productive astronomical observatory

648
00:28:35,888 --> 00:28:39,008
of all time and arguably the most

649
00:28:37,329 --> 00:28:42,128
productive scientific facility of all

650
00:28:39,009 --> 00:28:43,389
time because it is turning 25 everybody

651
00:28:42,128 --> 00:28:45,278
here in the building is going crazy

652
00:28:43,388 --> 00:28:47,258
planning all kinds of events and talks

653
00:28:45,278 --> 00:28:49,538
and presentations and we have a whole

654
00:28:47,259 --> 00:28:50,858
conference to vote up to this so instead

655
00:28:49,538 --> 00:28:51,799
of saying you know here's Hubble's

656

00:28:50,858 --> 00:28:53,119
greatest hits over the

657
00:28:51,799 --> 00:28:55,099
twenty-five years I think you should

658
00:28:53,119 --> 00:28:57,169
just follow this website and you'll see

659
00:28:55,099 --> 00:28:59,149
we have great video presentations coming

660
00:28:57,170 --> 00:29:00,860
out we're gonna have a big splash in

661
00:28:59,150 --> 00:29:02,900
April when the birthday actually rolls

662
00:29:00,859 --> 00:29:05,269
around it's gonna be fantastic

663
00:29:02,900 --> 00:29:07,550
so I'd rather spend more time talking

664
00:29:05,269 --> 00:29:10,009
about the future than the present so I'm

665
00:29:07,549 --> 00:29:11,539
going to move on to the immediate future

666
00:29:10,009 --> 00:29:14,839
for us

667
00:29:11,539 --> 00:29:16,220
the Hubble 2.0 so to speak which is what

668
00:29:14,839 --> 00:29:22,639
we call the James Webb Space Telescope

669
00:29:16,220 --> 00:29:24,680
now if you look at here it is and then

670
00:29:22,640 --> 00:29:26,570

you locate a to this T they don't look

671

00:29:24,680 --> 00:29:30,190

anything like each other nothing really

672

00:29:26,569 --> 00:29:33,129

I mean except there's a mirror there

673

00:29:30,190 --> 00:29:37,640

they're very very different pieces

674

00:29:33,130 --> 00:29:39,650

the reason is Hubble's not only 25 years

675

00:29:37,640 --> 00:29:41,810

old but it's a giant steel tube with a

676

00:29:39,650 --> 00:29:43,970

big piece of glass right if you go out

677

00:29:41,809 --> 00:29:47,329

in the lobby on your way out if you can

678

00:29:43,970 --> 00:29:48,650

make it past the Andromeda image back

679

00:29:47,329 --> 00:29:50,029

into the outer lobby you can see

680

00:29:48,650 --> 00:29:52,640

there's these banners hanging from the

681

00:29:50,029 --> 00:29:54,440

walls and there are pictures of the

682

00:29:52,640 --> 00:29:56,480

Hubble and the web primary mirrors to

683

00:29:54,440 --> 00:29:59,000

scale so you'll see the hollow primary

684

00:29:56,480 --> 00:30:02,120

mirror about 2.4 meters across which is

685
00:29:59,000 --> 00:30:03,680
about like this and the web mirror just

686
00:30:02,119 --> 00:30:05,569
Dwarfs it it goes all the way to the

687
00:30:03,680 --> 00:30:06,920
ceiling and we it's so big that we can't

688
00:30:05,569 --> 00:30:09,559
actually print it on a banner it's just

689
00:30:06,920 --> 00:30:13,789
a piece of it so I I I suggest you check

690
00:30:09,559 --> 00:30:15,619
out all those designed to be a telescope

691
00:30:13,789 --> 00:30:17,839
is optimized for observations in the

692
00:30:15,619 --> 00:30:19,459
infrared wavelengths those are

693
00:30:17,839 --> 00:30:22,069
wavelengths beyond what you can see with

694
00:30:19,460 --> 00:30:24,140
your eyes you know white becomes blue

695
00:30:22,069 --> 00:30:26,359
and then and then green and then red and

696
00:30:24,140 --> 00:30:27,980
once it's passed red you can't see it

697
00:30:26,359 --> 00:30:30,439
with your iron more there's some insects

698
00:30:27,980 --> 00:30:32,809
that can some probably nocturnal animals

699
00:30:30,440 --> 00:30:34,400
that can but humans can the reason we're

700
00:30:32,809 --> 00:30:36,019
doing that is to pick up a bunch of

701
00:30:34,400 --> 00:30:37,850
stuff that we can only see at those

702
00:30:36,019 --> 00:30:40,460
wavelengths I'll go through a bit of a

703
00:30:37,849 --> 00:30:42,109
science case this is a zoom on the

704
00:30:40,460 --> 00:30:44,390
Hubble's deepest image that Ultra Deep

705
00:30:42,109 --> 00:30:46,639
Field that I showed you and then at the

706
00:30:44,390 --> 00:30:47,280
end here we're gonna try to re simulate

707
00:30:46,640 --> 00:30:52,640
that

708
00:30:47,279 --> 00:30:55,139
as it would appear for JWST so there is

709
00:30:52,640 --> 00:30:56,640
transitioning to what JWST sees you see

710
00:30:55,140 --> 00:30:58,890
it's a straight to sharper image that

711
00:30:56,640 --> 00:31:01,500
comes from having a larger telescope but

712
00:30:58,890 --> 00:31:03,300
not only that now I'm going to do our

713

00:31:01,500 --> 00:31:06,000
pictures of galaxy gets sharper because

714
00:31:03,299 --> 00:31:08,730
we have a learner Tulsa but we can

715
00:31:06,000 --> 00:31:10,470
suddenly do all kinds of science here

716
00:31:08,730 --> 00:31:12,210
that we couldn't do before these

717
00:31:10,470 --> 00:31:14,309
galaxies the red ones the old ones the

718
00:31:12,210 --> 00:31:19,950
really distant ones become much sharper

719
00:31:14,309 --> 00:31:25,799
and much more easy to detect uh just let

720
00:31:19,950 --> 00:31:27,630
them run again it's kind of cool o jqsu

721
00:31:25,799 --> 00:31:30,629
in the same time we'll be able to go

722
00:31:27,630 --> 00:31:33,420
almost a factor of 10 beeper so take

723
00:31:30,630 --> 00:31:35,790
images that are detecting objects about

724
00:31:33,420 --> 00:31:38,130
1/10 as bright as what Hubble can do at

725
00:31:35,789 --> 00:31:41,609
the same time it's gonna be pretty

726
00:31:38,130 --> 00:31:43,530
amazing my personal favorite science

727
00:31:41,609 --> 00:31:45,809

cases is something I actually plan to do

728

00:31:43,529 --> 00:31:50,309

with Jada misty once they hand over the

729

00:31:45,809 --> 00:31:51,389

keys is to look at very best illa feels

730

00:31:50,309 --> 00:31:53,220

these are what this is one of those

731

00:31:51,390 --> 00:31:54,750

globular clusters that Frank pointed out

732

00:31:53,220 --> 00:31:55,890

in the image of Andromeda this is the

733

00:31:54,750 --> 00:32:00,150

globular cluster in our own galaxy

734

00:31:55,890 --> 00:32:04,560

called target you see there's just this

735

00:32:00,150 --> 00:32:07,590

is a action not a Hubble image but close

736

00:32:04,559 --> 00:32:09,359

enough this is this is a halogen here

737

00:32:07,589 --> 00:32:11,279

and you see it breaks up into individual

738

00:32:09,359 --> 00:32:13,799

stars right blue star red star mu star

739

00:32:11,279 --> 00:32:15,690

red star JD boost keeps gonna have this

740

00:32:13,799 --> 00:32:18,149

amazing device on it called a micro

741

00:32:15,690 --> 00:32:21,930

shredder array which is this array of

742
00:32:18,150 --> 00:32:23,580
little electronic doors and we can open

743
00:32:21,930 --> 00:32:26,330
and close those doors at will and take

744
00:32:23,579 --> 00:32:29,069
observations of individual stars

745
00:32:26,329 --> 00:32:30,869
that's our coping that door taking

746
00:32:29,069 --> 00:32:32,129
observations that star and just leave

747
00:32:30,869 --> 00:32:34,500
the others close

748
00:32:32,130 --> 00:32:36,180
pick out stars Reserve in these fields

749
00:32:34,500 --> 00:32:37,829
we can work out their age you can work

750
00:32:36,180 --> 00:32:39,630
out the metal content you can work out

751
00:32:37,829 --> 00:32:41,909
what this cluster came from and where

752
00:32:39,630 --> 00:32:44,940
it's going all from taking spectroscopy

753
00:32:41,910 --> 00:32:47,460
of these very dense fields this is the

754
00:32:44,940 --> 00:32:48,860
the scale of those little electronic

755
00:32:47,460 --> 00:32:51,410
doors at the scale

756
00:32:48,859 --> 00:32:53,539
human hair so pluck out a hair hold it

757
00:32:51,410 --> 00:32:55,160
up and say they made quarter of a

758
00:32:53,539 --> 00:32:57,079
million oohs little doors smaller than

759
00:32:55,160 --> 00:32:59,390
human hair in the space of about three

760
00:32:57,079 --> 00:33:03,169
to three inches squared it's quite a

761
00:32:59,390 --> 00:33:04,490
device by the way it operates at three

762
00:33:03,170 --> 00:33:08,870
hundred and something degrees below zero

763
00:33:04,490 --> 00:33:10,700
to Gen even if she is an infrared

764
00:33:08,869 --> 00:33:13,308
optimized telescope is going to turn

765
00:33:10,700 --> 00:33:15,019
images that look like this one very much

766
00:33:13,308 --> 00:33:17,089
like the pillars of creation that Frank

767
00:33:15,019 --> 00:33:21,099
just went through into images that look

768
00:33:17,089 --> 00:33:24,259
like this one right in other words a

769
00:33:21,099 --> 00:33:26,719
peering through this obscuring dust to

770

00:33:24,259 --> 00:33:28,519
see the star forming regions the young

771
00:33:26,720 --> 00:33:30,558
stars right air in the Jets that they

772
00:33:28,519 --> 00:33:32,359
power we're going to start seeing

773
00:33:30,558 --> 00:33:34,849
hundreds of images and star forming

774
00:33:32,359 --> 00:33:41,029
regions that look just like this which

775
00:33:34,849 --> 00:33:42,469
is deep so once we have done that and I

776
00:33:41,029 --> 00:33:44,240
should just say that this is something

777
00:33:42,470 --> 00:33:46,240
that hasn't happened yet right Jada

778
00:33:44,240 --> 00:33:48,980
misty is supposed to launch in about

779
00:33:46,240 --> 00:33:52,130
three and a half years at the end 2018

780
00:33:48,980 --> 00:33:52,669
we expect it to operate we hope for ten

781
00:33:52,130 --> 00:33:54,830
years

782
00:33:52,669 --> 00:33:58,100
so that'll carry us through almost the

783
00:33:54,829 --> 00:34:02,449
end of the next decade 20 28 2013

784
00:33:58,099 --> 00:34:03,668

perhaps Jada misty like any telescope

785

00:34:02,450 --> 00:34:06,140

that's come before it

786

00:34:03,669 --> 00:34:07,790

it's intended to revolutionize things

787

00:34:06,140 --> 00:34:10,190

it's intended to bring us knowledge that

788

00:34:07,789 --> 00:34:11,989

we never had before and more than that

789

00:34:10,190 --> 00:34:13,429

if it's anything like Hubble it's going

790

00:34:11,989 --> 00:34:15,378

to teach us to ask questions that we

791

00:34:13,429 --> 00:34:17,720

never thought in other words the thing

792

00:34:15,378 --> 00:34:18,648

we build it to do is actually a little

793

00:34:17,719 --> 00:34:20,539

bit of what it does

794

00:34:18,648 --> 00:34:22,159

most of what Hubble's famous for are

795

00:34:20,539 --> 00:34:23,779

things that its its designers never

796

00:34:22,159 --> 00:34:25,849

imagined their questions they never

797

00:34:23,780 --> 00:34:27,830

thought to ask and that's because the

798

00:34:25,849 --> 00:34:29,000

science moves along you come up with new

799

00:34:27,829 --> 00:34:32,000

discoveries and every new discovery

800

00:34:29,000 --> 00:34:33,949

raises a new question so it's very hard

801

00:34:32,000 --> 00:34:36,679

for us to predict where our field is

802

00:34:33,949 --> 00:34:41,178

going to be in 2028 at least when it

803

00:34:36,679 --> 00:34:44,480

comes to deep infrared observations of

804

00:34:41,179 --> 00:34:44,990

the universe so where do we go from

805

00:34:44,480 --> 00:34:47,929

there

806

00:34:44,989 --> 00:34:50,118

right where once we got David misty and

807

00:34:47,929 --> 00:34:55,070

we definitely will get it where do we go

808

00:34:50,119 --> 00:34:55,590

in well I like to motivate our work with

809

00:34:55,070 --> 00:34:56,970

this

810

00:34:55,590 --> 00:34:59,910

really fantastic quote not from

811

00:34:56,969 --> 00:35:01,980

astronomers a biologist rather famous

812

00:34:59,909 --> 00:35:05,309

biologists at Harvard uh and we'll see

813
00:35:01,980 --> 00:35:07,289
things for hands he's rated a lot of

814
00:35:05,309 --> 00:35:09,570
wonderful books about science generally

815
00:35:07,289 --> 00:35:11,070
and his life as a naturalist and his

816
00:35:09,570 --> 00:35:13,920
library recently was that the most

817
00:35:11,070 --> 00:35:15,990
important experiment in biology is the

818
00:35:13,920 --> 00:35:18,150
search for extraterrestrial life think

819
00:35:15,989 --> 00:35:20,449
of this this is a world-famous file that

820
00:35:18,150 --> 00:35:23,340
is telling us that the most important

821
00:35:20,449 --> 00:35:26,549
experiment in modern biology is an

822
00:35:23,340 --> 00:35:28,260
astronomy operation right that tells you

823
00:35:26,550 --> 00:35:31,670
something very important about where our

824
00:35:28,260 --> 00:35:34,740
field is going in the next decade and

825
00:35:31,670 --> 00:35:38,070
it's not just Hubble it's not just JWST

826
00:35:34,739 --> 00:35:40,319
NASA has deployed and will employ a

827

00:35:38,070 --> 00:35:42,150
whole array of missions at a smaller

828
00:35:40,320 --> 00:35:45,090
scale these are not the giant you know

829
00:35:42,150 --> 00:35:47,160
multibillion-dollar flagships but it has

830
00:35:45,090 --> 00:35:48,600
deployed the Kepler mission and there

831
00:35:47,159 --> 00:35:50,969
are two coming down the pike Old

832
00:35:48,599 --> 00:35:53,759
Testament after that I'll speak about

833
00:35:50,969 --> 00:35:55,949
three in a month which are designed to

834
00:35:53,760 --> 00:35:58,860
address this problem that Wilson has

835
00:35:55,949 --> 00:36:00,419
posed how can we find planets how can we

836
00:35:58,860 --> 00:36:02,430
find planets that might be bearing life

837
00:36:00,420 --> 00:36:06,710
and how can we find out a claim is

838
00:36:02,429 --> 00:36:11,539
actually there so we're on a pattern

839
00:36:06,710 --> 00:36:14,250
Kepler's great discovery has been of

840
00:36:11,539 --> 00:36:15,900
earth-sized planets capital is very good

841
00:36:14,250 --> 00:36:17,329

at finding all kinds of planets but it's

842

00:36:15,900 --> 00:36:21,000

especially good at finding earth-like

843

00:36:17,329 --> 00:36:24,029

planets and it's done that with exactly

844

00:36:21,000 --> 00:36:26,190

the same with it with it so that with an

845

00:36:24,030 --> 00:36:30,180

observing technique that I'll describe a

846

00:36:26,190 --> 00:36:32,579

moment called transits but the real

847

00:36:30,179 --> 00:36:34,799

important observation is that one out of

848

00:36:32,579 --> 00:36:38,909

every five sun-like stars has an

849

00:36:34,800 --> 00:36:40,590

earth-like planet one out of every five

850

00:36:38,909 --> 00:36:42,929

sun-like stars has an earth-like planet

851

00:36:40,590 --> 00:36:45,570

if you go back after the Andromeda in it

852

00:36:42,929 --> 00:36:48,599

you're going to see millions of sun-like

853

00:36:45,570 --> 00:36:50,220

stars that suggest that there are

854

00:36:48,599 --> 00:36:52,239

probably millions to hundreds of

855

00:36:50,219 --> 00:36:55,000

thousands of stars on earth life

856
00:36:52,239 --> 00:36:57,449
in that image right just statistically

857
00:36:55,000 --> 00:37:01,150
and our galaxy there are probably

858
00:36:57,449 --> 00:37:03,699
millions tens of millions of stars with

859
00:37:01,150 --> 00:37:07,300
earth-like cats that is a discovery that

860
00:37:03,699 --> 00:37:09,399
even those even those astronomers who

861
00:37:07,300 --> 00:37:11,560
discover the first exoplanets couldn't

862
00:37:09,400 --> 00:37:16,900
really imagine this is a very new result

863
00:37:11,559 --> 00:37:18,820
this is a 2014 well we're not only

864
00:37:16,900 --> 00:37:24,670
looking for earth-like planets if we

865
00:37:18,820 --> 00:37:26,380
want to solve wilson's puzzle we're

866
00:37:24,670 --> 00:37:29,440
looking for earth-like planets in what

867
00:37:26,380 --> 00:37:30,760
we call the habitable zone right you

868
00:37:29,440 --> 00:37:33,849
might think of this as a bit of a

869
00:37:30,760 --> 00:37:36,040
Goldilocks problem if a planet like the

870
00:37:33,849 --> 00:37:38,349
earth let's say is that the position of

871
00:37:36,039 --> 00:37:41,699
Venus in our own solar system or even

872
00:37:38,349 --> 00:37:44,109
worse mercury it's not a comfortable

873
00:37:41,699 --> 00:37:45,250
place where you might want to go to the

874
00:37:44,108 --> 00:37:47,500
beach or play golf

875
00:37:45,250 --> 00:37:50,409
it's like mercury where it's you know

876
00:37:47,500 --> 00:37:52,838
700 degrees during the daytime and 700

877
00:37:50,409 --> 00:37:56,079
degrees below or 4 degrees below zero at

878
00:37:52,838 --> 00:37:58,079
night it's not out of it's too hot while

879
00:37:56,079 --> 00:38:02,049
if you're at the distance of Mars or

880
00:37:58,079 --> 00:38:05,920
beyond also not good for going to the

881
00:38:02,050 --> 00:38:08,050
beach and golfing it's too cold so the

882
00:38:05,920 --> 00:38:11,409
habitable zone is it's more or less

883
00:38:08,050 --> 00:38:14,710
defined as where the radiation from the

884

00:38:11,409 --> 00:38:16,420
Sun is just right so that water is in

885
00:38:14,710 --> 00:38:18,699
liquid form at the surface temperature

886
00:38:16,420 --> 00:38:22,329
because water is the key ingredient of

887
00:38:18,699 --> 00:38:25,509
life at 70% of all of our bodies it's a

888
00:38:22,329 --> 00:38:29,019
bummer if the 7% of your body that's

889
00:38:25,510 --> 00:38:30,790
water freezes so in order for a planet

890
00:38:29,019 --> 00:38:32,139
called habitable by the astronomical

891
00:38:30,789 --> 00:38:34,719
standard it has to be in that region

892
00:38:32,139 --> 00:38:36,699
with us not too close to get to hot oil

893
00:38:34,719 --> 00:38:39,250
all the water not too far away to get

894
00:38:36,699 --> 00:38:41,289
too cold freeze all the water it has to

895
00:38:39,250 --> 00:38:46,539
be in this happening habitable something

896
00:38:41,289 --> 00:38:48,460
the htc so we have missions that can

897
00:38:46,539 --> 00:38:52,150
find earth-like planets Kepler has done

898
00:38:48,460 --> 00:38:53,679

it we have a definition we understand

899

00:38:52,150 --> 00:38:56,470

where those planets should be around

900

00:38:53,679 --> 00:38:58,389

their stars to be habitable once we

901

00:38:56,469 --> 00:38:59,419

found them how will we answer this

902

00:38:58,389 --> 00:39:00,828

question is there

903

00:38:59,420 --> 00:39:03,829

but living there is their life they're

904

00:39:00,829 --> 00:39:06,470

on that planet and it turns out this is

905

00:39:03,829 --> 00:39:07,849

a pretty straightforward problem when

906

00:39:06,469 --> 00:39:09,078

you think about it it's a challenging

907

00:39:07,849 --> 00:39:10,818

observation but it's a pretty

908

00:39:09,079 --> 00:39:12,798

straightforward problem and that's

909

00:39:10,818 --> 00:39:14,509

because if you take a spectrum

910

00:39:12,798 --> 00:39:16,670

just like news he's better than the Sun

911

00:39:14,510 --> 00:39:18,970

with the prism he's like front-of-house

912

00:39:16,670 --> 00:39:21,619

respected in the Sun with his scrape

913
00:39:18,969 --> 00:39:24,949
there are features in the spectrum of

914
00:39:21,619 --> 00:39:28,160
the earth that betray the presence of

915
00:39:24,949 --> 00:39:30,710
what on the earth there called me

916
00:39:28,159 --> 00:39:34,338
calling out biomarkers it's a marker for

917
00:39:30,710 --> 00:39:36,380
a biosphere a biomarker molecule the

918
00:39:34,338 --> 00:39:39,230
easiest one to pick out if you have the

919
00:39:36,380 --> 00:39:42,980
correct wavelength range covered is the

920
00:39:39,230 --> 00:39:48,409
water these big divots in the spectrum

921
00:39:42,980 --> 00:39:49,818
here are from water okay these big

922
00:39:48,409 --> 00:39:53,139
things in the spectrum here are from

923
00:39:49,818 --> 00:39:56,389
water light hits the Earth's atmosphere

924
00:39:53,139 --> 00:39:58,250
some of those photons from the Sun get

925
00:39:56,389 --> 00:40:00,019
trapped by water molecule and never go

926
00:39:58,250 --> 00:40:02,568
anywhere again and it reradiating to the

927
00:40:00,019 --> 00:40:04,338
infrared so those like those photons

928
00:40:02,568 --> 00:40:05,630
that light drops out it's a spectrum and

929
00:40:04,338 --> 00:40:11,989
it shows up just like that

930
00:40:05,630 --> 00:40:14,780
there's also here the effect of the dust

931
00:40:11,989 --> 00:40:16,338
in the atmosphere and then the ozone in

932
00:40:14,780 --> 00:40:17,599
the atmosphere which is what protects us

933
00:40:16,338 --> 00:40:20,838
from the ultraviolet radiation that

934
00:40:17,599 --> 00:40:24,380
introduces a very clear-cut drop of the

935
00:40:20,838 --> 00:40:26,358
spectrum there's oxygen the molecule

936
00:40:24,380 --> 00:40:29,030
we're all breathing to live has these

937
00:40:26,358 --> 00:40:31,670
little signs right in there

938
00:40:29,030 --> 00:40:33,680
ozone is itself a very important

939
00:40:31,670 --> 00:40:35,510
biomarker because it doesn't exist with

940
00:40:33,679 --> 00:40:40,548
these other molecules in the absence of

941

00:40:35,510 --> 00:40:44,349
life ozone is a very clear signature

942
00:40:40,548 --> 00:40:47,088
that you have biochemistry going on and

943
00:40:44,349 --> 00:40:48,450
then finally these other things carbon

944
00:40:47,088 --> 00:40:51,170
dioxide and methane

945
00:40:48,449 --> 00:40:53,639
which should produce carbon dioxide

946
00:40:51,170 --> 00:40:57,570
maintained by living people and then

947
00:40:53,639 --> 00:41:01,500
consumed by sorry by plants and then

948
00:40:57,570 --> 00:41:05,338
consumed oxygen is consumed by us

949
00:41:01,500 --> 00:41:10,500
methane is another case where it's

950
00:41:05,338 --> 00:41:13,320
either emitted by bacteria or by my

951
00:41:10,500 --> 00:41:15,719
hands so if you can detect all of these

952
00:41:13,320 --> 00:41:17,789
biomarkers in the spectrum of an

953
00:41:15,719 --> 00:41:20,639
earth-like planet in its habitable zone

954
00:41:17,789 --> 00:41:23,550
you have the answer that tells you that

955
00:41:20,639 --> 00:41:24,900

on that planet at least there's strong

956

00:41:23,550 --> 00:41:27,180
evidence that there's life there

957

00:41:24,900 --> 00:41:29,099
creating these signatures which

958

00:41:27,179 --> 00:41:31,259
otherwise would not exist

959

00:41:29,099 --> 00:41:33,240
this is not what Mars looks like this is

960

00:41:31,260 --> 00:41:34,859
not what Venus looks like the

961

00:41:33,239 --> 00:41:36,989
uninhabited planets in our solar system

962

00:41:34,858 --> 00:41:39,598
don't look anything like this the earth

963

00:41:36,989 --> 00:41:44,009
does because we live here along with a

964

00:41:39,599 --> 00:41:45,960
lot of plants so one way to detect a

965

00:41:44,010 --> 00:41:48,660
biomarker is to use the method that

966

00:41:45,960 --> 00:41:51,150
Kepler has used to detect planets and

967

00:41:48,659 --> 00:41:54,210
that's the so called transitive this is

968

00:41:51,150 --> 00:41:56,000
an illustration actually to see if you

969

00:41:54,210 --> 00:42:00,539
have a star a planet orbiting that star

970
00:41:56,000 --> 00:42:02,789
if it's oriented just right right if the

971
00:42:00,539 --> 00:42:04,920
orbit of the planet is more or less in

972
00:42:02,789 --> 00:42:06,960
the plane that you're looking in that

973
00:42:04,920 --> 00:42:08,579
startled that planet will pass in front

974
00:42:06,960 --> 00:42:10,230
of start will make it even to the star

975
00:42:08,579 --> 00:42:12,930
just a little tiny bit brighter like

976
00:42:10,230 --> 00:42:15,030
it'll take 110 thousand of the photons

977
00:42:12,929 --> 00:42:16,710
out of the image so you have to you know

978
00:42:15,030 --> 00:42:19,800
if you can measure one part in 10,000

979
00:42:16,710 --> 00:42:22,679
you can detect us and you can then

980
00:42:19,800 --> 00:42:24,420
measure the planet's atmosphere if the

981
00:42:22,679 --> 00:42:27,179
planet passes in front of the star of

982
00:42:24,420 --> 00:42:29,818
the star by looking for these spectral

983
00:42:27,179 --> 00:42:31,230
features in the light that passes from

984
00:42:29,818 --> 00:42:35,068
the star through the planet's atmosphere

985
00:42:31,230 --> 00:42:37,260
into our telescopes so this is one way

986
00:42:35,068 --> 00:42:39,809
to detect these biomarker molecules but

987
00:42:37,260 --> 00:42:42,240
it only works if the planet transits

988
00:42:39,809 --> 00:42:44,150
right it only works if this happens if

989
00:42:42,239 --> 00:42:46,429
the star and the planet is or

990
00:42:44,150 --> 00:42:48,050
- just so it just planet every

991
00:42:46,429 --> 00:42:50,359
once-in-a-while passes in from the start

992
00:42:48,050 --> 00:42:51,860
if it's oriented a different way where

993
00:42:50,360 --> 00:42:54,110
you say you have to star and the planets

994
00:42:51,860 --> 00:42:55,849
going around it like this it never

995
00:42:54,110 --> 00:42:57,019
actually passes in front of the start it

996
00:42:55,849 --> 00:43:00,380
doesn't work and that's actually the

997
00:42:57,019 --> 00:43:01,969
case most of the time because of the

998

00:43:00,380 --> 00:43:03,619
orbits are just random you know they

999
00:43:01,969 --> 00:43:05,779
have you have to be lucky for them to

1000
00:43:03,619 --> 00:43:07,400
translate this so that's probably not

1001
00:43:05,780 --> 00:43:09,500
going to be the way that we figure out

1002
00:43:07,400 --> 00:43:13,300
at least for lots of nearby planets

1003
00:43:09,500 --> 00:43:16,130
whether they have is five miles right

1004
00:43:13,300 --> 00:43:19,160
but anyway this is a technique that we

1005
00:43:16,130 --> 00:43:23,599
will use with JWST going back to that

1006
00:43:19,159 --> 00:43:25,190
fantastic observatory it Jake jr. yes he

1007
00:43:23,599 --> 00:43:28,579
may be able to use this transit

1008
00:43:25,190 --> 00:43:30,740
technique to detect some biomarker

1009
00:43:28,579 --> 00:43:33,920
molecules especially water and methane

1010
00:43:30,739 --> 00:43:35,719
what are called super water worlds so

1011
00:43:33,920 --> 00:43:38,000
something that's two times or three or

1012
00:43:35,719 --> 00:43:41,059

four times the Earth's mass rocky in the

1013

00:43:38,000 --> 00:43:43,010

core but surrounded by a big ocean the

1014

00:43:41,059 --> 00:43:45,980

university might be able to detect water

1015

00:43:43,010 --> 00:43:47,240

and methane on those planets the

1016

00:43:45,980 --> 00:43:50,000

spectrum of look like this and I know

1017

00:43:47,239 --> 00:43:51,799

this appears to be a total mess but it's

1018

00:43:50,000 --> 00:43:53,599

a simulated spectrum by the way this is

1019

00:43:51,800 --> 00:43:55,340

not real data one reason you know that

1020

00:43:53,599 --> 00:43:59,659

the telescope is still in part some

1021

00:43:55,340 --> 00:44:03,530

ground and number two it looks a little

1022

00:43:59,659 --> 00:44:05,210

better than real data actually but this

1023

00:44:03,530 --> 00:44:06,800

is a simulated spectrum with jegos T

1024

00:44:05,210 --> 00:44:08,240

because believe me all the astronomers

1025

00:44:06,800 --> 00:44:09,920

are ramped up we're thinking about it

1026

00:44:08,239 --> 00:44:11,059

you know this even though it's a park on

1027
00:44:09,920 --> 00:44:13,369
the ground we're launching in three

1028
00:44:11,059 --> 00:44:14,570
years and we're ready to go right so we

1029
00:44:13,369 --> 00:44:16,940
have to start thinking about what we're

1030
00:44:14,570 --> 00:44:18,710
going to find so generous you may be

1031
00:44:16,940 --> 00:44:20,450
able to reach these water world planets

1032
00:44:18,710 --> 00:44:22,250
but it's not going to be able to get to

1033
00:44:20,449 --> 00:44:24,489
genuine earth-like planets you know just

1034
00:44:22,250 --> 00:44:27,159
like the earth one so one person asked

1035
00:44:24,489 --> 00:44:30,369
and it's certainly not going to do that

1036
00:44:27,159 --> 00:44:32,920
for a large number of plants so it's a

1037
00:44:30,369 --> 00:44:34,869
step in the right direction it's a way

1038
00:44:32,920 --> 00:44:36,340
to prove that the techniques work it's

1039
00:44:34,869 --> 00:44:37,719
maybe a way to make an important

1040
00:44:36,340 --> 00:44:40,900
discovery there's a water world out

1041
00:44:37,719 --> 00:44:45,119
there with something look at but it's

1042
00:44:40,900 --> 00:44:47,889
not really the answer to Wilson's claim

1043
00:44:45,119 --> 00:44:50,679
so what is the answer what is going to

1044
00:44:47,889 --> 00:44:52,420
get us this evidence that there's a

1045
00:44:50,679 --> 00:44:53,859
separate evolutionary pathway for life

1046
00:44:52,420 --> 00:44:56,430
that's been in separate origin of life

1047
00:44:53,860 --> 00:44:59,079
on another planet in our house

1048
00:44:56,429 --> 00:45:02,799
the ultimate goal really is another

1049
00:44:59,079 --> 00:45:04,150
living earth like our own we already

1050
00:45:02,800 --> 00:45:05,590
know school children on earth already

1051
00:45:04,150 --> 00:45:07,750
learned that there are these worlds

1052
00:45:05,590 --> 00:45:09,820
orbiting other stars and what we like is

1053
00:45:07,750 --> 00:45:11,320
for the future generations and I don't

1054
00:45:09,820 --> 00:45:13,269
mean the distant future I don't need a

1055

00:45:11,320 --> 00:45:16,180
thousand years from now I mean my

1056
00:45:13,269 --> 00:45:19,150
children right possibly get children but

1057
00:45:16,179 --> 00:45:21,190
probably my own right next generation

1058
00:45:19,150 --> 00:45:23,920
school trailers to fight to know with

1059
00:45:21,190 --> 00:45:25,179
the same certainty would know this right

1060
00:45:23,920 --> 00:45:29,470
that there's life on some of those

1061
00:45:25,179 --> 00:45:31,269
worlds a increasingly large number of

1062
00:45:29,469 --> 00:45:33,099
genres myself included that's why I'm

1063
00:45:31,269 --> 00:45:35,079
here but you know a large part of our

1064
00:45:33,099 --> 00:45:36,339
community is confident of you that we

1065
00:45:35,079 --> 00:45:40,119
can actually do this

1066
00:45:36,340 --> 00:45:41,530
within two decades because we're

1067
00:45:40,119 --> 00:45:43,750
starting to see you have the technology

1068
00:45:41,530 --> 00:45:47,730
we have the ability to build a telescope

1069
00:45:43,750 --> 00:45:50,380

that can do this so how are you doing

1070

00:45:47,730 --> 00:45:52,840

well it's much different from what I

1071

00:45:50,380 --> 00:45:55,240

said Kepler does and what Jacob is he

1072

00:45:52,840 --> 00:45:57,730

will do because what we want to do is

1073

00:45:55,239 --> 00:45:59,500

break open this this restriction of

1074

00:45:57,730 --> 00:46:01,599

having to have the planet pass in front

1075

00:45:59,500 --> 00:46:04,559

of the star as well that doesn't happen

1076

00:46:01,599 --> 00:46:06,909

very often for typical stars

1077

00:46:04,559 --> 00:46:09,759

statistically we've worked out that 20%

1078

00:46:06,909 --> 00:46:11,500

of sun-like stars have planets but

1079

00:46:09,760 --> 00:46:13,380

that's by extrapolating from a much

1080

00:46:11,500 --> 00:46:17,230

smaller number of millions with category

1081

00:46:13,380 --> 00:46:19,390

so the way to really prove this works is

1082

00:46:17,230 --> 00:46:21,940

to just figure out a way to take a

1083

00:46:19,389 --> 00:46:25,000

picture of the planet go out to the

1084
00:46:21,940 --> 00:46:25,500
thousand nearest stars find the planets

1085
00:46:25,000 --> 00:46:27,119
there

1086
00:46:25,500 --> 00:46:30,780
take your picture right that's worth a

1087
00:46:27,119 --> 00:46:32,069
thousand words so every minute you try

1088
00:46:30,780 --> 00:46:33,990
to use is an instrument called a

1089
00:46:32,070 --> 00:46:35,760
coronagraph I want to get all until the

1090
00:46:33,989 --> 00:46:38,849
technical and an optical jargon that's

1091
00:46:35,760 --> 00:46:40,650
involved here but basically what you do

1092
00:46:38,849 --> 00:46:43,289
is when you point your telescope you put

1093
00:46:40,650 --> 00:46:46,170
something in the way that blocks the

1094
00:46:43,289 --> 00:46:48,779
Starlight so you can see the planet now

1095
00:46:46,170 --> 00:46:51,240
I have here an illustration using a star

1096
00:46:48,780 --> 00:46:52,890
a bunch of planets in the habitable zone

1097
00:46:51,239 --> 00:46:55,109
around that star it wouldn't have that

1098
00:46:52,889 --> 00:46:57,989
many they could all gravitationally

1099
00:46:55,110 --> 00:47:00,480
eject each other but that's just a model

1100
00:46:57,989 --> 00:47:02,429
and the idea is to have the coronagraph

1101
00:47:00,480 --> 00:47:04,110
brought block the Starlight for reasons

1102
00:47:02,429 --> 00:47:05,719
I'll explain in a minute so that you can

1103
00:47:04,110 --> 00:47:07,200
see the planet now we already do

1104
00:47:05,719 --> 00:47:07,919
measurements with things like

1105
00:47:07,199 --> 00:47:10,230
coronagraphs

1106
00:47:07,920 --> 00:47:12,420
in fact they were invented to study the

1107
00:47:10,230 --> 00:47:15,269
Sun if you want to study anything here

1108
00:47:12,420 --> 00:47:17,309
the Sun like the Kirk the the corona of

1109
00:47:15,269 --> 00:47:19,380
the Sun or a comment that happens to be

1110
00:47:17,309 --> 00:47:21,570
a comment right there since from a NASA

1111
00:47:19,380 --> 00:47:23,220
solar mission you have to block the Sun

1112

00:47:21,570 --> 00:47:24,330
because the Sun is the brightest thing

1113
00:47:23,219 --> 00:47:25,889
in the sky right you wouldn't see

1114
00:47:24,329 --> 00:47:27,750
anything near it if you didn't block it

1115
00:47:25,889 --> 00:47:29,579
out so people have figured out a way to

1116
00:47:27,750 --> 00:47:32,699
block out starlight to see stuff nearby

1117
00:47:29,579 --> 00:47:34,289
and that's what we intend to do the idea

1118
00:47:32,699 --> 00:47:38,699
is to build up the Stars so you can see

1119
00:47:34,289 --> 00:47:43,259
the planets there right but it's really

1120
00:47:38,699 --> 00:47:46,439
really really really hard right because

1121
00:47:43,260 --> 00:47:48,570
the planet is 10 billion times fainter

1122
00:47:46,440 --> 00:47:50,010
than the star I'm looking at now the

1123
00:47:48,570 --> 00:47:51,690
kinds of stars we're talking about are

1124
00:47:50,010 --> 00:47:53,550
literally the kinds of stars you can see

1125
00:47:51,690 --> 00:47:55,200
if you walk out into the streets and

1126
00:47:53,550 --> 00:47:57,810

Martin here and look up there that

1127

00:47:55,199 --> 00:47:59,460

bright they're bright stars they're not

1128

00:47:57,809 --> 00:48:01,110

the 28th magnitude stars that you're

1129

00:47:59,460 --> 00:48:03,090

seeing in the Andromeda image in the

1130

00:48:01,110 --> 00:48:05,340

lobby these are bright stars but the

1131

00:48:03,090 --> 00:48:06,990

planet because it doesn't emit any light

1132

00:48:05,340 --> 00:48:09,180

of its own it's only picking up the

1133

00:48:06,989 --> 00:48:12,509

light that the star shines on right it's

1134

00:48:09,179 --> 00:48:14,669

picking up earth shine right it's 10

1135

00:48:12,510 --> 00:48:16,320

billion times fainter in the host star so

1136

00:48:14,670 --> 00:48:18,269

how in the world are you going to take a

1137

00:48:16,320 --> 00:48:20,460

spectrum of the thing that's sitting

1138

00:48:18,269 --> 00:48:21,659

right next to something that's we then

1139

00:48:20,460 --> 00:48:24,579

you know at end of the arc second or

1140

00:48:21,659 --> 00:48:28,250

something that's a 10 billion

1141
00:48:24,579 --> 00:48:28,489
this is a real engineering job you all

1142
00:48:28,250 --> 00:48:31,010
right

1143
00:48:28,489 --> 00:48:32,899
in fact this problem detecting an

1144
00:48:31,010 --> 00:48:34,640
earth-like planet in its habitable zone

1145
00:48:32,900 --> 00:48:35,869
a tenth of an arcsecond way from a

1146
00:48:34,639 --> 00:48:39,109
bright star at ten billion times

1147
00:48:35,869 --> 00:48:41,059
brighter it's actually no harder than

1148
00:48:39,110 --> 00:48:42,620
this guy so if you figure out how to

1149
00:48:41,059 --> 00:48:44,779
solve this problem you can figure out

1150
00:48:42,619 --> 00:48:47,089
the plan right it's this problem let's

1151
00:48:44,780 --> 00:48:48,650
put a telescope in Baltimore and let's

1152
00:48:47,090 --> 00:48:51,860
put a searchlight in Los Angeles

1153
00:48:48,650 --> 00:48:56,570
and then let's put a firefly next to

1154
00:48:51,860 --> 00:48:59,000
that searchlight solve the problem and

1155
00:48:56,570 --> 00:49:01,490
final Firefly for all the searchlights

1156
00:48:59,000 --> 00:49:03,199
in Los Angeles from Baltimore you got it

1157
00:49:01,489 --> 00:49:05,359
fixed it works

1158
00:49:03,199 --> 00:49:07,159
that's how challenging this problem is

1159
00:49:05,360 --> 00:49:09,470
yeah I don't want I don't want to

1160
00:49:07,159 --> 00:49:11,389
minimize the challenge of altering this

1161
00:49:09,469 --> 00:49:13,669
is why it's going to take us 20 years to

1162
00:49:11,389 --> 00:49:16,190
get to this point but it's actually

1163
00:49:13,670 --> 00:49:18,019
something that that people who build

1164
00:49:16,190 --> 00:49:19,909
instruments and work with telescopes on

1165
00:49:18,019 --> 00:49:21,440
the ground in space are spending their

1166
00:49:19,909 --> 00:49:23,299
careers trying to figure out we have a

1167
00:49:21,440 --> 00:49:25,070
whole group of people here in what's

1168
00:49:23,300 --> 00:49:27,170
called high contrast imaging believe me

1169

00:49:25,070 --> 00:49:29,750
this is a high contrast fainting and a

1170
00:49:27,170 --> 00:49:33,460
really bright thing they're looking for

1171
00:49:29,750 --> 00:49:40,219
the fireflies in searchlights so I think

1172
00:49:33,460 --> 00:49:41,720
okay well the mission I've been teasing

1173
00:49:40,219 --> 00:49:42,949
all along is something that we've

1174
00:49:41,719 --> 00:49:46,069
started to call the High Definition

1175
00:49:42,949 --> 00:49:50,679
Space Telescope it would be a new Space

1176
00:49:46,070 --> 00:49:53,330
Telescope following on JWST it would

1177
00:49:50,679 --> 00:49:54,739
orbit at the earth style two points in

1178
00:49:53,329 --> 00:49:56,449
the same place Jamie guessed he is going

1179
00:49:54,739 --> 00:49:59,750
and sort of a gravitationally happy spot

1180
00:49:56,449 --> 00:50:01,789
million miles beyond the moon we'd like

1181
00:49:59,750 --> 00:50:04,039
to see an aperture for the telescope of

1182
00:50:01,789 --> 00:50:06,500
10 to 12 meters which is about the same

1183
00:50:04,039 --> 00:50:08,029

size as the room here so you know not

1184

00:50:06,500 --> 00:50:13,130
small more like the room in this

1185

00:50:08,030 --> 00:50:14,630
direction but still it's big it has to

1186

00:50:13,130 --> 00:50:16,940
be deployable mirror just like jadibooti

1187

00:50:14,630 --> 00:50:20,329
so it'll all fold up origami style and

1188

00:50:16,940 --> 00:50:22,940
fit in rocket cars ultraviolet in your

1189

00:50:20,329 --> 00:50:24,769
throat wavelengths we'd really like for

1190

00:50:22,940 --> 00:50:26,480
it to be more like Hubble and less like

1191

00:50:24,769 --> 00:50:27,199
you to do is T so that robots or

1192

00:50:26,480 --> 00:50:28,639
astronauts

1193

00:50:27,199 --> 00:50:30,588
go in there and replace the instruments

1194

00:50:28,639 --> 00:50:32,539
that's been the reason that Hubble has

1195

00:50:30,588 --> 00:50:34,699
been so successful over 25 years that's

1196

00:50:32,539 --> 00:50:36,829
a reason to live that long so that's

1197

00:50:34,699 --> 00:50:38,299
what we'd like and of course these

1198
00:50:36,829 --> 00:50:40,940
things take time so we're looking into

1199
00:50:38,300 --> 00:50:42,650
decades or so before this is a

1200
00:50:40,940 --> 00:50:44,329
comparative mirror sizes there's the

1201
00:50:42,650 --> 00:50:45,769
humble mirror if you go out and lobby as

1202
00:50:44,329 --> 00:50:47,630
I said you can see that banner that

1203
00:50:45,769 --> 00:50:50,150
tells you how big it really is that's

1204
00:50:47,630 --> 00:50:52,700
rated to see the scale and our High

1205
00:50:50,150 --> 00:50:55,420
Definition space also this is your thing

1206
00:50:52,699 --> 00:50:58,129
it's pretty big

1207
00:50:55,420 --> 00:51:00,559
okay so why does it need to be serviced

1208
00:50:58,130 --> 00:51:03,519
let's take the stars within 200

1209
00:51:00,559 --> 00:51:06,469
light-years which is about 17 parsecs

1210
00:51:03,519 --> 00:51:07,849
that's all the stars but that from the

1211
00:51:06,469 --> 00:51:10,338
list of actual stars at that distance

1212
00:51:07,849 --> 00:51:14,359
okay that's our galactic neighborhood in

1213
00:51:10,338 --> 00:51:17,509
the side of the center okay let's now

1214
00:51:14,358 --> 00:51:18,828
say well we know that about 20% of those

1215
00:51:17,510 --> 00:51:20,690
have worked like planets we don't know

1216
00:51:18,829 --> 00:51:23,599
which ones but let's just randomly pick

1217
00:51:20,690 --> 00:51:26,358
20% if you only go up 5 meter telescope

1218
00:51:23,599 --> 00:51:27,800
you only got a few right but if you go

1219
00:51:26,358 --> 00:51:30,500
to 10 meters now you're starting to talk

1220
00:51:27,800 --> 00:51:33,710
about real numbers and the reason that

1221
00:51:30,500 --> 00:51:35,838
matters is that you know we don't have

1222
00:51:33,710 --> 00:51:37,639
to be lucky it's possible that all of

1223
00:51:35,838 --> 00:51:39,619
all we are like planets you know if

1224
00:51:37,639 --> 00:51:41,509
every sun-like star has an earth-like

1225
00:51:39,619 --> 00:51:43,160
planet it might be there only one

1226

00:51:41,510 --> 00:51:45,650
percent of those have just the right

1227
00:51:43,159 --> 00:51:48,409
conditions to have developed life to

1228
00:51:45,650 --> 00:51:51,800
have these biomarkers to have bacteria

1229
00:51:48,409 --> 00:51:53,899
and bipeds right so we don't want to

1230
00:51:51,800 --> 00:51:55,789
gamble it too much right if you're gonna

1231
00:51:53,900 --> 00:51:58,220
build a big telescope and launch it into

1232
00:51:55,789 --> 00:52:00,099
space and really you know spend a lot of

1233
00:51:58,219 --> 00:52:02,449
money and waste a lot of people's time

1234
00:52:00,099 --> 00:52:04,460
you don't want to gamble on just doing

1235
00:52:02,449 --> 00:52:06,019
it with 10 planets because it would say

1236
00:52:04,460 --> 00:52:07,579
if only 1% of those planets have life

1237
00:52:06,019 --> 00:52:10,338
and you only roll the dice in time

1238
00:52:07,579 --> 00:52:11,720
you're not going to win right so what we

1239
00:52:10,338 --> 00:52:13,159
want to do is we roll the dice enough

1240
00:52:11,719 --> 00:52:15,379

times that we know we're going to come

1241

00:52:13,159 --> 00:52:15,960

up or we can really predict confidently

1242

00:52:15,380 --> 00:52:18,570

we're going to come

1243

00:52:15,960 --> 00:52:21,150

winters even if people die someone

1244

00:52:18,570 --> 00:52:23,338

guesses so turns out the number you

1245

00:52:21,150 --> 00:52:26,369

really eat is more like 50 to 70 we'd

1246

00:52:23,338 --> 00:52:27,869

really like 100 planets and that forces

1247

00:52:26,369 --> 00:52:29,490

us to these very warm temperatures

1248

00:52:27,869 --> 00:52:31,619

because we have to use stars that are

1249

00:52:29,489 --> 00:52:33,539

progressively further away and planets

1250

00:52:31,619 --> 00:52:35,250

that are progressively fan so that

1251

00:52:33,539 --> 00:52:39,179

forces us to be in this region between

1252

00:52:35,250 --> 00:52:42,260

10 and 12 meters to pick up 70 50 70 100

1253

00:52:39,179 --> 00:52:44,759

plants that's a 10 millimeter Tulsa

1254

00:52:42,260 --> 00:52:46,920

that's as I said that's critical because

1255
00:52:44,760 --> 00:52:48,990
we don't know the actual rate of wyeth

1256
00:52:46,920 --> 00:52:53,760
on these earth-like planets and we have

1257
00:52:48,989 --> 00:52:55,169
to improve our odds by aiming high okay

1258
00:52:53,760 --> 00:52:57,690
so it's a simple equation between a

1259
00:52:55,170 --> 00:52:59,700
large telescope and 50 years for a lot

1260
00:52:57,690 --> 00:53:01,650
of planets maybe life we don't know we

1261
00:52:59,699 --> 00:53:03,509
have to take we have the first find

1262
00:53:01,650 --> 00:53:05,280
these by going to the star calling out

1263
00:53:03,510 --> 00:53:07,740
the star light imaging the earth-like

1264
00:53:05,280 --> 00:53:10,500
planet taking a spectrum and hoping that

1265
00:53:07,739 --> 00:53:14,009
get this expect right with the water or

1266
00:53:10,500 --> 00:53:15,358
the oxygen and the ozone and that would

1267
00:53:14,010 --> 00:53:16,830
be the ramp loss that would be the

1268
00:53:15,358 --> 00:53:19,079
spectrum of earth-like planet and

1269
00:53:16,829 --> 00:53:21,088
habitable zone of the star showing

1270
00:53:19,079 --> 00:53:28,130
biological molecules and that's going to

1271
00:53:21,088 --> 00:53:30,690
be you know in the newspaper right 35

1272
00:53:28,130 --> 00:53:32,640
discoveries announced I guarantee you

1273
00:53:30,690 --> 00:53:34,500
will never see a spectrum like that

1274
00:53:32,639 --> 00:53:35,670
they'll show some artist's conception of

1275
00:53:34,500 --> 00:53:38,519
the plan because they never show

1276
00:53:35,670 --> 00:53:45,960
spectroscopy in the newspaper presumably

1277
00:53:38,519 --> 00:53:46,920
bob was not going to have any but that's

1278
00:53:45,960 --> 00:53:49,320
not all

1279
00:53:46,920 --> 00:53:51,240
you're not only discovering earth-like

1280
00:53:49,320 --> 00:53:52,380
planets with potentially life on them

1281
00:53:51,239 --> 00:53:54,209
but you're going to completely

1282
00:53:52,380 --> 00:53:56,430
revolutionize the rest of the stronger

1283

00:53:54,210 --> 00:53:58,108
right 10 meter telescope in space at 12

1284
00:53:56,429 --> 00:54:00,598
meter telescope in space this is a big

1285
00:53:58,108 --> 00:54:02,190
deal and it tells us all kinds of things

1286
00:54:00,599 --> 00:54:05,160
we didn't know before about galaxies

1287
00:54:02,190 --> 00:54:06,960
stars everything even think of and what

1288
00:54:05,159 --> 00:54:08,639
it really does is follow through this

1289
00:54:06,960 --> 00:54:11,050
promised I were part of the akane who

1290
00:54:08,639 --> 00:54:13,869
won the Nobel Prize in Physics in 2002

1291
00:54:11,050 --> 00:54:15,190
and x-ray astronomy he was also the

1292
00:54:13,869 --> 00:54:18,009
first director of the Space Telescope

1293
00:54:15,190 --> 00:54:19,599
Science Institute 21st century

1294
00:54:18,010 --> 00:54:21,460
astronomers are uniquely positioned to

1295
00:54:19,599 --> 00:54:24,190
study evolution of the universe in order

1296
00:54:21,460 --> 00:54:26,139
to relate causally related cause elite

1297
00:54:24,190 --> 00:54:27,909

would fit the chain of causes the

1298

00:54:26,139 --> 00:54:30,009

physical conditions during a Big Bang to

1299

00:54:27,909 --> 00:54:32,710

the development of our Navy and our team

1300

00:54:30,010 --> 00:54:34,360

at mature and there really is an actual

1301

00:54:32,710 --> 00:54:36,190

link between those two things in the way

1302

00:54:34,360 --> 00:54:37,870

that they are so the frontier for

1303

00:54:36,190 --> 00:54:39,250

astronomy is not only to discover these

1304

00:54:37,869 --> 00:54:41,799

earth-like planets improvements like

1305

00:54:39,250 --> 00:54:44,050

their but to figure out how we got right

1306

00:54:41,800 --> 00:54:47,410

which is the same way that we got here

1307

00:54:44,050 --> 00:54:50,140

and I like to illustrate this profound

1308

00:54:47,409 --> 00:54:52,029

fact with the answer to a question that

1309

00:54:50,139 --> 00:54:54,009

Neil Tyson was asked I think on a radio

1310

00:54:52,030 --> 00:54:56,140

show it's actually a pretty cool YouTube

1311

00:54:54,010 --> 00:54:57,850

video if you dig it out what is the most

1312
00:54:56,139 --> 00:55:02,500
astounding fact you could share with us

1313
00:54:57,849 --> 00:55:04,119
about the universe it wasn't his vest it

1314
00:55:02,500 --> 00:55:06,130
was the knowledge that the atoms

1315
00:55:04,119 --> 00:55:07,900
comprise life on Earth the atoms that

1316
00:55:06,130 --> 00:55:09,250
make up the human body are traceable to

1317
00:55:07,900 --> 00:55:11,590
the crucibles that cooked light elements

1318
00:55:09,250 --> 00:55:13,389
into heavier elements and all the

1319
00:55:11,590 --> 00:55:15,010
fundamental ingredients of life itself

1320
00:55:13,389 --> 00:55:17,559
that's the fusion of hydrogen to helium

1321
00:55:15,010 --> 00:55:20,050
to carbon nitrogen to oxygen in the

1322
00:55:17,559 --> 00:55:22,059
interiors of stars these ingredients

1323
00:55:20,050 --> 00:55:23,800
become part of glass count glass gas

1324
00:55:22,059 --> 00:55:25,269
clouds that form the next generation of

1325
00:55:23,800 --> 00:55:26,560
solar system stars with orbiting planets

1326
00:55:25,269 --> 00:55:28,750
and those planets now have the

1327
00:55:26,559 --> 00:55:30,279
ingredients for what so that when I woke

1328
00:55:28,750 --> 00:55:31,719
up at the night sky and I know that we

1329
00:55:30,280 --> 00:55:32,170
are artists universe we are in this

1330
00:55:31,719 --> 00:55:34,389
universe

1331
00:55:32,170 --> 00:55:37,119
but perhaps more important than that is

1332
00:55:34,389 --> 00:55:38,529
the fact that the universe is in us you

1333
00:55:37,119 --> 00:55:40,569
may have heard me our star stuff and

1334
00:55:38,530 --> 00:55:41,530
that is literally true all the carbon

1335
00:55:40,570 --> 00:55:43,600
all the nitrogen all

1336
00:55:41,530 --> 00:55:46,480
and all magnesium iron everything can

1337
00:55:43,599 --> 00:55:48,210
think of here your body the room came

1338
00:55:46,480 --> 00:55:50,679
out of the star that's pretty profound

1339
00:55:48,210 --> 00:55:53,170
it's so profound that it has t-shirt

1340

00:55:50,679 --> 00:55:55,629
right you are here right what we're

1341
00:55:53,170 --> 00:55:57,070
really saying it's not you are here

1342
00:55:55,630 --> 00:56:03,160
that's true you know we're here very

1343
00:55:57,070 --> 00:56:05,410
galaxy it's wrong we're here right the

1344
00:56:03,159 --> 00:56:07,509
stuff in you used to be in a star used

1345
00:56:05,409 --> 00:56:09,849
to be in the interstellar gas some of it

1346
00:56:07,510 --> 00:56:12,370
used to be in intergalactic space

1347
00:56:09,849 --> 00:56:16,029
because galaxies like to eject material

1348
00:56:12,369 --> 00:56:19,259
out of intergalactic space over time so

1349
00:56:16,030 --> 00:56:21,490
this whole story of the origin of life

1350
00:56:19,260 --> 00:56:23,310
goes through the intergalactic medium

1351
00:56:21,489 --> 00:56:25,839
galaxies the interstellar medium

1352
00:56:23,309 --> 00:56:29,409
supernovae right you used to be part of

1353
00:56:25,840 --> 00:56:31,450
a supernova explosion at some point this

1354
00:56:29,409 --> 00:56:33,849

is the whole story of cosmic birth of

1355

00:56:31,449 --> 00:56:37,029

living earth so what I very briefly go

1356

00:56:33,849 --> 00:56:38,619

through this this evolution from from

1357

00:56:37,030 --> 00:56:40,600

the black exceeds through the birth of

1358

00:56:38,619 --> 00:56:43,480

galaxies through star clusters through

1359

00:56:40,599 --> 00:56:45,789

planet forming into the solar system to

1360

00:56:43,480 --> 00:56:47,139

tell you how this telescope the same

1361

00:56:45,789 --> 00:56:49,090

telescope that's potentially going to

1362

00:56:47,139 --> 00:56:51,489

discover life into the world is going to

1363

00:56:49,090 --> 00:56:53,920

blow open this whole story of how that

1364

00:56:51,489 --> 00:56:55,809

life got there and ourselves right it's

1365

00:56:53,920 --> 00:56:58,659

actually pretty amazing to think that

1366

00:56:55,809 --> 00:57:00,849

even if the life we were to discover

1367

00:56:58,659 --> 00:57:03,159

were to have you know seven heads and to

1368

00:57:00,849 --> 00:57:06,130

drive on the other side of roads we

1369
00:57:03,159 --> 00:57:08,500
would still have this in common right we

1370
00:57:06,130 --> 00:57:11,010
all came out of the same basic common

1371
00:57:08,500 --> 00:57:13,389
origins stars galaxies and planets

1372
00:57:11,010 --> 00:57:16,210
however you know whatever language they

1373
00:57:13,389 --> 00:57:18,639
speak even if they're just unicellular

1374
00:57:16,210 --> 00:57:23,559
bacteria we at least have that talk

1375
00:57:18,639 --> 00:57:25,599
about what we're calling this h TST does

1376
00:57:23,559 --> 00:57:27,429
an amazing thing it improves the

1377
00:57:25,599 --> 00:57:29,349
resolution with which we can observe the

1378
00:57:27,429 --> 00:57:31,539
universe by more than a factor of five

1379
00:57:29,349 --> 00:57:34,420
in one dimension or 25 in another

1380
00:57:31,539 --> 00:57:37,750
dimension over huh it allows us to

1381
00:57:34,420 --> 00:57:39,490
resolve very important thresholds and I

1382
00:57:37,750 --> 00:57:42,579
like to illustrate this with a very

1383
00:57:39,489 --> 00:57:44,259
simple analogy right the gaming image

1384
00:57:42,579 --> 00:57:45,489
sharpness between Hubble which we've all

1385
00:57:44,260 --> 00:57:47,380
been marveling about

1386
00:57:45,489 --> 00:57:49,839
right why look at the end Rafa galaxy

1387
00:57:47,380 --> 00:57:52,660
the image sharpness between Hubble and

1388
00:57:49,840 --> 00:57:54,940
this HGST is exactly the same as between

1389
00:57:52,659 --> 00:57:56,349
the standard definition TVs and in the

1390
00:57:54,940 --> 00:58:02,650
eighties were encased in wooden boxes

1391
00:57:56,349 --> 00:58:05,110
right and the new ultra 4k HD TVs and

1392
00:58:02,650 --> 00:58:07,539
can still barely afford right it's a

1393
00:58:05,110 --> 00:58:09,579
factor of 25 and image sharpness and

1394
00:58:07,539 --> 00:58:12,579
that's going to totally revolutionize

1395
00:58:09,579 --> 00:58:15,969
the vision we have of galaxies stars and

1396
00:58:12,579 --> 00:58:17,949
everything else what I want to make this

1397

00:58:15,969 --> 00:58:19,659
very concrete so you're the great

1398
00:58:17,949 --> 00:58:20,949
postdoc here who likes to make fake

1399
00:58:19,659 --> 00:58:22,539
galaxies and compare them to real

1400
00:58:20,949 --> 00:58:24,669
galaxies and figure out what galaxies

1401
00:58:22,539 --> 00:58:28,210
are doing and he's helped me to simulate

1402
00:58:24,670 --> 00:58:29,980
a galaxy a trench of 2 so this is 10

1403
00:58:28,210 --> 00:58:31,630
billion light years away it's 10 years

1404
00:58:29,980 --> 00:58:34,780
10 million years back in time this

1405
00:58:31,630 --> 00:58:36,820
galaxies Hubble has taken pictures of

1406
00:58:34,780 --> 00:58:38,980
thousands of galaxies that look just

1407
00:58:36,820 --> 00:58:39,730
like this right this is looks like real

1408
00:58:38,980 --> 00:58:45,340
holiday

1409
00:58:39,730 --> 00:58:47,980
it's a discount see at this area if we

1410
00:58:45,340 --> 00:58:50,760
zoom in to it start forming discs you

1411
00:58:47,980 --> 00:58:53,409

really can't see much right it's a more

1412

00:58:50,760 --> 00:58:57,220

even Hubble them which is only you know

1413

00:58:53,409 --> 00:58:59,889

7 8 feet across can't make out all the

1414

00:58:57,219 --> 00:59:01,989

detail well I said janitors he's gonna

1415

00:58:59,889 --> 00:59:04,539

fly that's true I'm gonna do better it's

1416

00:59:01,989 --> 00:59:06,399

vision is sharper but it only observes

1417

00:59:04,539 --> 00:59:07,989

in the infrared it's so it's going to

1418

00:59:06,400 --> 00:59:10,780

miss a lot of the important light

1419

00:59:07,989 --> 00:59:12,429

especially the youngest stars the blue

1420

00:59:10,780 --> 00:59:14,440

starting the drama is out there those

1421

00:59:12,429 --> 00:59:18,368

are the youngest stars they can really

1422

00:59:14,440 --> 00:59:20,590

show up in the JWST image that's like

1423

00:59:18,369 --> 00:59:22,390

this so it's still even though it's a

1424

00:59:20,590 --> 00:59:26,289

sharper picture it's not capturing the

1425

00:59:22,389 --> 00:59:28,690

whole range of what there is to see but

1426
00:59:26,289 --> 00:59:32,199
this look at that compare that to this

1427
00:59:28,690 --> 00:59:34,480
right night and day that's a 12 meter

1428
00:59:32,199 --> 00:59:39,669
telescope observing the same wavelength

1429
00:59:34,480 --> 00:59:41,530
ranges so right now you're seeing

1430
00:59:39,670 --> 00:59:43,510
individual star forming regions all

1431
00:59:41,530 --> 00:59:44,859
these little blobs what used to be just

1432
00:59:43,510 --> 00:59:46,450
a blur breaks up into

1433
00:59:44,858 --> 00:59:48,389
individual star forming regions can

1434
00:59:46,449 --> 00:59:51,460
actually see what's going on there right

1435
00:59:48,389 --> 00:59:54,219
this is these are the building blocks of

1436
00:59:51,460 --> 00:59:56,559
galaxies there's another see you guys on

1437
00:59:54,219 --> 00:59:59,459
satellite galaxies pretty much gone

1438
00:59:56,559 --> 00:59:59,460
right

1439
01:00:04,829 --> 01:00:06,890
you

1440
01:00:08,460 --> 01:00:14,579
and the images from the telethia mitosis

1441
01:00:11,010 --> 01:00:16,260
so this unique spatial resolution from

1442
01:00:14,579 --> 01:00:18,539
having this enormous telescope that's 12

1443
01:00:16,260 --> 01:00:21,090
meter tall so allows us to resolve

1444
01:00:18,539 --> 01:00:24,360
things at a hundred parsecs which is 300

1445
01:00:21,090 --> 01:00:26,850
light-years everywhere in the observable

1446
01:00:24,360 --> 01:00:33,780
universe something you've never been

1447
01:00:26,849 --> 01:00:35,429
able to do before and that's not only

1448
01:00:33,780 --> 01:00:37,380
that but actually I just lied to you

1449
01:00:35,429 --> 01:00:39,929
because I said that was galaxies that's

1450
01:00:37,380 --> 01:00:41,519
true that's part of a galaxy but the

1451
01:00:39,929 --> 01:00:44,699
luminous parts of galaxies the part you

1452
01:00:41,519 --> 01:00:47,599
can see are really only a bit of the

1453
01:00:44,699 --> 01:00:50,609
story let's skip ahead there's a galaxy

1454

01:00:47,599 --> 01:00:56,039
but in fact galaxies are surrounded by

1455
01:00:50,610 --> 01:00:57,900
this very diffuse gaseous medium which

1456
01:00:56,039 --> 01:00:59,789
you can't see in images it's just it

1457
01:00:57,900 --> 01:01:01,920
just doesn't light up in star light the

1458
01:00:59,789 --> 01:01:04,650
stars aren't there but this is the fuel

1459
01:01:01,920 --> 01:01:06,000
that creates galaxies and in fact some

1460
01:01:04,650 --> 01:01:07,200
of those heavy elements the carbon

1461
01:01:06,000 --> 01:01:09,480
nitrogen and other stuff that I

1462
01:01:07,199 --> 01:01:11,789
mentioned earlier used to be out here in

1463
01:01:09,480 --> 01:01:14,309
this so-called circum galactic medium

1464
01:01:11,789 --> 01:01:17,730
and which found its way into a galaxy

1465
01:01:14,309 --> 01:01:20,489
form stars planets people told you know

1466
01:01:17,730 --> 01:01:22,800
toes and everything else and we've never

1467
01:01:20,489 --> 01:01:25,319
seen this stuff right we know it's there

1468
01:01:22,800 --> 01:01:26,880

because you can see it absorbing light

1469

01:01:25,320 --> 01:01:29,430

from the background but we can't take a

1470

01:01:26,880 --> 01:01:31,170

picture of it this Observatory will be

1471

01:01:29,429 --> 01:01:32,609

able to do that and so we'll be able to

1472

01:01:31,170 --> 01:01:35,250

see that galaxies are actually

1473

01:01:32,610 --> 01:01:38,010

surrounded by this rich medium of gas

1474

01:01:35,250 --> 01:01:40,139

that's feeding them that's receiving the

1475

01:01:38,010 --> 01:01:42,240

products of their output and moreover

1476

01:01:40,139 --> 01:01:44,400

this stuff recycles over billions of

1477

01:01:42,239 --> 01:01:46,199

years this gas goes in a galaxy forms of

1478

01:01:44,400 --> 01:01:49,110

star gets kicked out again comes back in

1479

01:01:46,199 --> 01:01:54,960

on this great recycling process and we

1480

01:01:49,110 --> 01:01:57,210

can watch that happen if we not only

1481

01:01:54,960 --> 01:02:01,139

that if that's not enough like the knife

1482

01:01:57,210 --> 01:02:03,599

salesman says but wait there's more at

1483
01:02:01,139 --> 01:02:06,239
the at the resolution that this observer

1484
01:02:03,599 --> 01:02:10,380
can achieve virtually every star in the

1485
01:02:06,239 --> 01:02:12,799
Milky Way moves okay so if you watch a

1486
01:02:10,380 --> 01:02:16,920
star and find a star to wait 10 years

1487
01:02:12,800 --> 01:02:18,630
it'll move right the the velocities we

1488
01:02:16,920 --> 01:02:20,909
can resolve with the tariff

1489
01:02:18,630 --> 01:02:22,980
are actually just kind of my ball right

1490
01:02:20,909 --> 01:02:24,538
out to the nearest stars you can detect

1491
01:02:22,980 --> 01:02:28,349
motion that's as fast as a giant

1492
01:02:24,539 --> 01:02:30,420
tortoise right 0.2 miles per hour so go

1493
01:02:28,349 --> 01:02:32,039
to the zoo like a giant for them if you

1494
01:02:30,420 --> 01:02:34,079
wait if he walked for 10 years without

1495
01:02:32,039 --> 01:02:42,089
stopping and you put it out of 10

1496
01:02:34,079 --> 01:02:44,609
parsecs and then you live them up it's a

1497
01:02:42,088 --> 01:02:47,518
really slow motion right virtually every

1498
01:02:44,608 --> 01:02:49,710
star is moving faster than that out to

1499
01:02:47,518 --> 01:02:52,649
100 parsecs up to 10 kiloparsecs which

1500
01:02:49,710 --> 01:02:55,170
encompasses the entire entire disk of

1501
01:02:52,650 --> 01:02:58,230
the Milky Way we can text up it's moving

1502
01:02:55,170 --> 01:02:59,548
as fast as a Formula one racer out to

1503
01:02:58,230 --> 01:03:01,858
the Earth's galaxy like the Andromeda

1504
01:02:59,548 --> 01:03:03,449
galaxy anything that's moving about as

1505
01:03:01,858 --> 01:03:06,088
fast as the Space Shuttle or spacecraft

1506
01:03:03,449 --> 01:03:08,879
does in orbit also detectable motion and

1507
01:03:06,088 --> 01:03:11,518
and this is amazing because it turns the

1508
01:03:08,880 --> 01:03:13,619
entire galaxy into a movie right

1509
01:03:11,518 --> 01:03:15,959
you can now study not only the static

1510
01:03:13,619 --> 01:03:18,240
universe what stuff looks like when you

1511

01:03:15,960 --> 01:03:20,130
take its picture but watch its motion

1512
01:03:18,239 --> 01:03:22,709
over time so imagine taking that

1513
01:03:20,130 --> 01:03:24,900
Andromeda image in the lobby there and

1514
01:03:22,710 --> 01:03:27,269
seeing it and seeing all the motions of

1515
01:03:24,900 --> 01:03:29,789
the stars and watching all the dynamics

1516
01:03:27,268 --> 01:03:32,250
of the stars and moving and forming over

1517
01:03:29,789 --> 01:03:38,400
time it will be possible to do all of

1518
01:03:32,250 --> 01:03:40,440
this will not only be able to do that

1519
01:03:38,400 --> 01:03:42,630
we'll be able to measure the masses of

1520
01:03:40,440 --> 01:03:44,429
stars individual masses of individual

1521
01:03:42,630 --> 01:03:46,858
stars all the way out past Andromeda

1522
01:03:44,429 --> 01:03:48,358
will be able to see stars forming in

1523
01:03:46,858 --> 01:03:49,858
environments where they currently can't

1524
01:03:48,358 --> 01:03:52,500
this is a Hubble image of the star

1525
01:03:49,858 --> 01:03:54,210

forming region called 32oz it's in our

1526

01:03:52,500 --> 01:03:55,199

one of our own satellite galaxies called

1527

01:03:54,210 --> 01:03:58,858

Magellanic Clouds

1528

01:03:55,199 --> 01:04:00,449

and Hubble sees doesn't were there Frank

1529

01:03:58,858 --> 01:04:02,338

was showing you earlier a lot of those

1530

01:04:00,449 --> 01:04:04,768

star clusters in Andromeda or just did

1531

01:04:02,338 --> 01:04:05,730

they just become a continuous blur in

1532

01:04:04,768 --> 01:04:08,548

the center because we don't have the

1533

01:04:05,730 --> 01:04:10,108

resolution to pick it out it's just he's

1534

01:04:08,548 --> 01:04:12,480

going to be able to see that breaking

1535

01:04:10,108 --> 01:04:14,548

the individual stars count them and work

1536

01:04:12,480 --> 01:04:16,548

out how they got what their masses are

1537

01:04:14,548 --> 01:04:19,349

at having either

1538

01:04:16,548 --> 01:04:21,239

finally one of my favorite products is

1539

01:04:19,349 --> 01:04:22,570

the solar system we went all the way to

1540
01:04:21,239 --> 01:04:24,759
the ends of the universe and now

1541
01:04:22,570 --> 01:04:26,950
that but this is just as much part

1542
01:04:24,760 --> 01:04:29,380
origins as anything else a lot of these

1543
01:04:26,949 --> 01:04:30,519
out of soldiers some objects when we

1544
01:04:29,380 --> 01:04:32,320
figure out what they're made of they

1545
01:04:30,519 --> 01:04:33,789
tell us what some of the oldest

1546
01:04:32,320 --> 01:04:35,019
components of the solar system are they

1547
01:04:33,789 --> 01:04:36,699
tell us how much carbon and nitrogen

1548
01:04:35,019 --> 01:04:38,829
option there was in the early solar

1549
01:04:36,699 --> 01:04:41,079
system when the earth won and they tell

1550
01:04:38,829 --> 01:04:44,860
us much about the history of our own

1551
01:04:41,079 --> 01:04:47,949
planetary system you know if you take an

1552
01:04:44,860 --> 01:04:49,990
image of Pluto with Hubble it looks like

1553
01:04:47,949 --> 01:04:51,819
that not so great

1554
01:04:49,989 --> 01:04:54,039
you can barely make out the fact that

1555
01:04:51,820 --> 01:04:55,450
it's not even a form service but if you

1556
01:04:54,039 --> 01:04:56,769
were to do it with this father you tell

1557
01:04:55,449 --> 01:05:00,489
us so suddenly you can actually see

1558
01:04:56,769 --> 01:05:02,110
service features we can resolve features

1559
01:05:00,489 --> 01:05:04,479
in the outer solar system and have the

1560
01:05:02,110 --> 01:05:06,880
orbit of Jupiter that are as large as

1561
01:05:04,480 --> 01:05:09,519
the island of Manhattan say right which

1562
01:05:06,880 --> 01:05:11,590
is pretty small twenty one of the

1563
01:05:09,519 --> 01:05:14,289
coolest things you can do is watch stuff

1564
01:05:11,590 --> 01:05:16,420
happen on the other planets so this is a

1565
01:05:14,289 --> 01:05:18,429
Hubble observation of the disk of the

1566
01:05:16,420 --> 01:05:20,260
Galilean satellite we're not going all

1567
01:05:18,429 --> 01:05:24,129
the way back to Galileo he discovered

1568

01:05:20,260 --> 01:05:27,280
this it's the ice world probably seen it

1569
01:05:24,130 --> 01:05:29,260
in how the pictures how also discovered

1570
01:05:27,280 --> 01:05:31,900
that it has divers right so those giant

1571
01:05:29,260 --> 01:05:34,510
ice plates crack open in and Jets of

1572
01:05:31,900 --> 01:05:37,570
water vapour come out this one is

1573
01:05:34,510 --> 01:05:39,550
probably about 200 kilometers tall what

1574
01:05:37,570 --> 01:05:42,430
is that 120 miles that's a pretty tall

1575
01:05:39,550 --> 01:05:44,170
geyser but we can't actually say exactly

1576
01:05:42,429 --> 01:05:46,210
how tall it is because Hubble just sees

1577
01:05:44,170 --> 01:05:48,039
a little bit of an indistinct word right

1578
01:05:46,210 --> 01:05:50,320
again it's a problem resolution you have

1579
01:05:48,039 --> 01:05:53,110
a bigger telescope so that you can see

1580
01:05:50,320 --> 01:05:54,700
the structure of those objects follow

1581
01:05:53,110 --> 01:05:56,680
over there evolution over time and learn

1582
01:05:54,699 --> 01:05:59,169

a lot about our solar system even

1583

01:05:56,679 --> 01:06:00,669

without sending the spacecraft which we

1584

01:05:59,170 --> 01:06:03,190

automate right it's great we sent

1585

01:06:00,670 --> 01:06:05,110

spacecraft out there to slip any outer

1586

01:06:03,190 --> 01:06:06,610

planets for years but you can't do that

1587

01:06:05,110 --> 01:06:08,500

for every planet you can't do it at all

1588

01:06:06,610 --> 01:06:10,570

times we have telescopes here were

1589

01:06:08,500 --> 01:06:13,210

pretty competitive with the image

1590

01:06:10,570 --> 01:06:15,400

quality so there's a lot of amazing

1591

01:06:13,210 --> 01:06:17,949

stuff you can do with this telescope

1592

01:06:15,400 --> 01:06:21,220

apart from finding life if that's not

1593

01:06:17,949 --> 01:06:22,449

enough what can I do particularly why

1594

01:06:21,219 --> 01:06:23,059

should involve other galaxies in the

1595

01:06:22,449 --> 01:06:25,669

universe

1596

01:06:23,059 --> 01:06:27,409

Kotzur better that's 300 layers can

1597
01:06:25,670 --> 01:06:29,059
detect virtually every galaxy that's

1598
01:06:27,409 --> 01:06:30,409
former stars at the epoch when our own

1599
01:06:29,059 --> 01:06:31,699
Milky Way point which means you're going

1600
01:06:30,409 --> 01:06:34,429
to see all the Milky Way these building

1601
01:06:31,699 --> 01:06:35,599
blocks and the entire history of

1602
01:06:34,429 --> 01:06:37,549
galaxies like it up through the

1603
01:06:35,599 --> 01:06:39,019
president we can observe individual

1604
01:06:37,550 --> 01:06:40,940
supernovae all the way back to the

1605
01:06:39,019 --> 01:06:42,650
beginning of the universe we can see

1606
01:06:40,940 --> 01:06:44,900
this nearly invisible gas feeding

1607
01:06:42,650 --> 01:06:46,910
galaxies and receiving their products

1608
01:06:44,900 --> 01:06:48,740
and recycling can watch the motion of

1609
01:06:46,909 --> 01:06:52,839
virtually any star we choose and a local

1610
01:06:48,739 --> 01:06:52,839
Group of galaxies and we can see

1611
01:06:54,219 --> 01:07:01,459
including those big models which is

1612
01:06:59,809 --> 01:07:09,469
older than it allows us to draw this

1613
01:07:01,460 --> 01:07:10,909
whole picture of cosmic birth so I just

1614
01:07:09,469 --> 01:07:13,939
want to leave you with the thought that

1615
01:07:10,909 --> 01:07:16,719
we're building on 400 years of

1616
01:07:13,940 --> 01:07:19,099
astronomical history right sorry

1617
01:07:16,719 --> 01:07:20,869
Galileo's first attempt to put a

1618
01:07:19,099 --> 01:07:24,380
telescope on the sky and figure out what

1619
01:07:20,869 --> 01:07:25,849
was there and his historical and

1620
01:07:24,380 --> 01:07:27,619
revolutionary discovery that there was a

1621
01:07:25,849 --> 01:07:30,230
world out there to know that wasn't

1622
01:07:27,619 --> 01:07:32,389
terrestrial all the way through the

1623
01:07:30,230 --> 01:07:34,639
astronomical pioneers of the last two

1624
01:07:32,389 --> 01:07:36,799
centuries through our present when we

1625

01:07:34,639 --> 01:07:39,799
started to grasp the idea that there may

1626
01:07:36,800 --> 01:07:42,050
be living planets out there and to think

1627
01:07:39,800 --> 01:07:44,840
that we're you know with 400 years of

1628
01:07:42,050 --> 01:07:47,750
this history behind us possibly only 20

1629
01:07:44,840 --> 01:07:52,430
years from discovering that life is a

1630
01:07:47,750 --> 01:07:54,500
really amazing idea to contemplate so

1631
01:07:52,429 --> 01:07:56,809
I'm excited about this I hope I've got

1632
01:07:54,500 --> 01:07:59,059
you a little bit excited about this I'd

1633
01:07:56,809 --> 01:08:01,549
like you to try and follow our progress

1634
01:07:59,059 --> 01:08:03,139
as we go along the particularly the

1635
01:08:01,550 --> 01:08:05,030
institute has a site called search for

1636
01:08:03,139 --> 01:08:08,420
life net where we post a lot of these

1637
01:08:05,030 --> 01:08:10,130
developments in this field as well as

1638
01:08:08,420 --> 01:08:12,349
some more in-depth material about this

1639
01:08:10,130 --> 01:08:15,050

particular telescope and there's the

1640

01:08:12,349 --> 01:08:18,769

usual websites for tracking what the

1641

01:08:15,050 --> 01:08:20,119

institute here is doing I hope that was

1642

01:08:18,770 --> 01:08:24,370

enjoyable and

1643

01:08:20,119 --> 01:08:24,369

I'm happy to take any questions you have

1644

01:08:47,159 --> 01:08:54,399

I almost hide this seemed to assume but

1645

01:08:52,270 --> 01:08:56,950

we need to be in the range of where

1646

01:08:54,399 --> 01:09:03,399

there's water and so on that's right

1647

01:08:56,949 --> 01:09:06,909

even if so that we need the liquid co2

1648

01:09:03,399 --> 01:09:08,858

yeah it's true so we are making a big

1649

01:09:06,909 --> 01:09:11,469

assumption when we talk this way it's

1650

01:09:08,859 --> 01:09:13,060

you could almost you could remove that

1651

01:09:11,469 --> 01:09:13,630

assumption or you could explain that

1652

01:09:13,060 --> 01:09:15,489

assumption

1653

01:09:13,630 --> 01:09:19,079

I just taking basically everything that

1654
01:09:15,488 --> 01:09:22,838
I said when I said why I would say like

1655
01:09:19,079 --> 01:09:29,680
as we understand carbon-based water

1656
01:09:22,838 --> 01:09:32,350
dependence and person giving I'll prove

1657
01:09:29,680 --> 01:09:34,180
it it's entirely possible people who

1658
01:09:32,350 --> 01:09:36,270
studied the origins of life here on

1659
01:09:34,180 --> 01:09:38,588
earth in these very extreme environments

1660
01:09:36,270 --> 01:09:42,060
speculate that there may be independent

1661
01:09:38,588 --> 01:09:44,409
strings like that here and elsewhere so

1662
01:09:42,060 --> 01:09:46,620
it's a very good point and what I'm

1663
01:09:44,409 --> 01:09:49,088
talking about is is life that we would

1664
01:09:46,619 --> 01:09:58,180
we have at least enough in common that

1665
01:09:49,088 --> 01:10:01,300
as farmer Mason so could you two get out

1666
01:09:58,180 --> 01:10:07,590
there with this and find this life then

1667
01:10:01,300 --> 01:10:07,590
you'll get the money watch I mean

1668
01:10:12,529 --> 01:10:21,500
I think a pic of the song yeah right

1669
01:10:18,850 --> 01:10:24,590
you know these are these are what we

1670
01:10:21,500 --> 01:10:30,590
call flagship missions help love the

1671
01:10:24,590 --> 01:10:33,350
flagship mission and mind you they only

1672
01:10:30,590 --> 01:10:35,720
exist because stronger members and the

1673
01:10:33,350 --> 01:10:37,700
general public and Congress and every

1674
01:10:35,720 --> 01:10:39,590
administration all came to the same

1675
01:10:37,699 --> 01:10:42,439
conclusion which is to make the great

1676
01:10:39,590 --> 01:10:44,150
discoveries you have to have big gains

1677
01:10:42,439 --> 01:10:46,339
in capability and to have a good case of

1678
01:10:44,149 --> 01:10:51,409
capability you have to keep pushing the

1679
01:10:46,340 --> 01:10:56,420
technology we're variable we all are

1680
01:10:51,409 --> 01:10:58,909
that our country and our government and

1681
01:10:56,420 --> 01:11:00,289
ourselves have agreed to support clients

1682

01:10:58,909 --> 01:11:02,329
at this scale for decades

1683
01:11:00,289 --> 01:11:06,890
okay so we're talking about over its

1684
01:11:02,329 --> 01:11:08,600
lifetime the grand scheme of things that

1685
01:11:06,890 --> 01:11:10,400
doesn't add up to much when you're

1686
01:11:08,600 --> 01:11:14,380
comparing it to other things that the

1687
01:11:10,399 --> 01:11:16,489
government spends its money on right but

1688
01:11:14,380 --> 01:11:24,109
what I think you're getting out of that

1689
01:11:16,489 --> 01:11:25,729
is Nobel laureate who discovered the

1690
01:11:24,109 --> 01:11:29,059
cosmic background radiation same as

1691
01:11:25,729 --> 01:11:30,889
marbles and the 1970s he was testifying

1692
01:11:29,060 --> 01:11:33,080
before Congress he is asked by one of

1693
01:11:30,890 --> 01:11:35,780
the budget skeptics mr. Wilson in what

1694
01:11:33,079 --> 01:11:38,300
sense does your proposal zurna Tory

1695
01:11:35,779 --> 01:11:42,289
defend the country and says sorry that's

1696
01:11:38,300 --> 01:11:46,810

not what makes it work that's something

1697

01:11:42,289 --> 01:11:46,810

to keep in mind when you're wiring money

1698

01:11:47,050 --> 01:11:57,710

it's illuminating all of us all all of

1699

01:11:50,750 --> 01:12:02,420

our citizens all of you man I think and

1700

01:11:57,710 --> 01:12:06,590

you say repair that telescope it helped

1701

01:12:02,420 --> 01:12:10,430

to raise that robotic or yeah it could

1702

01:12:06,590 --> 01:12:13,010

be either it's not very well known

1703

01:12:10,430 --> 01:12:14,720

really but nASA has brought this robotic

1704

01:12:13,010 --> 01:12:19,210

servicing capability to a pretty high

1705

01:12:14,720 --> 01:12:19,210

level brightness even to the point when

1706

01:12:29,890 --> 01:13:33,079

so they on the other hand tomorrow thing

1707

01:13:19,010 --> 01:14:00,010

is unique so oxygen mask you come from

1708

01:13:33,079 --> 01:14:04,189

from a source isn't life but oxygen 13

1709

01:14:00,010 --> 01:14:14,659

both like that were little lengthy we

1710

01:14:04,189 --> 01:14:17,109

have we 10% of you know we know how many

1711
01:14:14,659 --> 01:14:17,109
stars have

1712
01:14:18,779 --> 01:14:24,179
as are in their own habitable zones what

1713
01:14:21,149 --> 01:14:27,299
we don't know is given the start of age

1714
01:14:24,180 --> 01:14:29,310
the energy of this planet the mass of

1715
01:14:27,300 --> 01:14:32,579
the planet the after guys we don't know

1716
01:14:29,310 --> 01:14:35,280
how a very this is control the incidence

1717
01:14:32,579 --> 01:14:37,229
of life we know that on our own earth it

1718
01:14:35,279 --> 01:14:40,380
took billions of years to get where you

1719
01:14:37,229 --> 01:14:43,259
are now right if we had observed you

1720
01:14:40,380 --> 01:14:47,489
know if you observe the earth 500

1721
01:14:43,260 --> 01:14:51,180
million years ago where the sea is so

1722
01:14:47,489 --> 01:14:53,519
it's a very subtle problem and we have

1723
01:14:51,180 --> 01:14:56,430
to be open to the fact that most of the

1724
01:14:53,520 --> 01:15:05,040
times we look at what show us see it's

1725
01:14:56,430 --> 01:15:07,530
possible to always keeping with the

1726
01:15:05,039 --> 01:15:09,630
theme of big general questions in the

1727
01:15:07,529 --> 01:15:12,090
near in the hopefully near future when

1728
01:15:09,630 --> 01:15:13,319
we have a catalogue of planets that have

1729
01:15:12,090 --> 01:15:14,819
life as we know it

1730
01:15:13,319 --> 01:15:16,859
what do you envision we might do with

1731
01:15:14,819 --> 01:15:18,929
that information for example would there

1732
01:15:16,859 --> 01:15:21,869
be a way to communicate with as planters

1733
01:15:18,930 --> 01:15:24,060
so one of the nice side benefits of

1734
01:15:21,869 --> 01:15:26,939
observing planets and find life this way

1735
01:15:24,060 --> 01:15:28,320
would be startled really close they're

1736
01:15:26,939 --> 01:15:32,129
all within about fifty to a hundred

1737
01:15:28,319 --> 01:15:34,049
parsecs which is about 150 300 light

1738
01:15:32,130 --> 01:15:36,449
years now

1739

01:15:34,050 --> 01:15:38,190
light travels at a finite velocity which

1740
01:15:36,449 --> 01:15:40,920
means that if you send the radio signal

1741
01:15:38,189 --> 01:15:43,159
it takes fifty to a hundred years to get

1742
01:15:40,920 --> 01:15:43,159
there

1743
01:15:45,600 --> 01:15:50,260
but you know it's theoretically possible

1744
01:15:48,130 --> 01:15:52,779
that you could maintain a conversation

1745
01:15:50,260 --> 01:15:54,070
over such a long time so that that's

1746
01:15:52,779 --> 01:15:55,829
talking to ETS

1747
01:15:54,069 --> 01:15:57,460
I should point out I should not be

1748
01:15:55,829 --> 01:16:00,159
over-promising and I should point out

1749
01:15:57,460 --> 01:16:02,319
you know you can find life with these by

1750
01:16:00,159 --> 01:16:04,239
numbers awesome and ozone methane and it

1751
01:16:02,319 --> 01:16:06,340
doesn't have to be you know people

1752
01:16:04,239 --> 01:16:08,289
walking on thread doesn't have to be man

1753
01:16:06,340 --> 01:16:09,760

it could be bacteria but we at least

1754

01:16:08,289 --> 01:16:12,069

know that there has been an independent

1755

01:16:09,760 --> 01:16:16,500

origin of something living on that

1756

01:16:12,069 --> 01:16:18,969

planet they could be far ahead of us

1757

01:16:16,500 --> 01:16:21,250

another thing you can do is any more

1758

01:16:18,970 --> 01:16:22,990

scientific sense is you can take the

1759

01:16:21,250 --> 01:16:24,369

plants where you see the biomarkers in

1760

01:16:22,989 --> 01:16:26,439

and then everything else you know about

1761

01:16:24,369 --> 01:16:29,380

that content in that star and you can

1762

01:16:26,439 --> 01:16:30,939

start to work out if I if I see life

1763

01:16:29,380 --> 01:16:32,859

it's a star that's older than five

1764

01:16:30,939 --> 01:16:34,059

million years and the planets so and so

1765

01:16:32,859 --> 01:16:35,619

in this orbit and it's good an

1766

01:16:34,060 --> 01:16:37,720

opportunity to start to work out the

1767

01:16:35,619 --> 01:16:39,819

factors that actually may be possible

1768
01:16:37,720 --> 01:16:47,680
and that's going to nail down they say

1769
01:16:39,819 --> 01:16:50,409
we don't know now is it conceivable that

1770
01:16:47,680 --> 01:16:54,369
there could be life like things based on

1771
01:16:50,409 --> 01:17:07,630
something other than car as I understand

1772
01:16:54,369 --> 01:17:15,399
it that is chemical that's outside but I

1773
01:17:07,630 --> 01:17:17,859
understand that is really as you look at

1774
01:17:15,399 --> 01:17:20,049
the structures you see as far out as you

1775
01:17:17,859 --> 01:17:22,659
can see and then you look at like

1776
01:17:20,050 --> 01:17:24,640
certain high-energy particle Prime's is

1777
01:17:22,659 --> 01:17:28,960
there any like relationship between the

1778
01:17:24,640 --> 01:17:31,960
two ends of the you know there's an area

1779
01:17:28,960 --> 01:17:34,000
in between where people think about the

1780
01:17:31,960 --> 01:17:35,409
cosmological consequences of particle

1781
01:17:34,000 --> 01:17:39,189
physics that the energy scales that

1782
01:17:35,409 --> 01:17:41,470
certain pros you know there are some

1783
01:17:39,189 --> 01:17:42,649
high-energy there there are theories

1784
01:17:41,470 --> 01:17:44,539
based on high-energy

1785
01:17:42,649 --> 01:17:50,689
that explained the acceleration of

1786
01:17:44,539 --> 01:17:52,369
universe there's not much bearing of

1787
01:17:50,689 --> 01:17:56,210
high-energy physics directly on the

1788
01:17:52,369 --> 01:18:01,119
question of life and so to the extent

1789
01:17:56,210 --> 01:18:03,039
that universe has to make sense of all

1790
01:18:01,119 --> 01:18:05,960
right any other questions

1791
01:18:03,039 --> 01:18:08,869
all right well Mossman does different

1792
01:18:05,960 --> 01:18:11,000
question I apologize for it but I'm so

1793
01:18:08,869 --> 01:18:15,019
interested you should have picture of

1794
01:18:11,000 --> 01:18:18,738
the Andromeda galaxy taken in 1905 yes

1795
01:18:15,020 --> 01:18:22,550
and of course the whole able to make

1796

01:18:18,738 --> 01:18:25,039
representations to be no astronomer okay

1797
01:18:22,550 --> 01:18:30,980
that was a beautiful picture would you

1798
01:18:25,039 --> 01:18:33,590
mind telling us how do you still thanks

1799
01:18:30,979 --> 01:18:36,198
to the internet I found it there is you

1800
01:18:33,590 --> 01:18:38,630
go to what the Project Gutenberg I

1801
01:18:36,198 --> 01:18:41,448
believe is where I found it it was a

1802
01:18:38,630 --> 01:18:43,069
book that was published before copyright

1803
01:18:41,448 --> 01:18:46,849
was instituted in the United States and

1804
01:18:43,069 --> 01:18:52,908
it had so it was a 1915 or something

1805
01:18:46,850 --> 01:18:55,460
book book on Natural History and it had

1806
01:18:52,908 --> 01:19:07,129
all sorts of illustrations and it did

1807
01:18:55,460 --> 01:19:10,640
have that 1901 year keys observer so I

1808
01:19:07,130 --> 01:19:12,890
just I literally do a lot of searching

1809
01:19:10,640 --> 01:19:14,510
on the internet to find find my imagery

1810
01:19:12,890 --> 01:19:16,310

and that was what I happened to find

1811

01:19:14,510 --> 01:19:18,350

because finding those old photographs

1812

01:19:16,310 --> 01:19:20,810

too compared to today's photographs is

1813

01:19:18,350 --> 01:19:23,960

very important also to show the state of

1814

01:19:20,810 --> 01:19:29,780

photography a hundred years ago 114

1815

01:19:23,960 --> 01:19:31,969

years ago was still pretty good yes bio

1816

01:19:29,779 --> 01:19:34,158

signature you're searching for right now

1817

01:19:31,969 --> 01:19:37,520

what's the level of technology we got it

1818

01:19:34,158 --> 01:19:40,069

get to is James Webb yeah Tandi closer

1819

01:19:37,520 --> 01:19:41,719

to that goal ah it does it doesn't infer

1820

01:19:40,069 --> 01:19:43,039

some fairly significant ways so the

1821

01:19:41,719 --> 01:19:44,630

thing we're learning to do with web

1822

01:19:43,039 --> 01:19:47,029

which we cross our fingers and hope

1823

01:19:44,630 --> 01:19:48,980

works is to build the telescope that's

1824

01:19:47,029 --> 01:19:51,250

larger than what fits into rockets to

1825
01:19:48,979 --> 01:19:54,319
monkeys the deployables

1826
01:19:51,250 --> 01:19:57,319
anything that big enlarger has to be

1827
01:19:54,319 --> 01:20:00,170
launched folded up and then hold itself

1828
01:19:57,319 --> 01:20:02,149
upon us so that's one thing we're

1829
01:20:00,170 --> 01:20:04,069
approving what we're projecting see

1830
01:20:02,149 --> 01:20:06,469
that's called Technology Development and

1831
01:20:04,069 --> 01:20:06,979
housing heritage that look into the next

1832
01:20:06,469 --> 01:20:09,618
day

1833
01:20:06,979 --> 01:20:12,259
but the real challenge is this 10

1834
01:20:09,618 --> 01:20:15,019
billion Bakula it's getting the star leg

1835
01:20:12,260 --> 01:20:17,119
to go away to throw okay well let's just

1836
01:20:15,020 --> 01:20:19,190
take an example right do you want we

1837
01:20:17,118 --> 01:20:20,719
want to throw out the 10 billion photons

1838
01:20:19,189 --> 01:20:22,638
the particles of light coming from the

1839
01:20:20,719 --> 01:20:26,569
star and detect the one coming from the

1840
01:20:22,639 --> 01:20:28,039
planet these planets by the way when you

1841
01:20:26,569 --> 01:20:30,738
go over token your variable in one of

1842
01:20:28,039 --> 01:20:32,090
these planets one particle one photon

1843
01:20:30,738 --> 01:20:33,828
from that planet is going to hit that

1844
01:20:32,090 --> 01:20:37,069
giant mirror as we go around every

1845
01:20:33,828 --> 01:20:38,658
second that's up there so the

1846
01:20:37,069 --> 01:20:40,609
technological challenges to be able to

1847
01:20:38,658 --> 01:20:43,098
know about the Starlight it's like

1848
01:20:40,609 --> 01:20:45,408
finding one person if you took everybody

1849
01:20:43,099 --> 01:20:48,920
on earth and trying to find one person

1850
01:20:45,408 --> 01:20:57,379
right cosmic game will Where's Waldo

1851
01:20:48,920 --> 01:20:59,750
yeah the high contrast imaging is a very

1852
01:20:57,380 --> 01:21:02,270
demanding game where you have to throw

1853

01:20:59,750 --> 01:21:03,920
out that many photons and the ones you

1854
01:21:02,270 --> 01:21:07,489
don't want these people as you want and

1855
01:21:03,920 --> 01:21:09,078
requires very exquisite thermal and

1856
01:21:07,488 --> 01:21:12,408
mechanical stability like this thing has

1857
01:21:09,078 --> 01:21:15,229
to be totally still quiet

1858
01:21:12,408 --> 01:21:23,809
and it requires optical manipulation of

1859
01:21:15,229 --> 01:21:29,118
language that actually projecting out

1860
01:21:23,810 --> 01:21:30,800
saying yeah it's working okay it's

1861
01:21:29,118 --> 01:21:35,769
nine-thirty and we usually cut off at

1862
01:21:30,800 --> 01:21:35,770
9:30 so I want to thank Jason again

1863
01:21:42,979 --> 01:21:48,860
new year next month March third

1864
01:21:46,488 --> 01:21:50,808
dario Robledo a wonderful conversation

1865
01:21:48,859 --> 01:21:54,518
on the combination of art and science

1866
01:21:50,809 --> 01:21:54,519
see you all great night