PUBLIC LECTURE SERIES

How Dark is Space?

Featuring Guest Speaker:
Tod Lauer

1
00:00:07,749 --> 00:00:05,030
welcome to the space telescope public

2
00:00:11,669 --> 00:00:07,759
lecture series tonight's talk

3
00:00:15,749 --> 00:00:11,679
how dark is space by dr todd lauer of

4
00:00:19,510 --> 00:00:17,910
i'm your host dr frank summers of this

5
00:00:22,230 --> 00:00:19,520
office of public outreach here at the

6
00:00:25,109 --> 00:00:22,240
space telescope science institute

7
00:00:27,750 --> 00:00:25,119
and i really always make sure i thank

8
00:00:30,150 --> 00:00:27,760
this amazing tech team thomas marufu and

9
00:00:31,429 --> 00:00:30,160
grant justice who take this and get it

10
00:00:33,190 --> 00:00:31,439
out to you

11
00:00:35,030 --> 00:00:33,200
i also remind you that the space

12
00:00:39,430 --> 00:00:35,040
telescope public lecture series will be

13
00:00:44,549 --> 00:00:42,069

our upcoming talks we're going to have a

14
00:00:47,029 --> 00:00:44,559
talk on november 2nd but i haven't

15
00:00:48,630 --> 00:00:47,039
exactly pinned down who it's going to be

16
00:00:50,150 --> 00:00:48,640
and then of course

17
00:00:52,069 --> 00:00:50,160
what they're going to be talking about

18
00:00:53,830 --> 00:00:52,079
but don't worry i always

19
00:00:56,229 --> 00:00:53,840
make it through i got a whole bunch of

20
00:00:58,389 --> 00:00:56,239
people i just got to pin it down to just

21
00:01:01,110 --> 00:00:58,399
one of them for that so november 2nd

22
00:01:03,990 --> 00:01:01,120
there will be a talk and we'll find out

23
00:01:07,030 --> 00:01:04,000
soon about who that's going to be on

24
00:01:10,630 --> 00:01:07,040
december 7th we will have the james webb

25
00:01:13,750 --> 00:01:10,640
space telescope countdown to launch

26
00:01:15,670 --> 00:01:13,760
that speaker is also to be announced but

27
00:01:17,350 --> 00:01:15,680
that's not my problem that's somebody

28
00:01:20,149 --> 00:01:17,360
else who has to choose who's going to

29
00:01:22,870 --> 00:01:20,159
tell you all about this amazing uh the

30
00:01:25,429 --> 00:01:22,880
james webb space telescope mission as

31
00:01:27,590 --> 00:01:25,439
it's going to launch in december more

32
00:01:30,310 --> 00:01:27,600
about that in just a second

33
00:01:32,550 --> 00:01:30,320
in january on january 4th

34
00:01:35,590 --> 00:01:32,560
maria montesquieu's will be talking

35
00:01:38,390 --> 00:01:35,600
about galaxy clusters all right

36
00:01:40,950 --> 00:01:38,400
and if you want to know more about these

37
00:01:44,550 --> 00:01:40,960
talks you can go to our website

38
00:01:48,710 --> 00:01:46,630

public hyphen lectures

39
00:01:51,030 --> 00:01:48,720
or you can just go to your favorite

40
00:01:52,789 --> 00:01:51,040
search engine type in

41
00:01:55,190 --> 00:01:52,799
hubble public lecture series and you

42
00:01:57,190 --> 00:01:55,200
will find this page

43
00:01:58,630 --> 00:01:57,200
on this page on the left hand side you

44
00:02:01,030 --> 00:01:58,640
can

45
00:02:02,389 --> 00:02:01,040
find links to our webcast both on

46
00:02:04,310 --> 00:02:02,399
youtube

47
00:02:06,789 --> 00:02:04,320
and our webcast archive from the space

48
00:02:09,350 --> 00:02:06,799
telescope science institute

49
00:02:11,190 --> 00:02:09,360
on the right you can find our sign up

50
00:02:14,309 --> 00:02:11,200
for the email just simply enter your

51
00:02:16,550 --> 00:02:14,319
address hit subscribe and you will be on

52
00:02:18,390 --> 00:02:16,560
our email list

53
00:02:20,390 --> 00:02:18,400
also on the website we have

54
00:02:21,990 --> 00:02:20,400
all of the upcoming lectures

55
00:02:23,190 --> 00:02:22,000
and if you click on one of those

56
00:02:25,110 --> 00:02:23,200
lectures

57
00:02:27,190 --> 00:02:25,120
you will get the information about that

58
00:02:30,150 --> 00:02:27,200
lecture uh the full

59
00:02:32,550 --> 00:02:30,160
abstract of the talk as well as after

60
00:02:35,270 --> 00:02:32,560
it's been recorded links to the stsci

61
00:02:37,670 --> 00:02:35,280
webcast as well as the link to it on

62
00:02:39,910 --> 00:02:37,680
youtube

63
00:02:41,750 --> 00:02:39,920

in terms of email well as i said the

64
00:02:43,589 --> 00:02:41,760
announcements it's easiest just to sign

65
00:02:45,830 --> 00:02:43,599
up at the website

66
00:02:49,350 --> 00:02:45,840
you can also subscribe to our youtube

67
00:02:51,110 --> 00:02:49,360
channel that is youtube.com hubble space

68
00:02:52,550 --> 00:02:51,120
telescope all one word hubble space

69
00:02:55,190 --> 00:02:52,560
telescope

70
00:02:57,990 --> 00:02:55,200
when you subscribe you will get notices

71
00:03:00,470 --> 00:02:58,000
of our new videos as well as reminders

72
00:03:02,390 --> 00:03:00,480
of these live events

73
00:03:04,550 --> 00:03:02,400
finally if you have comments or

74
00:03:09,990 --> 00:03:04,560
questions you can send them to the email

75
00:03:13,589 --> 00:03:12,390
if you would like to follow us on social

76
00:03:15,910 --> 00:03:13,599
media

77
00:03:18,790 --> 00:03:15,920
for the hubble space telescope for the

78
00:03:21,110 --> 00:03:18,800
james webb space telescope and just

79
00:03:23,990 --> 00:03:21,120
s-test space telescope science institute

80
00:03:26,470 --> 00:03:24,000
in general we have facebook we have

81
00:03:27,910 --> 00:03:26,480
twitter we have youtube we have

82
00:03:31,030 --> 00:03:27,920
instagram

83
00:03:33,830 --> 00:03:31,040
and you can follow us at the tags there

84
00:03:36,149 --> 00:03:33,840
myself i do a tiny bit of social media

85
00:03:38,149 --> 00:03:36,159
on facebook and twitter

86
00:03:39,589 --> 00:03:38,159
actually a lot of it is all about just

87
00:03:41,750 --> 00:03:39,599
telling people about the public lecture

88
00:03:42,550 --> 00:03:41,760

series

89
00:03:45,270 --> 00:03:42,560
now

90
00:03:47,509 --> 00:03:45,280
our news from the universe for october

91
00:03:50,470 --> 00:03:47,519
2021

92
00:03:53,670 --> 00:03:50,480
and the top story tonight

93
00:03:55,830 --> 00:03:53,680
is the james webb space telescope

94
00:03:58,309 --> 00:03:55,840
save the date

95
00:04:00,550 --> 00:03:58,319
because we had a wonderful announcement

96
00:04:02,710 --> 00:04:00,560
from nasa this month

97
00:04:06,390 --> 00:04:02,720
that the james webb space telescope had

98
00:04:07,990 --> 00:04:06,400
completed its rigorous testing regimen

99
00:04:11,030 --> 00:04:08,000
and also

100
00:04:13,110 --> 00:04:11,040
that ariane space had a successful

101
00:04:14,869 --> 00:04:13,120
launch in july

102
00:04:18,870 --> 00:04:14,879
those two things the completion of

103
00:04:20,789 --> 00:04:18,880
testing and the aryan space a successful

104
00:04:23,110 --> 00:04:20,799
launch they were

105
00:04:25,350 --> 00:04:23,120
allowed them to set

106
00:04:28,390 --> 00:04:25,360
a target launch date for the james webb

107
00:04:30,629 --> 00:04:28,400
space telescope and that day is december

108
00:04:32,950 --> 00:04:30,639
18 2021

109
00:04:34,950 --> 00:04:32,960
which is of course why we're doing the

110
00:04:36,550 --> 00:04:34,960
countdown to launch talk

111
00:04:38,310 --> 00:04:36,560
in december

112
00:04:41,110 --> 00:04:38,320
the james webb space telescope is

113
00:04:43,510 --> 00:04:41,120

currently in shipment to the launch site

114
00:04:46,790 --> 00:04:43,520
and that launch site is

115
00:04:50,070 --> 00:04:46,800
the space port in french guiana this is

116
00:04:51,670 --> 00:04:50,080
the european european spaceport um where

117
00:04:54,150 --> 00:04:51,680
you can see it's just this

118
00:04:56,469 --> 00:04:54,160
amazing facility this is a gorgeous

119
00:04:57,990 --> 00:04:56,479
image i found on their website and in

120
00:05:00,310 --> 00:04:58,000
the front

121
00:05:04,230 --> 00:05:00,320
of this image is where they launched the

122
00:05:07,350 --> 00:05:04,240
ariane 5 rockets and jwst will be going

123
00:05:10,469 --> 00:05:07,360
up in an ariane 5 rocket and it also

124
00:05:12,790 --> 00:05:10,479
shows you why in this previous picture

125
00:05:15,670 --> 00:05:12,800
the james webb space helper is folded up

126
00:05:18,469 --> 00:05:15,680
like this because it needs to be folded

127
00:05:20,629 --> 00:05:18,479
up in order to fit in the top of that

128
00:05:22,310 --> 00:05:20,639
ariane 5 rocket

129
00:05:24,310 --> 00:05:22,320
then after launch it will have its

130
00:05:25,990 --> 00:05:24,320
unfolding and that will be an amazing

131
00:05:27,350 --> 00:05:26,000
stuff and you'll hear all about that in

132
00:05:28,790 --> 00:05:27,360
december

133
00:05:32,870 --> 00:05:28,800
so

134
00:05:33,830 --> 00:05:32,880
really happy holidays with both the

135
00:05:36,150 --> 00:05:33,840
launch

136
00:05:38,710 --> 00:05:36,160
and the deployment of the james webb

137
00:05:40,629 --> 00:05:38,720
space telescope

138
00:05:43,350 --> 00:05:40,639

our second story

139
00:05:46,550 --> 00:05:43,360
what's the matter with galaxy ngc

140
00:05:50,230 --> 00:05:47,909
which by the way i'm just going to call

141
00:05:52,710 --> 00:05:50,240
df2 from now on but i'm not going to

142
00:05:54,550 --> 00:05:52,720
start talking about df2 right now i'm

143
00:05:57,189 --> 00:05:54,560
going to first start talking about large

144
00:05:58,230 --> 00:05:57,199
galaxies with this example the sombrero

145
00:06:01,189 --> 00:05:58,240
galaxy

146
00:06:03,749 --> 00:06:01,199
now these large galaxies they contain

147
00:06:05,350 --> 00:06:03,759
matter all right and when you look at

148
00:06:07,830 --> 00:06:05,360
them you can say oh well there's stuff

149
00:06:10,390 --> 00:06:07,840
that shines we'll call this luminous

150
00:06:11,830 --> 00:06:10,400
matter right and when i say luminous

151
00:06:14,070 --> 00:06:11,840
matter it's not just stuff that you can

152
00:06:16,550 --> 00:06:14,080
see with the eye in the optical but it's

153
00:06:19,909 --> 00:06:16,560
also stuff that shines in infrared and

154
00:06:20,950 --> 00:06:19,919
ultraviolet and x-rays and gamma rays

155
00:06:23,110 --> 00:06:20,960
and

156
00:06:25,189 --> 00:06:23,120
all the um wavelengths of the

157
00:06:27,590 --> 00:06:25,199
electromagnetic spectrum so luminous

158
00:06:29,830 --> 00:06:27,600
matter is anything that shines okay and

159
00:06:31,990 --> 00:06:29,840
you can add up all the matter you that

160
00:06:34,629 --> 00:06:32,000
you see that is luminous

161
00:06:37,270 --> 00:06:34,639
you can also get an estimate of the mass

162
00:06:39,510 --> 00:06:37,280
in the galaxy using dynamics okay we'll

163
00:06:42,950 --> 00:06:39,520

call this dynamical matter so for

164
00:06:45,029 --> 00:06:42,960
example in this disc here the stars are

165
00:06:48,150 --> 00:06:45,039
spinning okay they're rotating around

166
00:06:50,390 --> 00:06:48,160
the disk and the motion of its rotation

167
00:06:53,029 --> 00:06:50,400
the speed of its rotation

168
00:06:55,830 --> 00:06:53,039
it tells you how much matter is

169
00:06:59,029 --> 00:06:55,840
producing that rotation right so the

170
00:07:01,670 --> 00:06:59,039
dynamics of the stars can give you an

171
00:07:05,350 --> 00:07:01,680
estimate of the mass in the galaxy

172
00:07:07,430 --> 00:07:05,360
now for most large galaxies what we find

173
00:07:09,830 --> 00:07:07,440
is that the dynamical matter the matter

174
00:07:12,150 --> 00:07:09,840
you get you know from the motions

175
00:07:13,510 --> 00:07:12,160
is much much greater than the luminous

176
00:07:15,510 --> 00:07:13,520
matter okay

177
00:07:18,070 --> 00:07:15,520
up to factor of 10

178
00:07:18,950 --> 00:07:18,080
and that means there's some non-luminous

179
00:07:20,950 --> 00:07:18,960
matter

180
00:07:22,469 --> 00:07:20,960
and non-luminous well we'll just call

181
00:07:23,350 --> 00:07:22,479
that dark

182
00:07:25,749 --> 00:07:23,360
so

183
00:07:28,710 --> 00:07:25,759
there is dark matter in these large

184
00:07:32,309 --> 00:07:28,720
galaxies up to 90 percent of the mass of

185
00:07:34,550 --> 00:07:32,319
these galaxies is dark matter

186
00:07:36,950 --> 00:07:34,560
so that's the normal thing it's kind of

187
00:07:39,270 --> 00:07:36,960
weird but actually it's for us in

188
00:07:41,029 --> 00:07:39,280

astronomy that's that's the normal

189
00:07:44,469 --> 00:07:41,039
now a weird thing

190
00:07:46,869 --> 00:07:44,479
is a galaxy like df2

191
00:07:49,189 --> 00:07:46,879
now this galaxy is wow that's really a

192
00:07:51,270 --> 00:07:49,199
puffball galaxy because when you look at

193
00:07:54,070 --> 00:07:51,280
this image you're actually looking

194
00:07:56,070 --> 00:07:54,080
through the galaxy right and you can see

195
00:07:58,629 --> 00:07:56,080
lots of other galaxies straight through

196
00:08:01,830 --> 00:07:58,639
this galaxy i mean it's really just you

197
00:08:04,950 --> 00:08:01,840
know stars in this big puffy cotton ball

198
00:08:07,029 --> 00:08:04,960
type shape but it's not very dense it's

199
00:08:08,550 --> 00:08:07,039
a low density galaxy that you can see

200
00:08:11,270 --> 00:08:08,560
straight through

201
00:08:14,869 --> 00:08:11,280
and some previous work on this galaxy

202
00:08:16,469 --> 00:08:14,879
had shown that it had very little or

203
00:08:17,990 --> 00:08:16,479
no dark matter

204
00:08:19,830 --> 00:08:18,000
and there were competing groups that

205
00:08:21,510 --> 00:08:19,840
said yes it does no it doesn't yes it

206
00:08:23,830 --> 00:08:21,520
does no it doesn't which is the way that

207
00:08:25,909 --> 00:08:23,840
science works right and in order to

208
00:08:28,550 --> 00:08:25,919
really settle this question they needed

209
00:08:32,149 --> 00:08:28,560
an accurate distance because if this

210
00:08:33,190 --> 00:08:32,159
galaxy is further away then it's bigger

211
00:08:35,269 --> 00:08:33,200
okay

212
00:08:37,350 --> 00:08:35,279
and would be more massive right and that

213
00:08:40,070 --> 00:08:37,360

would make the dark matter a problem

214
00:08:42,709 --> 00:08:40,080
but if it's closer in if it's closer to

215
00:08:45,030 --> 00:08:42,719
us then it's smaller and it's really not

216
00:08:47,110 --> 00:08:45,040
that much of a problem okay

217
00:08:48,150 --> 00:08:47,120
so what are they going to do

218
00:08:50,389 --> 00:08:48,160
well

219
00:08:53,350 --> 00:08:50,399
you're going to call hubble and hubble

220
00:08:54,710 --> 00:08:53,360
can see the individual stars in this

221
00:08:56,230 --> 00:08:54,720
galaxy

222
00:08:58,630 --> 00:08:56,240
and this pullout what you're supposed to

223
00:09:02,550 --> 00:08:58,640
notice are all those little red dots

224
00:09:04,870 --> 00:09:02,560
okay those red dots are red giant stars

225
00:09:06,870 --> 00:09:04,880
and there is a method called the tip of

226
00:09:08,949 --> 00:09:06,880
the red giant branch

227
00:09:11,430 --> 00:09:08,959
and where that the red giant stars reach

228
00:09:13,670 --> 00:09:11,440
a maximum brightness and from that

229
00:09:16,470 --> 00:09:13,680
maximum brightness you can accurately

230
00:09:18,949 --> 00:09:16,480
measure the distance to this galaxy and

231
00:09:20,389 --> 00:09:18,959
that's what they did with df2

232
00:09:22,550 --> 00:09:20,399
the result

233
00:09:24,870 --> 00:09:22,560
was that the distance was actually

234
00:09:26,790 --> 00:09:24,880
larger than previously thought

235
00:09:29,269 --> 00:09:26,800
pushing it further away making the

236
00:09:31,350 --> 00:09:29,279
galaxy bigger and making the problem

237
00:09:33,190 --> 00:09:31,360
with the dark matter even more

238
00:09:35,509 --> 00:09:33,200

problematic

239
00:09:39,350 --> 00:09:35,519
there is a maximum of about a few

240
00:09:42,150 --> 00:09:39,360
percent dark matter in this galaxy

241
00:09:43,190 --> 00:09:42,160
that is strange

242
00:09:45,269 --> 00:09:43,200
so

243
00:09:49,590 --> 00:09:45,279
the questions we then ask

244
00:09:52,310 --> 00:09:49,600
are well how can a galaxy this large

245
00:09:54,550 --> 00:09:52,320
form without any dark matter or very

246
00:09:56,470 --> 00:09:54,560
little dark matter in it right we don't

247
00:09:58,550 --> 00:09:56,480
understand a formation scenario because

248
00:10:00,949 --> 00:09:58,560
usually the dark matter serves as the

249
00:10:03,750 --> 00:10:00,959
gravitational seed that pulls everything

250
00:10:05,590 --> 00:10:03,760
in to form the very large galaxies well

251
00:10:08,310 --> 00:10:05,600
this is a you know sort of a dwarf

252
00:10:10,630 --> 00:10:08,320
galaxy level one it's a you know about a

253
00:10:13,110 --> 00:10:10,640
billion stars whereas our milky way

254
00:10:15,590 --> 00:10:13,120
galaxy is like 200 billion stars

255
00:10:17,269 --> 00:10:15,600
but those billion stars are spread out

256
00:10:19,670 --> 00:10:17,279
over a volume

257
00:10:21,990 --> 00:10:19,680
similar to the size or even larger than

258
00:10:25,030 --> 00:10:22,000
the size of our milky way galaxy so this

259
00:10:27,910 --> 00:10:25,040
is a strange galaxy in multiple ways

260
00:10:29,190 --> 00:10:27,920
furthermore when you find one object of

261
00:10:31,190 --> 00:10:29,200
this type

262
00:10:33,590 --> 00:10:31,200
you always have to ask well are there

263
00:10:35,829 --> 00:10:33,600

others and the main research group that

264
00:10:38,310 --> 00:10:35,839
announced this discovery

265
00:10:39,190 --> 00:10:38,320
says they already have one more which is

266
00:10:53,190 --> 00:10:39,200
a

267
00:10:55,990 --> 00:10:53,200
but they're going to study to find if

268
00:10:58,470 --> 00:10:56,000
they can find a class of these galaxies

269
00:11:01,110 --> 00:10:58,480
what environments they live in

270
00:11:04,389 --> 00:11:01,120
and use that to help understand

271
00:11:05,350 --> 00:11:04,399
how these galaxies without much dark

272
00:11:07,110 --> 00:11:05,360
matter

273
00:11:10,550 --> 00:11:07,120
could have formed

274
00:11:17,910 --> 00:11:13,670
now our top speed speaker tonight

275
00:11:18,790 --> 00:11:17,920
is coming to us uh as a very special uh

276
00:11:21,910 --> 00:11:18,800
guest

277
00:11:24,630 --> 00:11:21,920
todd has uh a wonderful reputation

278
00:11:27,430 --> 00:11:24,640
amongst astronomers he's a

279
00:11:28,949 --> 00:11:27,440
just a a brilliant speaker so you i know

280
00:11:32,230 --> 00:11:28,959
you're really going to enjoy him

281
00:11:34,310 --> 00:11:32,240
he works at the nsf's national optical

282
00:11:37,910 --> 00:11:34,320
and infrared astronomy research

283
00:11:40,790 --> 00:11:37,920
laboratory in tucson arizona

284
00:11:43,670 --> 00:11:40,800
he got his degrees from cal tech for his

285
00:11:46,389 --> 00:11:43,680
bachelor's and his phd from university

286
00:11:49,269 --> 00:11:46,399
of california santa cruz

287
00:11:51,829 --> 00:11:49,279
he also worked at princeton before

288
00:11:53,350 --> 00:11:51,839

joining the noir lab

289
00:11:55,590 --> 00:11:53,360
and

290
00:11:57,990 --> 00:11:55,600
he has a wonderful history with the

291
00:12:00,389 --> 00:11:58,000
hubble space telescope he was part of

292
00:12:01,750 --> 00:12:00,399
the original wide field planetary camera

293
00:12:03,990 --> 00:12:01,760
team

294
00:12:06,870 --> 00:12:04,000
and it's worked on things like black

295
00:12:10,870 --> 00:12:06,880
holes galactic structure stellar

296
00:12:11,670 --> 00:12:10,880
populations and large scale structure

297
00:12:16,470 --> 00:12:11,680
uh

298
00:12:18,069 --> 00:12:16,480
team for what he's going to tell you

299
00:12:21,829 --> 00:12:18,079
about tonight

300
00:12:24,870 --> 00:12:21,839
um and i won't step on those things and

301
00:12:28,150 --> 00:12:24,880
i would just finish with in early in his

302
00:12:31,030 --> 00:12:28,160
career he received the national the nasa

303
00:12:33,190 --> 00:12:31,040
exceptional science achievement award

304
00:12:34,550 --> 00:12:33,200
for his work on whitefield planetary

305
00:12:36,949 --> 00:12:34,560
camera one

306
00:12:39,750 --> 00:12:36,959
so uh todd will you turn on your video

307
00:12:42,470 --> 00:12:39,760
and such and share your screen

308
00:12:44,150 --> 00:12:42,480
i will share my i will share my screen

309
00:12:47,030 --> 00:12:44,160
okay all right

310
00:12:48,310 --> 00:12:47,040
ladies and gentlemen the eminent todd

311
00:12:50,629 --> 00:12:48,320
lauer

312
00:12:52,790 --> 00:12:50,639
all right the eminent toddler needs to

313
00:12:54,069 --> 00:12:52,800

find the share button there it is okay

314
00:12:56,150 --> 00:12:54,079
goody

315
00:12:58,310 --> 00:12:56,160
let's see okay in there

316
00:13:00,150 --> 00:12:58,320
okay thank you frank for that wonderful

317
00:13:02,629 --> 00:13:00,160
introduction

318
00:13:05,350 --> 00:13:02,639
so i'm going to talk about how dark is

319
00:13:08,310 --> 00:13:05,360
space and why not start with this

320
00:13:10,230 --> 00:13:08,320
wonderful graphic by this french

321
00:13:11,670 --> 00:13:10,240
surrealistic graphic illustrator ghee

322
00:13:13,430 --> 00:13:11,680
below

323
00:13:15,509 --> 00:13:13,440
who does these things for magazines

324
00:13:18,389 --> 00:13:15,519
newspapers what have you

325
00:13:20,069 --> 00:13:18,399
and the concept that he has here is very

326
00:13:22,310 --> 00:13:20,079
simple you have a couple astronomers

327
00:13:23,750 --> 00:13:22,320
looking out the dark slit of an

328
00:13:26,230 --> 00:13:23,760
observatory

329
00:13:27,990 --> 00:13:26,240
pitch black but wait there are shadows

330
00:13:29,670 --> 00:13:28,000
there there's light coming from the

331
00:13:31,190 --> 00:13:29,680
black space

332
00:13:33,430 --> 00:13:31,200
and that's what i'm going to talk about

333
00:13:35,110 --> 00:13:33,440
you know is there light coming from

334
00:13:37,190 --> 00:13:35,120
empty space

335
00:13:39,590 --> 00:13:37,200
and if there is what do we learn from

336
00:13:41,430 --> 00:13:39,600
that how do we know about it

337
00:13:43,110 --> 00:13:41,440
how do we measure it and what do we

338
00:13:45,350 --> 00:13:43,120

learn from it

339
00:13:46,550 --> 00:13:45,360
so the first question that we can take

340
00:13:48,949 --> 00:13:46,560
up is so

341
00:13:49,750 --> 00:13:48,959
why is it dark at night

342
00:13:51,189 --> 00:13:49,760
and

343
00:13:52,790 --> 00:13:51,199
your first reaction is like well you

344
00:13:54,069 --> 00:13:52,800
know i i think it has something to do

345
00:13:56,470 --> 00:13:54,079
with the sun going down i need an

346
00:13:59,750 --> 00:13:56,480
astronomer to tell me this you know

347
00:14:02,470 --> 00:13:59,760
uh but yeah so it the sun goes down and

348
00:14:06,069 --> 00:14:02,480
it gets dark at night but you know

349
00:14:08,790 --> 00:14:06,079
why why isn't there light at night

350
00:14:10,389 --> 00:14:08,800
there's a lot of things there

351
00:14:12,150 --> 00:14:10,399
here's a picture

352
00:14:14,150 --> 00:14:12,160
over the antarctic

353
00:14:16,550 --> 00:14:14,160
way at the south pole which is one of

354
00:14:19,269 --> 00:14:16,560
the darkest places on earth and there is

355
00:14:21,030 --> 00:14:19,279
the milky way and you can see

356
00:14:23,110 --> 00:14:21,040
a couple of our little satellite

357
00:14:25,269 --> 00:14:23,120
galaxies the magellanic clouds are there

358
00:14:27,750 --> 00:14:25,279
in the upper left of the screen and the

359
00:14:29,509 --> 00:14:27,760
image is peppered with stars

360
00:14:30,949 --> 00:14:29,519
and enough light if you will you know

361
00:14:32,790 --> 00:14:30,959
that with a long exposure with the

362
00:14:35,590 --> 00:14:32,800
camera you can see you know the south

363
00:14:38,389 --> 00:14:35,600

pole even at night so there is light

364
00:14:41,030 --> 00:14:38,399
coming from from space but it's dark

365
00:14:42,470 --> 00:14:41,040
they say okay well sure you know there's

366
00:14:44,710 --> 00:14:42,480
stars there

367
00:14:46,870 --> 00:14:44,720
we're looking at 400 billion suns in the

368
00:14:49,350 --> 00:14:46,880
milky way galaxy right there in front of

369
00:14:51,030 --> 00:14:49,360
us but uh you know you have to be a dark

370
00:14:54,150 --> 00:14:51,040
place to see a little bit of city light

371
00:14:56,069 --> 00:14:54,160
will push away those 400 billion suns

372
00:14:57,670 --> 00:14:56,079
so you say well they're far away and

373
00:15:00,470 --> 00:14:57,680
they're not that bright

374
00:15:03,430 --> 00:15:00,480
and that's why it's dark

375
00:15:05,430 --> 00:15:03,440
but if i put a galaxy behind this it'll

376
00:15:08,150 --> 00:15:05,440
be brighter if i put another galaxy

377
00:15:10,230 --> 00:15:08,160
behind it it would be brighter still

378
00:15:12,389 --> 00:15:10,240
if i piled it up it would be extremely

379
00:15:14,629 --> 00:15:12,399
bright

380
00:15:16,949 --> 00:15:14,639
and in fact if you look right into the

381
00:15:19,590 --> 00:15:16,959
heart of the milky way you see stars

382
00:15:21,430 --> 00:15:19,600
spread like dust as billions of stars on

383
00:15:23,350 --> 00:15:21,440
top of each other

384
00:15:25,829 --> 00:15:23,360
in this image you really can't separate

385
00:15:29,110 --> 00:15:25,839
one from the

386
00:15:31,269 --> 00:15:29,120
but it's still very very faint

387
00:15:33,910 --> 00:15:31,279
and this was something that came up an

388
00:15:37,110 --> 00:15:33,920

old discussion from a gentleman named

389
00:15:39,910 --> 00:15:37,120
older it's called albers paradox

390
00:15:41,350 --> 00:15:39,920
if you looked out at the universe at

391
00:15:43,670 --> 00:15:41,360
night

392
00:15:46,470 --> 00:15:43,680
and eventually if it were infinite you

393
00:15:47,910 --> 00:15:46,480
would hit another star stars upon stars

394
00:15:49,189 --> 00:15:47,920
no matter how far you look and that you

395
00:15:50,790 --> 00:15:49,199
say well they get faint around the fur

396
00:15:53,670 --> 00:15:50,800
away but there's more when you get

397
00:15:54,389 --> 00:15:53,680
further away and it perfectly balances

398
00:15:56,310 --> 00:15:54,399
and

399
00:15:59,350 --> 00:15:56,320
the night sky should be

400
00:16:01,509 --> 00:15:59,360
as bright as the surface of the sun

401
00:16:03,829 --> 00:16:01,519
and so the question why is it darkest

402
00:16:06,310 --> 00:16:03,839
night actually has this subtlety and it

403
00:16:07,829 --> 00:16:06,320
says something about the universe

404
00:16:09,189 --> 00:16:07,839
and if you looked at and said well

405
00:16:10,949 --> 00:16:09,199
there's not that much stuff out there

406
00:16:12,870 --> 00:16:10,959
then you've made a profound conclusion

407
00:16:15,350 --> 00:16:12,880
which is correct

408
00:16:17,030 --> 00:16:15,360
no no need to take a fancy course in

409
00:16:18,629 --> 00:16:17,040
astronomy you say it's dark at night it

410
00:16:20,870 --> 00:16:18,639
means there's not that much stuff out

411
00:16:23,110 --> 00:16:20,880
there the universe is finite

412
00:16:25,110 --> 00:16:23,120
in particular case

413
00:16:26,710 --> 00:16:25,120

you say does it go on in space or does

414
00:16:29,110 --> 00:16:26,720
it go on time the answer from the big

415
00:16:31,829 --> 00:16:29,120
bang is the universe has a beginning

416
00:16:32,790 --> 00:16:31,839
and so the deeper answer to why does it

417
00:16:34,710 --> 00:16:32,800
get

418
00:16:36,389 --> 00:16:34,720
dark at night the answer is because the

419
00:16:39,110 --> 00:16:36,399
universe

420
00:16:41,829 --> 00:16:39,120
is only 13 billion years old it had a

421
00:16:46,150 --> 00:16:41,839
beginning and that we've learned

422
00:16:51,670 --> 00:16:48,790
i put this here to illustrate

423
00:16:54,069 --> 00:16:51,680
a little bit of ober's paradox which is

424
00:16:55,990 --> 00:16:54,079
you know imagine yourself in a forest

425
00:16:57,910 --> 00:16:56,000
instead of stars we're going to be

426
00:16:59,509 --> 00:16:57,920
looking at trees and more trees and

427
00:17:00,550 --> 00:16:59,519
distance and you see here in this

428
00:17:02,069 --> 00:17:00,560
particular

429
00:17:04,549 --> 00:17:02,079
rendition

430
00:17:06,710 --> 00:17:04,559
that a lot of the trees overlap

431
00:17:08,390 --> 00:17:06,720
initially you know ultimately you will

432
00:17:10,470 --> 00:17:08,400
be looking at solid wood if the forest

433
00:17:12,230 --> 00:17:10,480
is big enough you can see some uh clear

434
00:17:14,069 --> 00:17:12,240
sky over there at the right you know

435
00:17:15,990 --> 00:17:14,079
this is a little tiny stand of trees

436
00:17:17,750 --> 00:17:16,000
it's not that big and so it is and

437
00:17:19,429 --> 00:17:17,760
that's that's the same thing is it you

438
00:17:21,990 --> 00:17:19,439

know if the universe were infinite

439
00:17:25,189 --> 00:17:22,000
ultimately everywhere you look you would

440
00:17:26,789 --> 00:17:25,199
see the surface of the star

441
00:17:28,630 --> 00:17:26,799
so that tells us right now that the

442
00:17:29,990 --> 00:17:28,640
question why is it dark at night is

443
00:17:31,430 --> 00:17:30,000
actually interesting it tells us

444
00:17:33,190 --> 00:17:31,440
something about the universe it tells us

445
00:17:35,029 --> 00:17:33,200
something profound the universe has

446
00:17:36,950 --> 00:17:35,039
finite age

447
00:17:38,230 --> 00:17:36,960
and that's pretty good and actually i'm

448
00:17:40,549 --> 00:17:38,240
afraid that what i'm going to tell you

449
00:17:42,630 --> 00:17:40,559
further may be a bit of a come down from

450
00:17:44,470 --> 00:17:42,640
that because we know it's dark we know

451
00:17:45,350 --> 00:17:44,480
why it's dark

452
00:17:47,830 --> 00:17:45,360
and

453
00:17:50,470 --> 00:17:47,840
we're going to ask instead how dark is

454
00:17:53,669 --> 00:17:50,480
it it's dark but how how subtly dark is

455
00:17:56,470 --> 00:17:53,679
it can we learn something from that

456
00:17:59,750 --> 00:17:56,480
and so let's look at

457
00:18:02,310 --> 00:17:59,760
this incredible image

458
00:18:05,750 --> 00:18:02,320
at first glance this may not look like a

459
00:18:08,789 --> 00:18:05,760
much it's a black image with lots of

460
00:18:10,310 --> 00:18:08,799
dots of color on it and speckles and

461
00:18:12,390 --> 00:18:10,320
what have you

462
00:18:14,230 --> 00:18:12,400
it is uh

463
00:18:17,190 --> 00:18:14,240

the deepest image ever taken with

464
00:18:18,789 --> 00:18:17,200
anything a hubble space telescope

465
00:18:20,710 --> 00:18:18,799
you want to take a long exposure with

466
00:18:23,350 --> 00:18:20,720
your camera you open the shutter for a

467
00:18:25,270 --> 00:18:23,360
while and you let the light build up

468
00:18:27,029 --> 00:18:25,280
this is what you get if you take the

469
00:18:30,230 --> 00:18:27,039
hubble space telescope and you let the

470
00:18:32,630 --> 00:18:30,240
light build up for 11 days

471
00:18:34,470 --> 00:18:32,640
11 days orbiting around the earth taking

472
00:18:36,230 --> 00:18:34,480
one picture after the other after the

473
00:18:37,430 --> 00:18:36,240
other after the other and adding them

474
00:18:39,110 --> 00:18:37,440
all together

475
00:18:41,830 --> 00:18:39,120
and what you're seeing here

476
00:18:43,990 --> 00:18:41,840
are galaxies and everything there is a

477
00:18:47,430 --> 00:18:44,000
galaxy i showed you the image

478
00:18:49,750 --> 00:18:47,440
the center of the milky way galaxy

479
00:18:51,909 --> 00:18:49,760
of billions of suns well this is an

480
00:18:54,549 --> 00:18:51,919
image looking at that shows the universe

481
00:18:58,390 --> 00:18:54,559
has billions or almost trillions

482
00:18:59,830 --> 00:18:58,400
of galaxies everything here is a galaxy

483
00:19:01,909 --> 00:18:59,840
many of them are bigger than their own

484
00:19:03,270 --> 00:19:01,919
galaxy

485
00:19:05,909 --> 00:19:03,280
and critically

486
00:19:08,310 --> 00:19:05,919
we're looking back in time

487
00:19:09,590 --> 00:19:08,320
because light takes a long time to get

488
00:19:11,590 --> 00:19:09,600

to us

489
00:19:13,350 --> 00:19:11,600
it's called the red shift is tells us

490
00:19:15,029 --> 00:19:13,360
how far away things are you know the

491
00:19:16,630 --> 00:19:15,039
universe is expanding the further away

492
00:19:19,350 --> 00:19:16,640
things are the faster they're going the

493
00:19:21,110 --> 00:19:19,360
further away and so we measure the speed

494
00:19:23,029 --> 00:19:21,120
that they're receding from us that tells

495
00:19:25,430 --> 00:19:23,039
us how far away they are

496
00:19:29,590 --> 00:19:25,440
and they're so far away that the look

497
00:19:32,390 --> 00:19:29,600
back time as we call it is significant

498
00:19:35,590 --> 00:19:32,400
the age of the universe is about 13.6

499
00:19:37,110 --> 00:19:35,600
billion years the earth is only 4.6

500
00:19:38,870 --> 00:19:37,120
billion years most

501
00:19:41,350 --> 00:19:38,880
of what we're seeing here the light came

502
00:19:43,350 --> 00:19:41,360
to us from the time before the earth was

503
00:19:45,909 --> 00:19:43,360
made

504
00:19:49,590 --> 00:19:45,919
and let's step into this a little bit

505
00:19:51,750 --> 00:19:49,600
i have a movie here

506
00:19:52,630 --> 00:19:51,760
this is actually made by frank summers

507
00:19:55,830 --> 00:19:52,640
who

508
00:19:57,430 --> 00:19:55,840
gave that a wonderful introduction

509
00:19:58,789 --> 00:19:57,440
and we're going to take the ultra deep

510
00:20:01,110 --> 00:19:58,799
field

511
00:20:02,310 --> 00:20:01,120
and we're going to take the redshifts

512
00:20:04,230 --> 00:20:02,320
and we're going to turn them into

513
00:20:05,750 --> 00:20:04,240

distances and then we're going to fly

514
00:20:07,990 --> 00:20:05,760
into it and so

515
00:20:12,310 --> 00:20:08,000
you're going deeper into this and you're

516
00:20:16,789 --> 00:20:14,870
back before the earth was made

517
00:20:18,549 --> 00:20:16,799
and ultimately because it's what we see

518
00:20:20,789 --> 00:20:18,559
in this picture we look back in time we

519
00:20:22,390 --> 00:20:20,799
can see when galaxies were being made

520
00:20:24,149 --> 00:20:22,400
and that's what we've learned by looking

521
00:20:25,909 --> 00:20:24,159
at pictures of this

522
00:20:27,350 --> 00:20:25,919
but what i want you to look at in this

523
00:20:29,190 --> 00:20:27,360
picture

524
00:20:31,190 --> 00:20:29,200
is the emptiness of space as the

525
00:20:33,190 --> 00:20:31,200
galaxies go by

526
00:20:35,190 --> 00:20:33,200
it's actually very clean

527
00:20:37,110 --> 00:20:35,200
you might expect little galaxies to be

528
00:20:38,950 --> 00:20:37,120
next to big galaxies or pieces of

529
00:20:40,870 --> 00:20:38,960
galaxies have come off in their

530
00:20:42,549 --> 00:20:40,880
collisions and interactions with each

531
00:20:43,990 --> 00:20:42,559
other and that's true

532
00:20:45,430 --> 00:20:44,000
and as powerful as the hubble space

533
00:20:48,549 --> 00:20:45,440
telescope is

534
00:20:51,990 --> 00:20:48,559
it cannot see infinitely deep

535
00:20:54,710 --> 00:20:52,000
when you look back in time we run out

536
00:20:56,950 --> 00:20:54,720
of galaxies the redshifted too far to

537
00:20:59,830 --> 00:20:56,960
see and a lot of them haven't been made

538
00:21:02,870 --> 00:20:59,840

yet and this region is what the james

539
00:21:04,630 --> 00:21:02,880
webb space telescope is going to do it's

540
00:21:07,110 --> 00:21:04,640
going to look even further back in time

541
00:21:08,789 --> 00:21:07,120
earlier in the creation of the universe

542
00:21:11,110 --> 00:21:08,799
than we could even do with the hubble in

543
00:21:14,870 --> 00:21:11,120
the ultra deep field

544
00:21:16,630 --> 00:21:14,880
but it's all counting galaxies

545
00:21:18,710 --> 00:21:16,640
and even with the most powerful

546
00:21:21,510 --> 00:21:18,720
instrument you ultimately run out of

547
00:21:22,549 --> 00:21:21,520
photons and so the question is

548
00:21:25,909 --> 00:21:22,559
how much

549
00:21:27,909 --> 00:21:25,919
everything that we can add up

550
00:21:30,070 --> 00:21:27,919
because maybe a galaxy is not bright

551
00:21:32,549 --> 00:21:30,080
enough or it's too far away or it's too

552
00:21:34,310 --> 00:21:32,559
small to make a point that the hubble

553
00:21:36,310 --> 00:21:34,320
can see but its light is still there

554
00:21:38,070 --> 00:21:36,320
it'll make a fog

555
00:21:40,630 --> 00:21:38,080
and so we ask

556
00:21:43,270 --> 00:21:40,640
in the picture like the ultra deep field

557
00:21:45,029 --> 00:21:43,280
how deep or how black is it between the

558
00:21:46,789 --> 00:21:45,039
galaxies because that will tell us what

559
00:21:47,990 --> 00:21:46,799
we're missing

560
00:21:50,310 --> 00:21:48,000
and there's a little trick here the

561
00:21:52,549 --> 00:21:50,320
hubble isn't any good at that the james

562
00:21:54,630 --> 00:21:52,559
webb space telescope will be no good at

563
00:21:56,230 --> 00:21:54,640

that and the reason is because the

564
00:21:58,549 --> 00:21:56,240
hubble orbits the earth it's in the

565
00:22:00,310 --> 00:21:58,559
inner solar system and the james webb

566
00:22:01,430 --> 00:22:00,320
telescope will be out a little further

567
00:22:02,950 --> 00:22:01,440
in the moon but it's still going to be

568
00:22:05,190 --> 00:22:02,960
close to the earth

569
00:22:07,350 --> 00:22:05,200
and being caught in the inner solar

570
00:22:09,590 --> 00:22:07,360
system

571
00:22:11,750 --> 00:22:09,600
it's vulnerable to a lot of the dust

572
00:22:14,230 --> 00:22:11,760
that the sun lights up so there's a fog

573
00:22:16,230 --> 00:22:14,240
you know this is this is the the dense

574
00:22:18,630 --> 00:22:16,240
city as it were you know and we've got

575
00:22:20,710 --> 00:22:18,640
this bright sun and it's lighting up all

576
00:22:23,590 --> 00:22:20,720
this dust from the asteroids grinding

577
00:22:25,750 --> 00:22:23,600
into each other and it fogs

578
00:22:27,510 --> 00:22:25,760
ultimately the images that we look at

579
00:22:29,750 --> 00:22:27,520
with the hubble space telescope so if i

580
00:22:31,830 --> 00:22:29,760
measured how bright that black is

581
00:22:33,830 --> 00:22:31,840
actually would be very very bright it'd

582
00:22:36,070 --> 00:22:33,840
be much brighter than with we could

583
00:22:37,909 --> 00:22:36,080
understand and the reason is

584
00:22:39,909 --> 00:22:37,919
because that's just the light from dust

585
00:22:41,110 --> 00:22:39,919
in the inner solar system it's a false

586
00:22:43,029 --> 00:22:41,120
signal

587
00:22:45,590 --> 00:22:43,039
and so that's why we're asking how dark

588
00:22:49,590 --> 00:22:45,600

it is because we would like

589
00:22:51,590 --> 00:22:49,600
okay to look between the galaxies

590
00:22:53,110 --> 00:22:51,600
and add up over the history of the

591
00:22:55,830 --> 00:22:53,120
universe how much light is coming from

592
00:22:57,590 --> 00:22:55,840
everything that made up light but

593
00:23:00,549 --> 00:22:57,600
the dust is blocking

594
00:23:02,950 --> 00:23:00,559
us out it's just the glow is too bright

595
00:23:05,029 --> 00:23:02,960
we have to get away from that

596
00:23:06,710 --> 00:23:05,039
and so the solution

597
00:23:08,870 --> 00:23:06,720
which i will talk about length is to use

598
00:23:10,710 --> 00:23:08,880
new horizons which is at the edge of the

599
00:23:12,950 --> 00:23:10,720
solar system

600
00:23:14,870 --> 00:23:12,960
but it's an interesting question um you

601
00:23:16,390 --> 00:23:14,880
know is there something

602
00:23:17,830 --> 00:23:16,400
unexpected

603
00:23:20,830 --> 00:23:17,840
what is the background and we know that

604
00:23:22,630 --> 00:23:20,840
the universe actually has

605
00:23:25,510 --> 00:23:22,640
backgrounds

606
00:23:27,029 --> 00:23:25,520
and this is this is a full sky image so

607
00:23:29,750 --> 00:23:27,039
it looks funny if you've seen the

608
00:23:31,270 --> 00:23:29,760
pictures uh you know of the globe

609
00:23:32,470 --> 00:23:31,280
that show all the nations to get you

610
00:23:34,390 --> 00:23:32,480
know all the continents everything

611
00:23:35,990 --> 00:23:34,400
that's the same kind of projection

612
00:23:38,789 --> 00:23:36,000
this though is the background to the

613
00:23:40,470 --> 00:23:38,799

universe it was very young this is not

614
00:23:42,149 --> 00:23:40,480
in light that we look at this is in

615
00:23:44,070 --> 00:23:42,159
microwaves if you've heard about the

616
00:23:45,590 --> 00:23:44,080
microwave background this was discovered

617
00:23:49,669 --> 00:23:45,600
in 60s

618
00:23:52,149 --> 00:23:49,679
by two scientists working for bell labs

619
00:23:54,149 --> 00:23:52,159
pensious and wilson

620
00:23:55,990 --> 00:23:54,159
who found static

621
00:23:57,750 --> 00:23:56,000
in their communication intent that they

622
00:24:00,230 --> 00:23:57,760
couldn't understand

623
00:24:01,590 --> 00:24:00,240
and being very dutiful because they were

624
00:24:03,190 --> 00:24:01,600
why they have great microwave

625
00:24:05,190 --> 00:24:03,200
communications with their satellites

626
00:24:06,630 --> 00:24:05,200
they tracked down the source of noise

627
00:24:09,590 --> 00:24:06,640
that turned out to be coming from the

628
00:24:11,669 --> 00:24:09,600
universe itself and as a revolutionary

629
00:24:13,590 --> 00:24:11,679
discovery is why

630
00:24:15,750 --> 00:24:13,600
we believe in the big bang

631
00:24:17,590 --> 00:24:15,760
because the big bang predicted this and

632
00:24:19,430 --> 00:24:17,600
the old theories went by the wayside

633
00:24:20,870 --> 00:24:19,440
when we started seeing the microwave

634
00:24:22,390 --> 00:24:20,880
background

635
00:24:24,149 --> 00:24:22,400
and so we studied this for the early

636
00:24:27,029 --> 00:24:24,159
history of the universe and what you're

637
00:24:28,549 --> 00:24:27,039
looking at is a map made with the planck

638
00:24:30,710 --> 00:24:28,559

satellite

639
00:24:33,510 --> 00:24:30,720
and you see the colors it's measuring

640
00:24:35,029 --> 00:24:33,520
temperature of the early universe

641
00:24:37,750 --> 00:24:35,039
and um

642
00:24:39,909 --> 00:24:37,760
or as we see it now redshifted and red

643
00:24:41,750 --> 00:24:39,919
is a little hot blue's cold

644
00:24:43,590 --> 00:24:41,760
it's fractions of a degree of actually

645
00:24:46,630 --> 00:24:43,600
about a thousandth of a degree what

646
00:24:48,950 --> 00:24:46,640
you're seeing here

647
00:24:50,630 --> 00:24:48,960
but where it's concentrated where it's a

648
00:24:52,390 --> 00:24:50,640
little bit bumpy that's where matter is

649
00:24:55,190 --> 00:24:52,400
going to gather as the universe ages and

650
00:24:57,510 --> 00:24:55,200
turns into the galaxy clusters

651
00:25:00,070 --> 00:24:57,520
the empty regions which are dark

652
00:25:01,750 --> 00:25:00,080
will expand and become even more empty

653
00:25:03,269 --> 00:25:01,760
and this is the start of the large scale

654
00:25:06,149 --> 00:25:03,279
structured universe so we got that by

655
00:25:07,669 --> 00:25:06,159
looking at the microwave background

656
00:25:09,190 --> 00:25:07,679
so what kind of other backgrounds are

657
00:25:10,950 --> 00:25:09,200
there well we know that there's an x-ray

658
00:25:13,190 --> 00:25:10,960
background we know there's an infrared

659
00:25:15,510 --> 00:25:13,200
background how about an ordinary light

660
00:25:19,269 --> 00:25:15,520
astronomers have a little confusing term

661
00:25:22,230 --> 00:25:19,279
for we call it the optical background

662
00:25:24,710 --> 00:25:22,240
but we want to ask is there a background

663
00:25:27,430 --> 00:25:24,720

between the galaxies

664
00:25:29,750 --> 00:25:27,440
which we're not aware of and you know if

665
00:25:30,630 --> 00:25:29,760
we get away from the inner solar system

666
00:25:32,950 --> 00:25:30,640
where

667
00:25:34,870 --> 00:25:32,960
you know the sunlit and dust you know

668
00:25:38,230 --> 00:25:34,880
fogs us out we see something to

669
00:25:40,310 --> 00:25:38,240
rediscover something interesting

670
00:25:43,269 --> 00:25:40,320
and so a theme that i'm going to play

671
00:25:46,470 --> 00:25:43,279
throughout the rest of this talk is

672
00:25:48,390 --> 00:25:46,480
how black is black how dark is dark

673
00:25:51,909 --> 00:25:48,400
and the thing is we are used to seeing

674
00:25:54,310 --> 00:25:51,919
light coming from dark or black things

675
00:25:57,110 --> 00:25:54,320
and so i put up this picture here

676
00:25:59,510 --> 00:25:57,120
this is a picture in front of our house

677
00:26:01,269 --> 00:25:59,520
in tucson uh arizona

678
00:26:04,070 --> 00:26:01,279
that's beatrice muller my wife who's a

679
00:26:07,029 --> 00:26:04,080
fellow astronomer and we've been living

680
00:26:08,149 --> 00:26:07,039
in this house for 25 years

681
00:26:16,470 --> 00:26:08,159
and

682
00:26:18,070 --> 00:26:16,480
excitement being at home with the

683
00:26:19,510 --> 00:26:18,080
pandemic you look for stuff like this

684
00:26:22,070 --> 00:26:19,520
they decided after all this time to

685
00:26:24,549 --> 00:26:22,080
repave uh the street

686
00:26:27,029 --> 00:26:24,559
and you've seen you know how black fresh

687
00:26:28,630 --> 00:26:27,039
asphalt is and it's really striking here

688
00:26:30,870 --> 00:26:28,640

you know the old asphalt you can see in

689
00:26:36,870 --> 00:26:30,880
the lower right corner and here's this

690
00:26:40,950 --> 00:26:38,470
a little bit later when they pave the

691
00:26:43,510 --> 00:26:40,960
other side they went out on the

692
00:26:45,029 --> 00:26:43,520
fresh asphalt and on there is you know

693
00:26:46,870 --> 00:26:45,039
the stuff on the left which had gotten a

694
00:26:48,710 --> 00:26:46,880
bit scuffed up over a week but then they

695
00:26:52,149 --> 00:26:48,720
paved the right part

696
00:26:54,630 --> 00:26:52,159
and that was black asphalt as jet black

697
00:26:57,110 --> 00:26:54,640
as you saw in the previous picture but

698
00:26:58,630 --> 00:26:57,120
you know it was in bright sunlight and i

699
00:27:00,950 --> 00:26:58,640
decided to take a picture of it and you

700
00:27:02,390 --> 00:27:00,960
see the shadow i made that's even darker

701
00:27:04,710 --> 00:27:02,400
still

702
00:27:07,669 --> 00:27:04,720
and so yes that asphalt was really

703
00:27:09,269 --> 00:27:07,679
uh was really black but you know

704
00:27:10,630 --> 00:27:09,279
when you actually put a cast of shadow

705
00:27:12,149 --> 00:27:10,640
on you can see well no there's actually

706
00:27:13,029 --> 00:27:12,159
still quite a bit of light coming from

707
00:27:14,710 --> 00:27:13,039
it

708
00:27:16,549 --> 00:27:14,720
and if you look in my shadow though you

709
00:27:18,710 --> 00:27:16,559
can see that there's little speckles and

710
00:27:20,470 --> 00:27:18,720
that's where you know the sunlight you

711
00:27:21,990 --> 00:27:20,480
were even the stuff not the sunlight

712
00:27:23,590 --> 00:27:22,000
because i'm saying that but all the

713
00:27:25,190 --> 00:27:23,600

light from the sky is actually lighting

714
00:27:26,310 --> 00:27:25,200
up the bright little uh pebbles and

715
00:27:27,590 --> 00:27:26,320
other things in it so you can see

716
00:27:29,510 --> 00:27:27,600
there's even light coming from the

717
00:27:31,590 --> 00:27:29,520
shadow

718
00:27:33,350 --> 00:27:31,600
in fact it's very surprising to see

719
00:27:36,389 --> 00:27:33,360
something that's completely dark and

720
00:27:38,149 --> 00:27:36,399
that's why i put this next picture

721
00:27:40,389 --> 00:27:38,159
of something that i just think is

722
00:27:42,230 --> 00:27:40,399
fascinating there's a paint you can buy

723
00:27:44,870 --> 00:27:42,240
called vanta black

724
00:27:47,430 --> 00:27:44,880
vantablack reflects only one percent of

725
00:27:49,510 --> 00:27:47,440
one percent or one ten thousands of

726
00:27:51,990 --> 00:27:49,520
the light that hits it

727
00:27:53,909 --> 00:27:52,000
and you're looking at two identical

728
00:27:56,230 --> 00:27:53,919
busts

729
00:27:57,510 --> 00:27:56,240
the one on the left in brass there is

730
00:27:59,990 --> 00:27:57,520
the same thing on the right it's just

731
00:28:01,750 --> 00:28:00,000
been painted with vanta black

732
00:28:04,070 --> 00:28:01,760
it's not a piece of construction paper

733
00:28:05,669 --> 00:28:04,080
it's not flat it is as 3d as the picture

734
00:28:08,789 --> 00:28:05,679
on the left but there's no light coming

735
00:28:09,750 --> 00:28:08,799
from it whatsoever and you lose any cues

736
00:28:11,190 --> 00:28:09,760
at all

737
00:28:13,029 --> 00:28:11,200
at what you're looking at there's no

738
00:28:14,389 --> 00:28:13,039

shadows there's no shading there's

739
00:28:16,549 --> 00:28:14,399
absolutely nothing just complete

740
00:28:18,549 --> 00:28:16,559
blackness and we're not used to seeing

741
00:28:20,230 --> 00:28:18,559
things that black

742
00:28:22,389 --> 00:28:20,240
and so this will come up at various

743
00:28:23,750 --> 00:28:22,399
times as i explain what we did you know

744
00:28:28,149 --> 00:28:23,760
how black

745
00:28:30,630 --> 00:28:28,159
and now we're going to get into

746
00:28:32,870 --> 00:28:30,640
a little bit of

747
00:28:34,710 --> 00:28:32,880
what i did and what i my friends and

748
00:28:38,549 --> 00:28:34,720
collaborators did with me this is a team

749
00:28:41,190 --> 00:28:38,559
effort this is a technical uh

750
00:28:43,510 --> 00:28:41,200
slide that i use for technical talks and

751
00:28:45,510 --> 00:28:43,520
there is the fancy term for what we're

752
00:28:47,110 --> 00:28:45,520
looking for is the cosmic optical

753
00:28:49,909 --> 00:28:47,120
background

754
00:28:51,830 --> 00:28:49,919
an optical is an astronomer's word for

755
00:28:53,750 --> 00:28:51,840
ordinary light you know light that you

756
00:28:55,990 --> 00:28:53,760
can see with your eyes you know that

757
00:28:57,750 --> 00:28:56,000
glass works with to bend around optics

758
00:28:59,430 --> 00:28:57,760
and so we call it optic with you use

759
00:29:01,750 --> 00:28:59,440
x-rays you have to use something else to

760
00:29:03,029 --> 00:29:01,760
do that microwaves to see that

761
00:29:05,110 --> 00:29:03,039
background require different

762
00:29:06,870 --> 00:29:05,120
instrumentation here we just use lenses

763
00:29:09,269 --> 00:29:06,880

and mirrors and so it's optics will work

764
00:29:10,710 --> 00:29:09,279
and we call that optical light

765
00:29:12,230 --> 00:29:10,720
and so we're looking for the optical

766
00:29:15,029 --> 00:29:12,240
background

767
00:29:16,630 --> 00:29:15,039
new horizons um

768
00:29:19,029 --> 00:29:16,640
is at the edge of the solar system it's

769
00:29:20,870 --> 00:29:19,039
50 times right now 50 times further away

770
00:29:22,710 --> 00:29:20,880
from the sun than the earth it's away

771
00:29:24,789 --> 00:29:22,720
from the sun and all the dust and

772
00:29:27,029 --> 00:29:24,799
everything the sun lights up

773
00:29:28,710 --> 00:29:27,039
and so with new horizons which is is

774
00:29:31,590 --> 00:29:28,720
leaving the solar system as hanging on

775
00:29:33,430 --> 00:29:31,600
the galaxy we have the opportunity

776
00:29:34,789 --> 00:29:33,440
to look

777
00:29:36,549 --> 00:29:34,799
and see if we can measure something

778
00:29:38,950 --> 00:29:36,559
about the universe in the background

779
00:29:41,350 --> 00:29:38,960
with new horizons instead of say the

780
00:29:43,990 --> 00:29:41,360
james webb space telescope or the hubble

781
00:29:47,990 --> 00:29:44,000
space telescope

782
00:29:50,310 --> 00:29:48,000
so this is new horizons

783
00:29:53,350 --> 00:29:50,320
it's a beautiful little spacecraft this

784
00:29:54,389 --> 00:29:53,360
it was launched in 2006 this is down at

785
00:29:56,149 --> 00:29:54,399
cape canaveral

786
00:29:58,470 --> 00:29:56,159
shortly before it's launched it's

787
00:30:00,310 --> 00:29:58,480
actually very small that the joke always

788
00:30:02,070 --> 00:30:00,320

is you know the shape and size are about

789
00:30:03,669 --> 00:30:02,080
right for a baby grand i think that's a

790
00:30:05,830 --> 00:30:03,679
fair description

791
00:30:08,710 --> 00:30:05,840
you have a radio dish there for sending

792
00:30:11,110 --> 00:30:08,720
stuff back it's wrapped in mylar to keep

793
00:30:12,950 --> 00:30:11,120
it insulated

794
00:30:15,190 --> 00:30:12,960
and

795
00:30:17,909 --> 00:30:15,200
it's going it was used to explore both

796
00:30:21,510 --> 00:30:17,919
pluto and jupiter and it was sent out

797
00:30:23,430 --> 00:30:21,520
the solar system in january 2006 of this

798
00:30:25,590 --> 00:30:23,440
atlas rocket

799
00:30:27,590 --> 00:30:25,600
it ejected it from the earth of the

800
00:30:29,029 --> 00:30:27,600
highest velocity that any spacecraft has

801
00:30:30,870 --> 00:30:29,039
departed the earth

802
00:30:32,710 --> 00:30:30,880
apollo astronauts took three days to go

803
00:30:36,230 --> 00:30:32,720
out to the moon new horizons

804
00:30:39,350 --> 00:30:36,240
would pass the moon in eight hours

805
00:30:41,669 --> 00:30:39,360
and so we escaped the earth we left the

806
00:30:43,909 --> 00:30:41,679
inner solar system with it

807
00:30:45,590 --> 00:30:43,919
we went past jupiter

808
00:30:48,230 --> 00:30:45,600
jupiter

809
00:30:50,230 --> 00:30:48,240
a little slingshot and through

810
00:30:52,870 --> 00:30:50,240
the new horizons even further out into

811
00:30:55,430 --> 00:30:52,880
space uh enabling us to get to pluto in

812
00:30:57,269 --> 00:30:55,440
a reasonable amount of time

813
00:30:59,990 --> 00:30:57,279

and the primary mission was exploring

814
00:31:03,110 --> 00:31:00,000
pluto which we did

815
00:31:04,870 --> 00:31:03,120
in january january excuse me july

816
00:31:07,110 --> 00:31:04,880
of 2015.

817
00:31:09,350 --> 00:31:07,120
and this was the same we turned we took

818
00:31:11,110 --> 00:31:09,360
pluto which was a little fuzzy dot we

819
00:31:13,350 --> 00:31:11,120
turned it into a whole new planet and

820
00:31:15,830 --> 00:31:13,360
world uh to explore

821
00:31:18,789 --> 00:31:15,840
and we went further um

822
00:31:21,029 --> 00:31:18,799
january new year's and 2019

823
00:31:23,029 --> 00:31:21,039
we looked at the kuiper belt object

824
00:31:25,509 --> 00:31:23,039
which was even further away is 40 times

825
00:31:27,909 --> 00:31:25,519
further away from the sun erikoff

826
00:31:29,350 --> 00:31:27,919
and this is about the size of manhattan

827
00:31:31,590 --> 00:31:29,360
and

828
00:31:33,190 --> 00:31:31,600
is what we hope is typical of kuiper

829
00:31:35,110 --> 00:31:33,200
belt objects none of which had been seen

830
00:31:37,269 --> 00:31:35,120
up close before and we learned just

831
00:31:39,269 --> 00:31:37,279
looking at these images with other

832
00:31:40,789 --> 00:31:39,279
things we did we really you know learned

833
00:31:43,509 --> 00:31:40,799
quite a bit about how they're formed and

834
00:31:46,470 --> 00:31:43,519
how the kuiper belt evolved

835
00:31:49,669 --> 00:31:46,480
the new horizons uh is leaving us

836
00:31:52,070 --> 00:31:49,679
is going deeper into space and out

837
00:31:54,070 --> 00:31:52,080
ultimately into the milky way galaxy

838
00:31:57,110 --> 00:31:54,080

and you can see its trajectory here so

839
00:31:58,630 --> 00:31:57,120
there is its launch down earth in 20

840
00:32:01,830 --> 00:31:58,640
2006

841
00:32:02,870 --> 00:32:01,840
out past jupiter for the slingshot

842
00:32:07,029 --> 00:32:02,880
pluto

843
00:32:09,830 --> 00:32:07,039
as i said 2015 ericot 2019

844
00:32:12,070 --> 00:32:09,840
and right now it's 50 what we call a you

845
00:32:13,509 --> 00:32:12,080
that's au is a little bit of a ruler

846
00:32:15,669 --> 00:32:13,519
that we use for measuring distance in

847
00:32:17,830 --> 00:32:15,679
the solar system it's very handy uh the

848
00:32:19,750 --> 00:32:17,840
earth's the size radius of the earth's

849
00:32:21,669 --> 00:32:19,760
orbit is 1au

850
00:32:24,310 --> 00:32:21,679
so at the distance of 1au that means

851
00:32:27,830 --> 00:32:24,320
earth things close to us jupiter is at 5

852
00:32:31,029 --> 00:32:27,840
very simple numbers pluto is like about

853
00:32:33,509 --> 00:32:31,039
eric hoth was at 44 we're now at 50 a.u

854
00:32:35,590 --> 00:32:33,519
getting further away

855
00:32:38,870 --> 00:32:35,600
space is very very dark

856
00:32:41,190 --> 00:32:38,880
and that space is absolutely dark

857
00:32:43,669 --> 00:32:41,200
where new horizons is going

858
00:32:44,950 --> 00:32:43,679
i would like to introduce the team

859
00:32:47,909 --> 00:32:44,960
the work

860
00:32:51,269 --> 00:32:47,919
that i'm talking about here was done

861
00:32:53,269 --> 00:32:51,279
with the new horizons team

862
00:32:57,029 --> 00:32:53,279
i have to say this is

863
00:32:59,830 --> 00:32:57,039

the finest group i've ever worked with

864
00:33:01,269 --> 00:32:59,840
there's a science fiction show

865
00:33:03,029 --> 00:33:01,279
that some of you may have seen at

866
00:33:05,590 --> 00:33:03,039
various times

867
00:33:07,990 --> 00:33:05,600
with in the title as they narrated is

868
00:33:10,310 --> 00:33:08,000
the statement you know to go boldly

869
00:33:13,110 --> 00:33:10,320
where no one has gone before to explain

870
00:33:13,909 --> 00:33:13,120
explore strange new worlds

871
00:33:16,149 --> 00:33:13,919
and

872
00:33:18,070 --> 00:33:16,159
this group really did that

873
00:33:20,149 --> 00:33:18,080
they explored pluto

874
00:33:23,830 --> 00:33:20,159
they explored ericoth we're looking for

875
00:33:25,350 --> 00:33:23,840
some place for a third place to go

876
00:33:27,590 --> 00:33:25,360
they made it work

877
00:33:29,269 --> 00:33:27,600
and it was been my pleasure to work with

878
00:33:30,549 --> 00:33:29,279
this group of people over the last six

879
00:33:32,870 --> 00:33:30,559
years

880
00:33:35,909 --> 00:33:32,880
i should introduce a few of them

881
00:33:38,470 --> 00:33:35,919
uh the pi there is alan stern who is

882
00:33:40,149 --> 00:33:38,480
third from left in the center

883
00:33:43,750 --> 00:33:40,159
he is at swirry

884
00:33:47,909 --> 00:33:43,760
southwest research in boulder colorado

885
00:33:49,190 --> 00:33:47,919
to his right is hal weaver the deputy pi

886
00:33:51,909 --> 00:33:49,200
who is at

887
00:33:53,509 --> 00:33:51,919
applied physics laboratory in maryland

888
00:33:55,669 --> 00:33:53,519

it's operated by johns hopkins

889
00:33:57,269 --> 00:33:55,679
university so it's apl jhu we call it

890
00:33:58,789 --> 00:33:57,279
for short

891
00:34:00,710 --> 00:33:58,799
and that's where this picture is taken

892
00:34:04,389 --> 00:34:00,720
where the camera is operated out of and

893
00:34:07,110 --> 00:34:04,399
then there's a left glenn fountain

894
00:34:08,950 --> 00:34:07,120
who is the was the project manager

895
00:34:10,790 --> 00:34:08,960
and then the incredible alice bowman

896
00:34:12,230 --> 00:34:10,800
who's the chief engineer in our version

897
00:34:15,190 --> 00:34:12,240
of scotty if i

898
00:34:18,389 --> 00:34:15,200
carry the star trek metaphor um

899
00:34:20,389 --> 00:34:18,399
a little bit further who knows every

900
00:34:22,710 --> 00:34:20,399
bit and piece of how new horizons works

901
00:34:24,310 --> 00:34:22,720
and save the day actually for the pluto

902
00:34:26,790 --> 00:34:24,320
encounter where we had a little bit of a

903
00:34:28,550 --> 00:34:26,800
difficulty with the spacecraft and the

904
00:34:30,710 --> 00:34:28,560
back of a hundred people and i've been

905
00:34:31,909 --> 00:34:30,720
my pleasure to know most of these people

906
00:34:33,669 --> 00:34:31,919
and what they've done and they've been

907
00:34:35,270 --> 00:34:33,679
very dedicated to getting the best out

908
00:34:38,149 --> 00:34:35,280
of the mission

909
00:34:40,310 --> 00:34:38,159
i also want to introduce my friend and

910
00:34:41,430 --> 00:34:40,320
the long collaborator mark postman who

911
00:34:46,470 --> 00:34:41,440
is

912
00:34:49,430 --> 00:34:46,480
the populations of galaxy's universe and

913
00:34:51,190 --> 00:34:49,440

i brought mark in uh to help us out mark

914
00:34:53,510 --> 00:34:51,200
being curious about everything helped

915
00:34:54,869 --> 00:34:53,520
out for you know more than populations

916
00:34:56,869 --> 00:34:54,879
of galaxies

917
00:34:58,390 --> 00:34:56,879
and it was a key player in the work i'm

918
00:35:00,790 --> 00:34:58,400
about to show you

919
00:35:04,069 --> 00:35:00,800
so we're going to measure how dark space

920
00:35:08,069 --> 00:35:06,790
the camera we're going to use is called

921
00:35:14,550 --> 00:35:08,079
lori

922
00:35:16,710 --> 00:35:14,560
on new horizons this is a picture of it

923
00:35:18,710 --> 00:35:16,720
it's out the back side of the spacecraft

924
00:35:20,150 --> 00:35:18,720
actually it was closed on that first

925
00:35:22,150 --> 00:35:20,160
picture i showed you but i could have

926
00:35:24,230 --> 00:35:22,160
pointed out the port if you look in

927
00:35:25,910 --> 00:35:24,240
there and i'll move my cursor around the

928
00:35:28,069 --> 00:35:25,920
primary mirror here it's a small

929
00:35:29,910 --> 00:35:28,079
telescope it's about eight inches

930
00:35:31,430 --> 00:35:29,920
in diameter some of you watching

931
00:35:33,750 --> 00:35:31,440
probably have telescopes that big or

932
00:35:35,829 --> 00:35:33,760
larger so it's a small amateur size

933
00:35:38,630 --> 00:35:35,839
reflective telescope and this is just

934
00:35:40,710 --> 00:35:38,640
reflecting the back wall that's that's a

935
00:35:43,030 --> 00:35:40,720
sort of standard mirror

936
00:35:45,030 --> 00:35:43,040
uh this is the secondary you know the

937
00:35:47,030 --> 00:35:45,040
light hits their focus is here bounces

938
00:35:49,270 --> 00:35:47,040

back goes down this black tube and then

939
00:35:51,670 --> 00:35:49,280
into the instrument uh itself where it's

940
00:35:54,790 --> 00:35:51,680
recorded it says ccd is small

941
00:35:56,790 --> 00:35:54,800
ccd compared to ccds only one k by one

942
00:35:59,190 --> 00:35:56,800
case uh smaller than what you have in

943
00:36:01,190 --> 00:35:59,200
your typical camera

944
00:36:03,270 --> 00:36:01,200
i can't resist pointing out something

945
00:36:05,510 --> 00:36:03,280
though because this will come up and

946
00:36:06,790 --> 00:36:05,520
this is more to deal with how black is

947
00:36:08,710 --> 00:36:06,800
black

948
00:36:10,230 --> 00:36:08,720
you see that the camera has these little

949
00:36:12,150 --> 00:36:10,240
baffles in it

950
00:36:13,910 --> 00:36:12,160
to prevent scattered light but also

951
00:36:15,430 --> 00:36:13,920
notice that it's not perfectly black

952
00:36:17,510 --> 00:36:15,440
this one you can see is a little gray

953
00:36:19,430 --> 00:36:17,520
and this one's deeper in you can still

954
00:36:21,430 --> 00:36:19,440
see it there's one third one in you can

955
00:36:22,950 --> 00:36:21,440
see it so there's still some light

956
00:36:27,190 --> 00:36:22,960
getting around for these they'll come up

957
00:36:31,349 --> 00:36:29,349
and so to measure um

958
00:36:33,990 --> 00:36:31,359
the darkness of space we're going to

959
00:36:35,670 --> 00:36:34,000
look out into our galaxy

960
00:36:38,390 --> 00:36:35,680
and this is

961
00:36:40,870 --> 00:36:38,400
a full sky image of the milky way galaxy

962
00:36:43,030 --> 00:36:40,880
it was taken with data from the gaia

963
00:36:45,270 --> 00:36:43,040

satellite operated by the european space

964
00:36:46,870 --> 00:36:45,280
agency and down here again you can see

965
00:36:49,030 --> 00:36:46,880
the little magellanic clouds or

966
00:36:50,470 --> 00:36:49,040
satellite galaxies

967
00:36:52,950 --> 00:36:50,480
and you can see a little bit of a

968
00:36:54,550 --> 00:36:52,960
difficulty you want to measure

969
00:36:56,390 --> 00:36:54,560
the background light from the universe

970
00:36:57,990 --> 00:36:56,400
but this big old galaxy is in the way

971
00:36:59,510 --> 00:36:58,000
you got this plane here you know we're

972
00:37:01,109 --> 00:36:59,520
not going to look here there's the bulge

973
00:37:03,670 --> 00:37:01,119
the black hole that you know the event

974
00:37:05,109 --> 00:37:03,680
horizon telescope image is right there

975
00:37:06,310 --> 00:37:05,119
smack in the middle

976
00:37:08,470 --> 00:37:06,320
so it's not going to be good to look

977
00:37:10,150 --> 00:37:08,480
here and you look at this and say

978
00:37:12,390 --> 00:37:10,160
how about there well it's still bright

979
00:37:14,069 --> 00:37:12,400
you can see it fades away as you get you

980
00:37:16,069 --> 00:37:14,079
know towards the poles but you know

981
00:37:17,829 --> 00:37:16,079
we're in the disk

982
00:37:19,829 --> 00:37:17,839
there's no place that we can go where

983
00:37:22,069 --> 00:37:19,839
there aren't any stars there's a lot of

984
00:37:24,069 --> 00:37:22,079
stars in the sky even when you look away

985
00:37:26,069 --> 00:37:24,079
from the milky way galaxy and you can

986
00:37:27,589 --> 00:37:26,079
see that here again you know

987
00:37:29,750 --> 00:37:27,599
right here it's very dark but it's not

988
00:37:31,589 --> 00:37:29,760

perfectly black so even at what we call

989
00:37:33,670 --> 00:37:31,599
the galaxy poles so let's say this is

990
00:37:35,750 --> 00:37:33,680
the equator there's a north pole and

991
00:37:38,710 --> 00:37:35,760
south galactic pole and we even have a

992
00:37:39,910 --> 00:37:38,720
system of galactic latitude that we use

993
00:37:41,510 --> 00:37:39,920
you know it's our own little coordinate

994
00:37:43,510 --> 00:37:41,520
system for you know bopping around the

995
00:37:46,230 --> 00:37:43,520
galaxy we have galactic longitude

996
00:37:47,910 --> 00:37:46,240
galactic latitude here are the poles

997
00:37:49,190 --> 00:37:47,920
so we want to be far away from the plane

998
00:37:50,630 --> 00:37:49,200
of the galaxy you know we're going to

999
00:37:53,190 --> 00:37:50,640
look up somewhere here where the star is

1000
00:37:54,630 --> 00:37:53,200
least thinner than everywhere else

1001
00:37:56,069 --> 00:37:54,640
and you know we will see the distant

1002
00:37:57,349 --> 00:37:56,079
universe so there's no question about

1003
00:37:58,950 --> 00:37:57,359
that

1004
00:38:00,710 --> 00:37:58,960
we have some other stuff to worry about

1005
00:38:01,589 --> 00:38:00,720
and this is another view of the galaxy

1006
00:38:02,710 --> 00:38:01,599
taken

1007
00:38:06,069 --> 00:38:02,720
in another

1008
00:38:07,349 --> 00:38:06,079
wavelength this is an infrared

1009
00:38:09,430 --> 00:38:07,359
image

1010
00:38:12,630 --> 00:38:09,440
of the milky way galaxy made with the

1011
00:38:14,390 --> 00:38:12,640
japanese akari satellite

1012
00:38:15,910 --> 00:38:14,400
and you can see the plane of the galaxy

1013
00:38:17,430 --> 00:38:15,920

this is in chord there's all you know

1014
00:38:19,030 --> 00:38:17,440
where the stars are there's the black

1015
00:38:20,790 --> 00:38:19,040
hole in the center again

1016
00:38:22,230 --> 00:38:20,800
but gosh look at what we're looking

1017
00:38:23,510 --> 00:38:22,240
through

1018
00:38:26,310 --> 00:38:23,520
it's kind of

1019
00:38:28,790 --> 00:38:26,320
cottony and fluffy up here and

1020
00:38:30,470 --> 00:38:28,800
it may look like if you

1021
00:38:33,349 --> 00:38:30,480
use your imagination a little bit like

1022
00:38:35,750 --> 00:38:33,359
the little cirrus in the daytime sky you

1023
00:38:37,510 --> 00:38:35,760
know when the storm is coming in

1024
00:38:40,710 --> 00:38:37,520
you know and the next day so you see

1025
00:38:43,030 --> 00:38:40,720
cirrus clouding up the clear sky in fact

1026
00:38:45,030 --> 00:38:43,040
we call this imaginatively infrared

1027
00:38:47,030 --> 00:38:45,040
serous because we're looking at the

1028
00:38:48,950 --> 00:38:47,040
actual heat radiation coming off the

1029
00:38:50,069 --> 00:38:48,960
dust it's not lit up

1030
00:38:52,470 --> 00:38:50,079
um

1031
00:38:53,349 --> 00:38:52,480
by reflecting light it's actually uh you

1032
00:38:55,990 --> 00:38:53,359
know

1033
00:38:57,829 --> 00:38:56,000
at 100 microns you can actually see

1034
00:38:59,510 --> 00:38:57,839
the dust directly just by the warmth

1035
00:39:01,030 --> 00:38:59,520
that gives off

1036
00:39:03,190 --> 00:39:01,040
but it's everywhere

1037
00:39:04,550 --> 00:39:03,200
it doesn't absorb a lot of light but it

1038
00:39:05,910 --> 00:39:04,560

does scatter

1039
00:39:07,990 --> 00:39:05,920
light from the milky way and this is

1040
00:39:10,069 --> 00:39:08,000
something we have to think about but

1041
00:39:12,550 --> 00:39:10,079
here though is an illustration of the

1042
00:39:15,829 --> 00:39:12,560
problem i started talking about notice

1043
00:39:17,670 --> 00:39:15,839
this band that cuts across the galaxy

1044
00:39:19,109 --> 00:39:17,680
like this well what's that all about

1045
00:39:20,630 --> 00:39:19,119
okay

1046
00:39:22,870 --> 00:39:20,640
well in a different coordinate system

1047
00:39:25,190 --> 00:39:22,880
that's the plane of our solar system

1048
00:39:27,510 --> 00:39:25,200
it's we've made this projection for the

1049
00:39:29,750 --> 00:39:27,520
galaxy so that's why it turns into an s

1050
00:39:32,310 --> 00:39:29,760
because you know our solar system cuts

1051
00:39:33,910 --> 00:39:32,320
at an angle about 66 degrees to the

1052
00:39:35,670 --> 00:39:33,920
milky way

1053
00:39:38,310 --> 00:39:35,680
and this is what's called zodiacal light

1054
00:39:41,109 --> 00:39:38,320
it's called zodiacal because the plane

1055
00:39:42,950 --> 00:39:41,119
of our solar system defines the zodiac

1056
00:39:44,550 --> 00:39:42,960
constellations

1057
00:39:46,150 --> 00:39:44,560
and if you look anywhere out in the

1058
00:39:48,470 --> 00:39:46,160
plane you'll see that's where the zodiac

1059
00:39:50,870 --> 00:39:48,480
constellations are and the dust in our

1060
00:39:53,990 --> 00:39:50,880
solar system is very concentrated around

1061
00:39:55,829 --> 00:39:54,000
that the sun lights it up

1062
00:39:58,710 --> 00:39:55,839
this case here the heat from the dust is

1063
00:39:59,670 --> 00:39:58,720

visible and this is the band of zodiacal

1064
00:40:02,069 --> 00:39:59,680
light

1065
00:40:04,710 --> 00:40:02,079
that completely bedevils your ability in

1066
00:40:07,030 --> 00:40:04,720
the inner solar system uh to look to the

1067
00:40:09,109 --> 00:40:07,040
distant universe it's very concentrated

1068
00:40:11,270 --> 00:40:09,119
here but even at now we're going to call

1069
00:40:13,270 --> 00:40:11,280
it the ecliptic poles because

1070
00:40:15,990 --> 00:40:13,280
the ecliptic that's our solar system it

1071
00:40:17,750 --> 00:40:16,000
has its own poles north and south

1072
00:40:20,069 --> 00:40:17,760
and even over here you can't see it in

1073
00:40:21,910 --> 00:40:20,079
this map but there's still dust there

1074
00:40:23,670 --> 00:40:21,920
and that's because we the earth is in

1075
00:40:25,829 --> 00:40:23,680
the plane of the solar system it defines

1076
00:40:27,990 --> 00:40:25,839
the plane and solar system there's dust

1077
00:40:30,550 --> 00:40:28,000
all around us and even if i look off of

1078
00:40:32,150 --> 00:40:30,560
the zodiac i still get zodiacal light

1079
00:40:36,390 --> 00:40:32,160
and so there's a background from this no

1080
00:40:40,309 --> 00:40:38,710
and this is um you know something you

1081
00:40:42,710 --> 00:40:40,319
can see yourself

1082
00:40:45,030 --> 00:40:42,720
again you know go to a faint uh you know

1083
00:40:46,309 --> 00:40:45,040
away from the city to look for the milky

1084
00:40:48,710 --> 00:40:46,319
way

1085
00:40:50,230 --> 00:40:48,720
i can go to uh outside the city and i

1086
00:40:52,790 --> 00:40:50,240
can see you know

1087
00:40:55,030 --> 00:40:52,800
the right time of year zodiacal light

1088
00:40:56,950 --> 00:40:55,040

and that you know is a bright glow

1089
00:40:58,550 --> 00:40:56,960
around the zodiac

1090
00:40:59,829 --> 00:40:58,560
and it's it's fascinating i've seen it

1091
00:41:02,150 --> 00:40:59,839
only a few times in my life and i've

1092
00:41:03,990 --> 00:41:02,160
seen it it's incredibly clear it's very

1093
00:41:05,430 --> 00:41:04,000
striking you have to be a dark place to

1094
00:41:07,270 --> 00:41:05,440
see it but it's very striking when you

1095
00:41:08,710 --> 00:41:07,280
see typically i think you know sorry

1096
00:41:09,829 --> 00:41:08,720
actually this is a good time of year

1097
00:41:12,790 --> 00:41:09,839
october

1098
00:41:14,550 --> 00:41:12,800
or march or a good time to see it

1099
00:41:16,950 --> 00:41:14,560
but that is

1100
00:41:18,710 --> 00:41:16,960
in this case you know and again the

1101
00:41:20,550 --> 00:41:18,720
visible light this is the dust

1102
00:41:22,550 --> 00:41:20,560
scattering light from the sun

1103
00:41:24,710 --> 00:41:22,560
it's very bright you wouldn't look for

1104
00:41:26,870 --> 00:41:24,720
faint galaxies you know looking right

1105
00:41:30,630 --> 00:41:26,880
through zodiacal light but it is there

1106
00:41:34,870 --> 00:41:32,470
and this now is more of a technical

1107
00:41:37,270 --> 00:41:34,880
diagram i won't get into it this little

1108
00:41:39,030 --> 00:41:37,280
cute picture here that's a map of dust

1109
00:41:41,829 --> 00:41:39,040
density and the solar system looking

1110
00:41:43,910 --> 00:41:41,839
down on it there you see these au again

1111
00:41:45,990 --> 00:41:43,920
uh heliocentric distance distance that

1112
00:41:48,630 --> 00:41:46,000
fancy word for distance from the sun

1113
00:41:50,630 --> 00:41:48,640

pluto's about 30 you know jupiter is

1114
00:41:53,190 --> 00:41:50,640
like five so right here

1115
00:41:55,670 --> 00:41:53,200
you know mercury venus mars jupiter all

1116
00:41:57,190 --> 00:41:55,680
crammed into this first tick mark

1117
00:41:58,230 --> 00:41:57,200
but look at what happens if you're in

1118
00:42:00,230 --> 00:41:58,240
the plane

1119
00:42:03,030 --> 00:42:00,240
the the strength of the zodiac light

1120
00:42:05,430 --> 00:42:03,040
drops by a factor of

1121
00:42:06,950 --> 00:42:05,440
almost 10 000 by the time i get out here

1122
00:42:09,829 --> 00:42:06,960
the 50 au

1123
00:42:12,550 --> 00:42:09,839
off the plane um you know it's still

1124
00:42:13,670 --> 00:42:12,560
it's still a substantial drop

1125
00:42:15,430 --> 00:42:13,680
going out here and this is where new

1126
00:42:17,589 --> 00:42:15,440
horizons is and that's why we want to

1127
00:42:19,670 --> 00:42:17,599
use new horizons for this because it's

1128
00:42:21,750 --> 00:42:19,680
clean out there we do not have zodiacal

1129
00:42:23,670 --> 00:42:21,760
light bothering us

1130
00:42:27,270 --> 00:42:23,680
so where do we look

1131
00:42:29,829 --> 00:42:27,280
this is another infrared map

1132
00:42:33,910 --> 00:42:29,839
it's taken by in this case the old irs

1133
00:42:35,430 --> 00:42:33,920
satellite which flew in in the 80s

1134
00:42:37,349 --> 00:42:35,440
and you know again you don't want to

1135
00:42:39,510 --> 00:42:37,359
look uh you know where the series is

1136
00:42:41,030 --> 00:42:39,520
strong and scattering light from the

1137
00:42:42,710 --> 00:42:41,040
galaxy so you do want to look at the

1138
00:42:44,630 --> 00:42:42,720

poles

1139
00:42:46,390 --> 00:42:44,640
we didn't for this work in this room we

1140
00:42:48,790 --> 00:42:46,400
actually didn't use new horizons

1141
00:42:51,510 --> 00:42:48,800
directly as it turns out uh for just

1142
00:42:53,430 --> 00:42:51,520
calibration purposes looking at distant

1143
00:42:56,309 --> 00:42:53,440
asteroids and whatnot the new horizons

1144
00:42:58,550 --> 00:42:56,319
had a lot of observations over the sky

1145
00:43:00,630 --> 00:42:58,560
we keep them in an archive for future

1146
00:43:02,470 --> 00:43:00,640
scientific use in this case we searched

1147
00:43:03,910 --> 00:43:02,480
through the archive and said oh well you

1148
00:43:05,990 --> 00:43:03,920
know there's some of these far away from

1149
00:43:06,950 --> 00:43:06,000
the galaxy and some of the exposures are

1150
00:43:08,710 --> 00:43:06,960
deep

1151
00:43:10,390 --> 00:43:08,720
these actually would be good for trying

1152
00:43:12,230 --> 00:43:10,400
to find the optical background of the

1153
00:43:13,990 --> 00:43:12,240
universe and so this is what we started

1154
00:43:15,670 --> 00:43:14,000
with and there were seven fields that we

1155
00:43:17,589 --> 00:43:15,680
were able to identify

1156
00:43:20,150 --> 00:43:17,599
which were suitable for doing this

1157
00:43:23,109 --> 00:43:21,829
so what you see when you looked at these

1158
00:43:24,470 --> 00:43:23,119
images

1159
00:43:26,309 --> 00:43:24,480
this is

1160
00:43:27,910 --> 00:43:26,319
what they might look like it really

1161
00:43:29,270 --> 00:43:27,920
doesn't look like much and i

1162
00:43:30,550 --> 00:43:29,280
deliberately destroyed these for a

1163
00:43:31,589 --> 00:43:30,560

particular

1164
00:43:34,710 --> 00:43:31,599
reason

1165
00:43:35,990 --> 00:43:34,720
i'm showing you uh the seven fields that

1166
00:43:37,750 --> 00:43:36,000
we looked at

1167
00:43:40,309 --> 00:43:37,760
as if they were seen with space

1168
00:43:42,230 --> 00:43:40,319
telescope as dark as space telescope

1169
00:43:44,390 --> 00:43:42,240
could get

1170
00:43:46,230 --> 00:43:44,400
and i set this up to contrast with what

1171
00:43:49,190 --> 00:43:46,240
we're going to see with new horizons and

1172
00:43:51,750 --> 00:43:49,200
this is this

1173
00:43:53,270 --> 00:43:51,760
it turns out that

1174
00:43:55,349 --> 00:43:53,280
pick the darkest sky of the space

1175
00:43:57,990 --> 00:43:55,359
telescope can see and you look at it

1176
00:44:00,390 --> 00:43:58,000
with new horizons it's right off the

1177
00:44:02,150 --> 00:44:00,400
right off the bat you know over 10 times

1178
00:44:04,069 --> 00:44:02,160
darker

1179
00:44:07,109 --> 00:44:04,079
as good as space telescope is it can

1180
00:44:09,109 --> 00:44:07,119
find incredibly faint galaxies

1181
00:44:11,349 --> 00:44:09,119
incredibly faint stars but it does

1182
00:44:13,270 --> 00:44:11,359
through uh through a sky which is still

1183
00:44:15,510 --> 00:44:13,280
relatively bright and that's the

1184
00:44:17,670 --> 00:44:15,520
brightness set the space telescope

1185
00:44:20,309 --> 00:44:17,680
this is what we're looking at

1186
00:44:22,710 --> 00:44:20,319
and so what do i want to do

1187
00:44:25,349 --> 00:44:22,720
or what do we want to do and the answer

1188
00:44:26,790 --> 00:44:25,359

is okay it looks pretty simple and if i

1189
00:44:29,030 --> 00:44:26,800
gave you these images you could try to

1190
00:44:31,510 --> 00:44:29,040
do it yourself let's say well okay uh

1191
00:44:33,829 --> 00:44:31,520
you know i've got these images

1192
00:44:35,670 --> 00:44:33,839
yeah there's lots of stars and even even

1193
00:44:37,910 --> 00:44:35,680
these images because again you saw that

1194
00:44:39,430 --> 00:44:37,920
image of stars everywhere

1195
00:44:41,430 --> 00:44:39,440
there's some faint galaxies they have to

1196
00:44:44,309 --> 00:44:41,440
go but you know they're not incredibly

1197
00:44:45,910 --> 00:44:44,319
crowded so let's look around and

1198
00:44:48,309 --> 00:44:45,920
make a measurement between the stars

1199
00:44:50,790 --> 00:44:48,319
let's block block the stars out and

1200
00:44:52,550 --> 00:44:50,800
measure things in between and we'll make

1201
00:44:54,309 --> 00:44:52,560
a measurement

1202
00:44:56,150 --> 00:44:54,319
and that's the measurement of how bright

1203
00:44:57,829 --> 00:44:56,160
the background sky is

1204
00:44:59,430 --> 00:44:57,839
but that leads to a lot of work which

1205
00:45:00,710 --> 00:44:59,440
i'm going to talk to you about because

1206
00:45:02,870 --> 00:45:00,720
there's other things that come in

1207
00:45:04,950 --> 00:45:02,880
besides this background that we're

1208
00:45:07,109 --> 00:45:04,960
looking for and that's what we had to be

1209
00:45:08,790 --> 00:45:07,119
very careful about

1210
00:45:11,190 --> 00:45:08,800
one of the first questions is are you

1211
00:45:12,710 --> 00:45:11,200
fooling yourself in in some way that you

1212
00:45:13,589 --> 00:45:12,720
don't know about

1213
00:45:15,589 --> 00:45:13,599

um

1214
00:45:18,550 --> 00:45:15,599
night time is something in the way that

1215
00:45:20,390 --> 00:45:18,560
doesn't really exist in the universe

1216
00:45:22,230 --> 00:45:20,400
even where it's dark

1217
00:45:23,750 --> 00:45:22,240
being at night is really in the shadow

1218
00:45:26,630 --> 00:45:23,760
of the sun

1219
00:45:28,630 --> 00:45:26,640
if you're on a spacecraft even you know

1220
00:45:30,790 --> 00:45:28,640
50 a.u out you're still in bright

1221
00:45:32,950 --> 00:45:30,800
sunlight the sun's is surprisingly

1222
00:45:34,870 --> 00:45:32,960
bright uh even that you know as far as

1223
00:45:36,870 --> 00:45:34,880
we've gone i mean been able to lit up

1224
00:45:38,630 --> 00:45:36,880
pluto for us lit up era cloth you know

1225
00:45:39,990 --> 00:45:38,640
quite easily

1226
00:45:41,910 --> 00:45:40,000
and so

1227
00:45:44,150 --> 00:45:41,920
it lights up the spacecraft as well and

1228
00:45:45,670 --> 00:45:44,160
so the first question was you know we

1229
00:45:47,510 --> 00:45:45,680
had to make sure that we were looking

1230
00:45:49,190 --> 00:45:47,520
you know fully away from the sun with

1231
00:45:51,030 --> 00:45:49,200
these images that we found the archive

1232
00:45:52,470 --> 00:45:51,040
well we we selected them that you know

1233
00:45:54,230 --> 00:45:52,480
they were at least angrily far away from

1234
00:45:57,030 --> 00:45:54,240
the sun

1235
00:45:58,309 --> 00:45:57,040
but we were concerned um

1236
00:46:01,990 --> 00:45:58,319
you know was there light that was

1237
00:46:03,750 --> 00:46:02,000
getting in anyway so here is um

1238
00:46:05,510 --> 00:46:03,760

here is you know what the spacecraft

1239
00:46:07,990 --> 00:46:05,520
looks like just lit up in sunlight and

1240
00:46:10,550 --> 00:46:08,000
there's lorry there you know it's it's

1241
00:46:12,710 --> 00:46:10,560
aperture it has a door which opens it

1242
00:46:14,790 --> 00:46:12,720
opens only once it's blown open and it

1243
00:46:17,270 --> 00:46:14,800
stays open for the whole mission

1244
00:46:19,190 --> 00:46:17,280
but wait what are these things here ah

1245
00:46:21,510 --> 00:46:19,200
gee okay well these are help us with

1246
00:46:23,349 --> 00:46:21,520
navigation these are our star trackers

1247
00:46:24,790 --> 00:46:23,359
which we get to position the spacecraft

1248
00:46:26,870 --> 00:46:24,800
from and they kind of stick out a little

1249
00:46:29,910 --> 00:46:26,880
bit oh gosh

1250
00:46:31,270 --> 00:46:29,920
you know are they lit up by the sun

1251
00:46:33,829 --> 00:46:31,280
and this is by the way while you work

1252
00:46:35,190 --> 00:46:33,839
with a good team there was a team member

1253
00:46:37,190 --> 00:46:35,200
um

1254
00:46:39,109 --> 00:46:37,200
named mark bowie who is incredibly

1255
00:46:41,190 --> 00:46:39,119
clever with anything with the spacecraft

1256
00:46:43,589 --> 00:46:41,200
i and i didn't know what to talk to him

1257
00:46:45,589 --> 00:46:43,599
about except you know i asked mark what

1258
00:46:47,030 --> 00:46:45,599
tell me what i don't know

1259
00:46:48,550 --> 00:46:47,040
and he said you should think about the

1260
00:46:51,030 --> 00:46:48,560
spacecraft

1261
00:46:53,190 --> 00:46:51,040
and then i talked to um a planetary

1262
00:46:55,109 --> 00:46:53,200
astronomer who was an artist named dan

1263
00:46:57,829 --> 00:46:55,119

durda who was not on the team but close

1264
00:46:59,510 --> 00:46:57,839
to the team and he had this art this

1265
00:47:02,150 --> 00:46:59,520
model which rendered new horizons just

1266
00:47:04,550 --> 00:47:02,160
because he liked putting it in images

1267
00:47:06,950 --> 00:47:04,560
and we used that to do the geometry of

1268
00:47:08,630 --> 00:47:06,960
those fields and we said how you know

1269
00:47:11,270 --> 00:47:08,640
when new horizons is making his

1270
00:47:13,270 --> 00:47:11,280
observations was a dark enough and so we

1271
00:47:14,630 --> 00:47:13,280
did figured out the geometry for those

1272
00:47:16,870 --> 00:47:14,640
images we figured out the geometry of

1273
00:47:19,430 --> 00:47:16,880
the spacecraft we lit it up with the sun

1274
00:47:20,950 --> 00:47:19,440
and here are for five of the fields i

1275
00:47:22,230 --> 00:47:20,960
said there are seven but two of the few

1276
00:47:24,950 --> 00:47:22,240
you know that had the exact same

1277
00:47:27,190 --> 00:47:24,960
geometry and you see look at this okay

1278
00:47:28,630 --> 00:47:27,200
here's the sun

1279
00:47:30,470 --> 00:47:28,640
let's let this up here and there are

1280
00:47:32,950 --> 00:47:30,480
those star trackers

1281
00:47:35,430 --> 00:47:32,960
oh okay they're lit up a little bit oh

1282
00:47:37,829 --> 00:47:35,440
gosh here they're lit up a lot oh what's

1283
00:47:39,990 --> 00:47:37,839
this oh that's this this little latch

1284
00:47:43,109 --> 00:47:40,000
thing over here to laurie oh gosh that's

1285
00:47:44,950 --> 00:47:43,119
in a little bit of sunlight too

1286
00:47:46,710 --> 00:47:44,960
and then we stuck you know we measured

1287
00:47:49,510 --> 00:47:46,720
how much light we were getting in and

1288
00:47:51,030 --> 00:47:49,520

we're pleased to find out um that you

1289
00:47:52,309 --> 00:47:51,040
know not much was getting in the camera

1290
00:47:53,990 --> 00:47:52,319
in fact the trivial amount that wasn't

1291
00:47:55,349 --> 00:47:54,000
going to hurt us but this is the kind of

1292
00:47:57,270 --> 00:47:55,359
thing you have to think about you know

1293
00:47:58,549 --> 00:47:57,280
when you're measuring how dark something

1294
00:48:00,309 --> 00:47:58,559
is

1295
00:48:01,670 --> 00:48:00,319
what's the light that's coming in that's

1296
00:48:02,630 --> 00:48:01,680
bothering you that has nothing to do

1297
00:48:05,109 --> 00:48:02,640
with that

1298
00:48:07,750 --> 00:48:05,119
in fact um we had a

1299
00:48:09,190 --> 00:48:07,760
telecon once and when you know we're

1300
00:48:11,510 --> 00:48:09,200
working on this

1301
00:48:13,670 --> 00:48:11,520
and alice bowman was there and alan

1302
00:48:15,990 --> 00:48:13,680
stern was there and you were killing

1303
00:48:17,589 --> 00:48:16,000
time before it started and

1304
00:48:19,190 --> 00:48:17,599
i asked alan so are you sure that

1305
00:48:22,390 --> 00:48:19,200
there's no navigation lights in the

1306
00:48:24,710 --> 00:48:22,400
spacecraft because alan is a pilot and

1307
00:48:27,109 --> 00:48:24,720
and is really you know loves thinking

1308
00:48:28,950 --> 00:48:27,119
about spacecraft there's no reason to

1309
00:48:30,870 --> 00:48:28,960
put navigation lights on new horizons

1310
00:48:32,549 --> 00:48:30,880
but it would look cool all the same and

1311
00:48:33,430 --> 00:48:32,559
this you know got laughters around the

1312
00:48:35,030 --> 00:48:33,440
group

1313
00:48:37,190 --> 00:48:35,040

no we're not going to put we're not

1314
00:48:39,030 --> 00:48:37,200
going to put light bulbs to wink on and

1315
00:48:40,710 --> 00:48:39,040
off you know the enterprise has them but

1316
00:48:42,790 --> 00:48:40,720
new horizon doesn't but it's that kind

1317
00:48:43,990 --> 00:48:42,800
of thing you think about you know what

1318
00:48:45,190 --> 00:48:44,000
light could be there that you haven't

1319
00:48:46,630 --> 00:48:45,200
thought about

1320
00:48:47,910 --> 00:48:46,640
it's going to give you a positive signal

1321
00:48:49,510 --> 00:48:47,920
it's going to be completely wrong

1322
00:48:50,950 --> 00:48:49,520
because you didn't account for it that's

1323
00:48:51,670 --> 00:48:50,960
what we had to do and that's why we got

1324
00:48:53,349 --> 00:48:51,680
this

1325
00:48:55,030 --> 00:48:53,359
rendering software

1326
00:48:56,950 --> 00:48:55,040
to look and see you know was there

1327
00:49:00,630 --> 00:48:56,960
something coming in

1328
00:49:02,790 --> 00:49:00,640
well we got another thing to worry about

1329
00:49:04,470 --> 00:49:02,800
you know what about starlight we're

1330
00:49:05,910 --> 00:49:04,480
looking at fields you saw there are

1331
00:49:08,950 --> 00:49:05,920
stars in the images but what about

1332
00:49:10,230 --> 00:49:08,960
bright stars away from they're not in

1333
00:49:11,990 --> 00:49:10,240
there but they're still putting light

1334
00:49:13,349 --> 00:49:12,000
into the camera

1335
00:49:15,670 --> 00:49:13,359
and we know

1336
00:49:17,430 --> 00:49:15,680
what how lori the camera responds this

1337
00:49:19,030 --> 00:49:17,440
is again another technical graph but

1338
00:49:21,430 --> 00:49:19,040

this is actually how it responds to

1339
00:49:22,470 --> 00:49:21,440
sunlight notice this compressed scale

1340
00:49:30,309 --> 00:49:22,480
here

1341
00:49:32,790 --> 00:49:30,319
16 orders of magnitude

1342
00:49:35,349 --> 00:49:32,800
and the light goes with sort of like

1343
00:49:38,309 --> 00:49:35,359
14 of those and i had to use a new word

1344
00:49:39,430 --> 00:49:38,319
quadrillion you've got million billion

1345
00:49:42,829 --> 00:49:39,440
trillion

1346
00:49:45,190 --> 00:49:42,839
quadrillion and so

1347
00:49:46,790 --> 00:49:45,200
sunlight coming straight into the camera

1348
00:49:49,750 --> 00:49:46,800
we pointed the camera at the sun which

1349
00:49:52,150 --> 00:49:49,760
by the way would ruin it

1350
00:49:55,990 --> 00:49:52,160
but going all the way out to 90 degrees

1351
00:49:56,829 --> 00:49:56,000
here the sunlight intensity drops by

1352
00:49:59,270 --> 00:49:56,839
by a

1353
00:50:02,790 --> 00:49:59,280
quadrillion but if you point near the

1354
00:50:04,549 --> 00:50:02,800
sun um whoops not ready for that one yet

1355
00:50:06,390 --> 00:50:04,559
you still see sunlight coming in very

1356
00:50:07,990 --> 00:50:06,400
faintly and the sky is actually pretty

1357
00:50:09,910 --> 00:50:08,000
bright unless you're actually in the new

1358
00:50:11,829 --> 00:50:09,920
horizon shadow because the sunlight is

1359
00:50:13,510 --> 00:50:11,839
hitting directly into the lorry aperture

1360
00:50:15,430 --> 00:50:13,520
and it's scattering around remember that

1361
00:50:17,589 --> 00:50:15,440
baffle was not you know completely

1362
00:50:19,510 --> 00:50:17,599
perfect you can still see it which means

1363
00:50:20,630 --> 00:50:19,520

it was scattering light

1364
00:50:23,109 --> 00:50:20,640
and

1365
00:50:25,190 --> 00:50:23,119
if that can scatter sunlight

1366
00:50:26,870 --> 00:50:25,200
well star bright star

1367
00:50:28,470 --> 00:50:26,880
is going to get in the same way it's not

1368
00:50:29,910 --> 00:50:28,480
going to be that bright but you better

1369
00:50:32,150 --> 00:50:29,920
think about it okay because you're

1370
00:50:33,349 --> 00:50:32,160
looking for something very faint and so

1371
00:50:36,069 --> 00:50:33,359
we made

1372
00:50:38,470 --> 00:50:36,079
we took every

1373
00:50:39,990 --> 00:50:38,480
catalog we we could get to help us out

1374
00:50:41,670 --> 00:50:40,000
and we were going from very bright stars

1375
00:50:43,270 --> 00:50:41,680
to very faint stars

1376
00:50:45,190 --> 00:50:43,280
this is something mark and i worked on

1377
00:50:47,670 --> 00:50:45,200
very very closely it took us three

1378
00:50:49,190 --> 00:50:47,680
catalogs we needed a catalog of bright

1379
00:50:51,829 --> 00:50:49,200
stars that you could see with your own

1380
00:50:53,910 --> 00:50:51,839
eye and then we needed a catalog with

1381
00:50:55,430 --> 00:50:53,920
you can see with small telescopes and

1382
00:50:57,030 --> 00:50:55,440
that was a parkas and then we needed

1383
00:50:58,870 --> 00:50:57,040
gaia to get us to the faintest stars

1384
00:51:00,790 --> 00:50:58,880
that lori could see

1385
00:51:02,309 --> 00:51:00,800
and this is this is again more technical

1386
00:51:03,270 --> 00:51:02,319
diagram but this is what we had to worry

1387
00:51:05,349 --> 00:51:03,280
about

1388
00:51:07,030 --> 00:51:05,359

so here is the field of view of lori

1389
00:51:08,470 --> 00:51:07,040
another logarithmic scale tenth of

1390
00:51:09,990 --> 00:51:08,480
degree 1 degree

1391
00:51:11,829 --> 00:51:10,000
10 degrees so this is you know

1392
00:51:14,309 --> 00:51:11,839
compressed

1393
00:51:16,630 --> 00:51:14,319
but we said what star is putting what

1394
00:51:18,790 --> 00:51:16,640
into lori this is to be in the camera

1395
00:51:20,950 --> 00:51:18,800
you have to be inside this thing but

1396
00:51:22,470 --> 00:51:20,960
what's this over here here is a star and

1397
00:51:24,790 --> 00:51:22,480
the brightness

1398
00:51:26,710 --> 00:51:24,800
zero to five those are stars you can see

1399
00:51:29,270 --> 00:51:26,720
with your eye

1400
00:51:32,230 --> 00:51:29,280
binoculars out to seven small telescopes

1401
00:51:33,589 --> 00:51:32,240
out to 14 big telescopes out to 20 if

1402
00:51:35,270 --> 00:51:33,599
you look in them

1403
00:51:36,630 --> 00:51:35,280
so bright faint

1404
00:51:38,390 --> 00:51:36,640
i don't know what this star is but it

1405
00:51:40,309 --> 00:51:38,400
has a name and the astronomer will

1406
00:51:42,230 --> 00:51:40,319
almost certainly know you know by name

1407
00:51:45,430 --> 00:51:42,240
and it's 10 degrees away

1408
00:51:47,670 --> 00:51:45,440
nothing close to the camera but

1409
00:51:48,950 --> 00:51:47,680
gosh we know from our little scale here

1410
00:51:51,349 --> 00:51:48,960
there's a lot of light going to come

1411
00:51:52,950 --> 00:51:51,359
from that here is something that's

1412
00:51:54,790 --> 00:51:52,960
third magnitude these are called

1413
00:51:56,309 --> 00:51:54,800

magnitudes it's three

1414
00:51:58,549 --> 00:51:56,319
that's putting in a lot of light into

1415
00:52:00,470 --> 00:51:58,559
this and so we had to go over the whole

1416
00:52:02,950 --> 00:52:00,480
sky integrate up with all these star

1417
00:52:04,470 --> 00:52:02,960
catalogs and ask the question how much

1418
00:52:06,069 --> 00:52:04,480
scattered light were we getting into

1419
00:52:07,349 --> 00:52:06,079
because again if we didn't think about

1420
00:52:08,790 --> 00:52:07,359
that we say oh look at all that light

1421
00:52:12,470 --> 00:52:08,800
we're getting and it's completely wrong

1422
00:52:15,349 --> 00:52:13,750
now there's something else we have to

1423
00:52:16,950 --> 00:52:15,359
think about

1424
00:52:21,190 --> 00:52:16,960
so here we're back at the ultra deep

1425
00:52:23,829 --> 00:52:21,200
field and these are these beautiful

1426
00:52:25,990 --> 00:52:23,839
galaxies that took couple a week to

1427
00:52:28,790 --> 00:52:26,000
detect and pick up well

1428
00:52:30,549 --> 00:52:28,800
they're going to be in our field too

1429
00:52:32,069 --> 00:52:30,559
and we have a small telescope and we

1430
00:52:33,430 --> 00:52:32,079
won't see them like hubble will but

1431
00:52:35,990 --> 00:52:33,440
there's going to put in light all the

1432
00:52:37,750 --> 00:52:36,000
same so we better account for

1433
00:52:39,030 --> 00:52:37,760
uh how much galaxy light's in there so

1434
00:52:40,230 --> 00:52:39,040
that's something else we had to worry

1435
00:52:42,069 --> 00:52:40,240
about

1436
00:52:42,870 --> 00:52:42,079
and this is something again that mark

1437
00:52:45,430 --> 00:52:42,880
and i

1438
00:52:48,069 --> 00:52:45,440

worked on this is excessively technical

1439
00:52:49,270 --> 00:52:48,079
and sorry excuse me for showing this but

1440
00:52:52,710 --> 00:52:49,280
this is

1441
00:52:55,510 --> 00:52:52,720
what we know about the populations of

1442
00:52:58,390 --> 00:52:55,520
galaxies uh in the universe

1443
00:53:00,870 --> 00:52:58,400
you see uh six little plots well those

1444
00:53:03,349 --> 00:53:00,880
are different colors um if you looked in

1445
00:53:05,190 --> 00:53:03,359
the ultraviolet light blue light

1446
00:53:07,030 --> 00:53:05,200
v-band that's called visible band that's

1447
00:53:08,870 --> 00:53:07,040
what the eye is most sensitive sensitive

1448
00:53:11,030 --> 00:53:08,880
to it's kind of green

1449
00:53:12,390 --> 00:53:11,040
red infrared

1450
00:53:14,470 --> 00:53:12,400
and then a little bit

1451
00:53:15,510 --> 00:53:14,480
further infrared so these are different

1452
00:53:18,150 --> 00:53:15,520
colors

1453
00:53:20,549 --> 00:53:18,160
and you see there's a steep curve

1454
00:53:22,470 --> 00:53:20,559
and this is faint this way and this is

1455
00:53:25,670 --> 00:53:22,480
number this way so

1456
00:53:27,190 --> 00:53:25,680
here we go from this way okay galaxies

1457
00:53:29,270 --> 00:53:27,200
in green light

1458
00:53:31,589 --> 00:53:29,280
not many bright ones lots and lots

1459
00:53:33,349 --> 00:53:31,599
whoops see my cursor lots and lots of

1460
00:53:35,430 --> 00:53:33,359
faint ones and this is true for all of

1461
00:53:37,349 --> 00:53:35,440
them there's another curse stars do the

1462
00:53:38,150 --> 00:53:37,359
same thing but they're easier to get rid

1463
00:53:40,150 --> 00:53:38,160

of

1464
00:53:43,030 --> 00:53:40,160
it turns out when you get past a certain

1465
00:53:44,950 --> 00:53:43,040
faintness it's galaxies that you see not

1466
00:53:46,630 --> 00:53:44,960
stars there aren't as many of them but

1467
00:53:48,309 --> 00:53:46,640
this is something else that we had to

1468
00:53:50,150 --> 00:53:48,319
account for is how much galaxy light

1469
00:53:51,829 --> 00:53:50,160
were we getting

1470
00:53:54,549 --> 00:53:51,839
so here's the answer

1471
00:53:55,589 --> 00:53:54,559
that we were going for

1472
00:53:57,990 --> 00:53:55,599
and so

1473
00:53:59,510 --> 00:53:58,000
we had seven fields that we looked at

1474
00:54:00,630 --> 00:53:59,520
and here are measurements from seven

1475
00:54:03,349 --> 00:54:00,640
fields

1476
00:54:04,870 --> 00:54:03,359
and we got the solid signal and all the

1477
00:54:07,270 --> 00:54:04,880
fields you see there are error bars

1478
00:54:08,790 --> 00:54:07,280
there that's pretty precise look at that

1479
00:54:11,109 --> 00:54:08,800
and i won't tell you what the units are

1480
00:54:12,790 --> 00:54:11,119
unless you know that you're good you

1481
00:54:14,950 --> 00:54:12,800
know what nanowatts per meter square per

1482
00:54:16,470 --> 00:54:14,960
series there's probably some of you who

1483
00:54:17,910 --> 00:54:16,480
don't know what that is and i won't

1484
00:54:22,390 --> 00:54:17,920
explain it

1485
00:54:24,549 --> 00:54:22,400
than that but just take the number

1486
00:54:27,270 --> 00:54:24,559
and so whatever this mystery is

1487
00:54:29,670 --> 00:54:27,280
mysterious number is take like 35 we see

1488
00:54:31,430 --> 00:54:29,680

35 of this thing and you know that

1489
00:54:33,270 --> 00:54:31,440
doesn't matter what we call it if we're

1490
00:54:35,750 --> 00:54:33,280
using hubble space telescope which is

1491
00:54:38,789 --> 00:54:35,760
all fogged out compared to this this

1492
00:54:42,470 --> 00:54:38,799
would be up at 300 or a thousand okay

1493
00:54:44,309 --> 00:54:42,480
so what we're seeing is really dark

1494
00:54:46,230 --> 00:54:44,319
but

1495
00:54:48,470 --> 00:54:46,240
that's just a raw signal that that's

1496
00:54:49,750 --> 00:54:48,480
what we measured from that slide several

1497
00:54:51,270 --> 00:54:49,760
times back i just showed you the

1498
00:54:53,670 --> 00:54:51,280
pictures and this is what i get you know

1499
00:54:55,829 --> 00:54:53,680
we just measured off the pictures

1500
00:54:57,589 --> 00:54:55,839
so is there something here and we need

1501
00:54:59,190 --> 00:54:57,599
to you know look at the budget what

1502
00:55:00,309 --> 00:54:59,200
could be making

1503
00:55:01,910 --> 00:55:00,319
this

1504
00:55:03,430 --> 00:55:01,920
signal up here

1505
00:55:04,950 --> 00:55:03,440
is it something interesting or is it

1506
00:55:06,390 --> 00:55:04,960
something obvious or is it something

1507
00:55:08,630 --> 00:55:06,400
stupid

1508
00:55:11,109 --> 00:55:08,640
so i was just talking about galaxies so

1509
00:55:13,750 --> 00:55:11,119
let's talk about galaxies

1510
00:55:15,990 --> 00:55:13,760
wrong cursor

1511
00:55:17,349 --> 00:55:16,000
let's go back so you see yeah so here we

1512
00:55:19,910 --> 00:55:17,359
go

1513
00:55:21,670 --> 00:55:19,920

so i said there are faint galaxies that

1514
00:55:23,910 --> 00:55:21,680
are in our field that we can't see how

1515
00:55:27,030 --> 00:55:23,920
much light did they put in

1516
00:55:31,829 --> 00:55:29,510
so okay and you know we compared to lots

1517
00:55:33,829 --> 00:55:31,839
of different people who work with galaxy

1518
00:55:35,349 --> 00:55:33,839
counts and that number is pretty good

1519
00:55:37,430 --> 00:55:35,359
it's known from the work with hubble

1520
00:55:39,829 --> 00:55:37,440
it's going to be refined with james webb

1521
00:55:42,150 --> 00:55:39,839
space telescope when that launches

1522
00:55:43,670 --> 00:55:42,160
you see there there's a big gap um

1523
00:55:46,549 --> 00:55:43,680
between the light contributed by

1524
00:55:49,030 --> 00:55:46,559
galaxies and what we actually measure

1525
00:55:51,910 --> 00:55:49,040
that's huge

1526
00:55:53,349 --> 00:55:51,920
well okay uh faint stars we got some of

1527
00:55:56,630 --> 00:55:53,359
that

1528
00:55:58,789 --> 00:55:56,640
aren't as many stars in our fields as

1529
00:56:00,870 --> 00:55:58,799
galaxies so you know that's not a big

1530
00:56:02,870 --> 00:56:00,880
correction

1531
00:56:05,829 --> 00:56:02,880
but i went on and on about scattered

1532
00:56:07,670 --> 00:56:05,839
starlight you know light from stars off

1533
00:56:09,270 --> 00:56:07,680
away from the camera coming in it's like

1534
00:56:11,030 --> 00:56:09,280
lens flare by the way you know you see

1535
00:56:13,430 --> 00:56:11,040
this when the sun you know isn't in the

1536
00:56:15,670 --> 00:56:13,440
picture but it's still flaring in

1537
00:56:17,430 --> 00:56:15,680
well that contributes to this and that's

1538
00:56:19,109 --> 00:56:17,440

our scattered starlight these are bright

1539
00:56:20,470 --> 00:56:19,119
stars that we're not looking at they're

1540
00:56:22,390 --> 00:56:20,480
not getting in the camera but they're

1541
00:56:24,069 --> 00:56:22,400
off and they're bouncing around those

1542
00:56:25,430 --> 00:56:24,079
baffles and they're still putting light

1543
00:56:27,829 --> 00:56:25,440
into the images

1544
00:56:29,430 --> 00:56:27,839
and so they're contributing

1545
00:56:31,109 --> 00:56:29,440
of what you're seeing here and that's

1546
00:56:34,309 --> 00:56:31,119
the gold

1547
00:56:37,030 --> 00:56:34,319
and i also talked about that infrared

1548
00:56:39,990 --> 00:56:37,040
cirrus around the galaxy you know that

1549
00:56:41,910 --> 00:56:40,000
stuff is up there and it's bouncing in

1550
00:56:43,430 --> 00:56:41,920
light from other stars in the galaxy and

1551
00:56:45,030 --> 00:56:43,440
it's putting in a little fog in the

1552
00:56:46,630 --> 00:56:45,040
images

1553
00:56:48,309 --> 00:56:46,640
and that's this there

1554
00:56:50,470 --> 00:56:48,319
and we don't really know it as well as

1555
00:56:51,670 --> 00:56:50,480
we'd like there's two different re

1556
00:56:55,349 --> 00:56:51,680
research

1557
00:56:56,870 --> 00:56:55,359
papers it said what it is and one's in

1558
00:56:58,150 --> 00:56:56,880
in dark green we like that better

1559
00:57:00,069 --> 00:56:58,160
because it's smaller so we made that

1560
00:57:03,349 --> 00:57:00,079
more obvious but

1561
00:57:05,030 --> 00:57:03,359
there is the one in faint pale green and

1562
00:57:06,710 --> 00:57:05,040
it's somewhere between that and so this

1563
00:57:09,589 --> 00:57:06,720

is what we're left with

1564
00:57:11,510 --> 00:57:09,599
and this is interesting

1565
00:57:12,950 --> 00:57:11,520
this now is

1566
00:57:14,390 --> 00:57:12,960
all the light

1567
00:57:16,230 --> 00:57:14,400
that we think we can account for we

1568
00:57:18,789 --> 00:57:16,240
think we've done our homework we think

1569
00:57:21,910 --> 00:57:18,799
that we have seen what's there

1570
00:57:23,589 --> 00:57:21,920
and we don't make it up to

1571
00:57:25,430 --> 00:57:23,599
our actual measurements

1572
00:57:27,990 --> 00:57:25,440
there's a difference here

1573
00:57:29,910 --> 00:57:28,000
there's a gap there is extra signal

1574
00:57:31,910 --> 00:57:29,920
that's unaccounted for

1575
00:57:33,829 --> 00:57:31,920
it's origin and purpose still a total

1576
00:57:36,150 --> 00:57:33,839
mystery

1577
00:57:37,349 --> 00:57:36,160
but whatever it is

1578
00:57:38,950 --> 00:57:37,359
it's as

1579
00:57:41,349 --> 00:57:38,960
big as

1580
00:57:43,109 --> 00:57:41,359
the light from galaxies

1581
00:57:44,710 --> 00:57:43,119
so what we're finding here is that

1582
00:57:46,630 --> 00:57:44,720
accounting for the faint galaxies we

1583
00:57:50,309 --> 00:57:46,640
still have something just as important

1584
00:57:53,670 --> 00:57:52,390
so we'll get into a little bit of how

1585
00:57:56,230 --> 00:57:53,680
how much light is this and that's

1586
00:57:58,390 --> 00:57:56,240
something i do want to explain to you so

1587
00:58:00,470 --> 00:57:58,400
um if you don't like

1588
00:58:03,030 --> 00:58:00,480

this unit over here which is nanowatts

1589
00:58:04,950 --> 00:58:03,040
per square meter per steradian

1590
00:58:06,549 --> 00:58:04,960
i have what i'm hoping is a better unit

1591
00:58:08,390 --> 00:58:06,559
that i'd like to introduce and common

1592
00:58:11,510 --> 00:58:08,400
usage in the astronomical world and

1593
00:58:13,829 --> 00:58:11,520
that's the fridge

1594
00:58:15,829 --> 00:58:13,839
so um i showed you the outside of my

1595
00:58:18,069 --> 00:58:15,839
house

1596
00:58:19,510 --> 00:58:18,079
and if you walked into our kitchen and

1597
00:58:21,109 --> 00:58:19,520
opened up the refrigerator it probably

1598
00:58:23,270 --> 00:58:21,119
looked like your refrigerator and this

1599
00:58:24,950 --> 00:58:23,280
is the middle of the night

1600
00:58:26,390 --> 00:58:24,960
so i think you know

1601
00:58:27,829 --> 00:58:26,400
all of us who are bad and raid

1602
00:58:29,270 --> 00:58:27,839
refrigerators in the middle of night you

1603
00:58:31,990 --> 00:58:29,280
know what it looks like and you can

1604
00:58:33,829 --> 00:58:32,000
picture being in the black house and uh

1605
00:58:34,870 --> 00:58:33,839
you know nothing else on but the light

1606
00:58:36,390 --> 00:58:34,880
from the refrigerator you know how

1607
00:58:37,589 --> 00:58:36,400
bright that is and you can see you know

1608
00:58:39,589 --> 00:58:37,599
it doesn't

1609
00:58:41,750 --> 00:58:39,599
really even light up the kitchen that

1610
00:58:44,230 --> 00:58:41,760
much

1611
00:58:45,510 --> 00:58:44,240
now let's take one step further

1612
00:58:48,390 --> 00:58:45,520
okay

1613
00:58:51,589 --> 00:58:48,400

let's not talk about my kitchen

1614
00:58:53,750 --> 00:58:51,599
let's talk about the neighbors kitchen

1615
00:58:57,990 --> 00:58:53,760
and so let's go um

1616
00:59:00,710 --> 00:58:58,000
out to the country away from the city

1617
00:59:02,710 --> 00:59:00,720
and pick a clear brilliant moonless

1618
00:59:04,549 --> 00:59:02,720
night

1619
00:59:05,910 --> 00:59:04,559
and here

1620
00:59:07,349 --> 00:59:05,920
you know that's i should say another

1621
00:59:09,109 --> 00:59:07,359
neighbor's cabin but let's say they're

1622
00:59:10,789 --> 00:59:09,119
in the foreground they're in the right

1623
00:59:12,630 --> 00:59:10,799
that's your cabin it's where you you're

1624
00:59:13,910 --> 00:59:12,640
living and there you can see already

1625
00:59:15,589 --> 00:59:13,920
that you know you've got more light

1626
00:59:18,549 --> 00:59:15,599
there coming out than it's coming out of

1627
00:59:20,549 --> 00:59:18,559
your refrigerator

1628
00:59:21,910 --> 00:59:20,559
and so you know you go to bed and it's

1629
00:59:24,390 --> 00:59:21,920
the middle of night you turn off all the

1630
00:59:26,470 --> 00:59:24,400
lights you've left your curtains open so

1631
00:59:28,150 --> 00:59:26,480
you can see you know you would see the

1632
00:59:30,150 --> 00:59:28,160
moonlight when it comes in somebody

1633
00:59:32,230 --> 00:59:30,160
drives the road along and swings the

1634
00:59:34,870 --> 00:59:32,240
light across the lake you know you'd

1635
00:59:36,230 --> 00:59:34,880
probably see their lights

1636
00:59:37,750 --> 00:59:36,240
so here's

1637
00:59:41,270 --> 00:59:37,760
your neighbor there

1638
00:59:43,750 --> 00:59:41,280

and they're a kilometer away from you

1639
00:59:45,510 --> 00:59:43,760
and your neighbor goes in to their

1640
00:59:47,670 --> 00:59:45,520
kitchen in the middle of night and opens

1641
00:59:49,270 --> 00:59:47,680
their refrigerator

1642
00:59:52,309 --> 00:59:49,280
and lights up their kitchen and the

1643
00:59:54,710 --> 00:59:52,319
light spills out of the window and gets

1644
00:59:57,190 --> 00:59:54,720
into your windows over here

1645
00:59:58,470 --> 00:59:57,200
that's how bright this unknown radiation

1646
01:00:00,150 --> 00:59:58,480
is

1647
01:00:02,710 --> 01:00:00,160
actually that's so bright if you add up

1648
01:00:04,309 --> 01:00:02,720
all the galaxies in the universe uh and

1649
01:00:07,109 --> 01:00:04,319
coming into your kitchen that's how

1650
01:00:08,549 --> 01:00:07,119
that's albright is it's very very faint

1651
01:00:10,069 --> 01:00:08,559
you might notice the moon but you

1652
01:00:11,990 --> 01:00:10,079
probably won't be woken up in the middle

1653
01:00:14,230 --> 01:00:12,000
of night by your neighbor raiding his

1654
01:00:15,109 --> 01:00:14,240
refrigerator the kilometer away in the

1655
01:00:16,870 --> 01:00:15,119
lake

1656
01:00:18,549 --> 01:00:16,880
but you can picture this

1657
01:00:20,150 --> 01:00:18,559
you know if you look directly at it you

1658
01:00:22,390 --> 01:00:20,160
can see it it's you know in that sense

1659
01:00:24,230 --> 01:00:22,400
it's interesting it's uh i think a way

1660
01:00:25,670 --> 01:00:24,240
of feeling the light i'm going to give

1661
01:00:27,109 --> 01:00:25,680
you another way

1662
01:00:29,750 --> 01:00:27,119
and that's actually how i found this

1663
01:00:30,710 --> 01:00:29,760

picture

1664
01:00:32,470 --> 01:00:30,720
for those of you who know your

1665
01:00:35,270 --> 01:00:32,480
constellations and you should all know

1666
01:00:38,470 --> 01:00:35,280
your constellations

1667
01:00:40,630 --> 01:00:38,480
you can see a bit of orion here there is

1668
01:00:42,710 --> 01:00:40,640
betelgeuse and rigel

1669
01:00:44,950 --> 01:00:42,720
and the belt of orion and its sword

1670
01:00:47,589 --> 01:00:44,960
underneath where the ryan nebula is and

1671
01:00:48,549 --> 01:00:47,599
star formation is taking place

1672
01:00:52,150 --> 01:00:48,559
and

1673
01:00:54,309 --> 01:00:52,160
winter is on its way if you get up you

1674
01:00:56,630 --> 01:00:54,319
know late now you can see orion coming

1675
01:00:59,829 --> 01:00:56,640
up and it'll be spectacular across the

1676
01:01:01,430 --> 01:00:59,839
skies you know as we go into winter

1677
01:01:03,829 --> 01:01:01,440
over here is the brightest star in the

1678
01:01:05,510 --> 01:01:03,839
sky and that's sirius and you've heard

1679
01:01:07,589 --> 01:01:05,520
you know sirius black that's the one

1680
01:01:09,910 --> 01:01:07,599
he's named after

1681
01:01:11,430 --> 01:01:09,920
and it turns out that if you don't like

1682
01:01:13,190 --> 01:01:11,440
my refrigerator units then i'm going to

1683
01:01:15,270 --> 01:01:13,200
give you sirius

1684
01:01:17,670 --> 01:01:15,280
the light coming from sirius the night

1685
01:01:20,390 --> 01:01:17,680
sky is equal to this unknown component

1686
01:01:22,549 --> 01:01:20,400
lighting up the landscape

1687
01:01:23,670 --> 01:01:22,559
and so if you can see a moon moon rise

1688
01:01:25,270 --> 01:01:23,680

with lighting up your window in the

1689
01:01:27,349 --> 01:01:25,280
middle of night you probably you know

1690
01:01:29,190 --> 01:01:27,359
won't be woken up when sirius clears the

1691
01:01:30,710 --> 01:01:29,200
horizon but that's how much light

1692
01:01:32,789 --> 01:01:30,720
makes this unknown component that we're

1693
01:01:36,630 --> 01:01:32,799
talking about

1694
01:01:38,470 --> 01:01:36,640
so a little bit on what is it

1695
01:01:39,829 --> 01:01:38,480
so go to the next slide

1696
01:01:41,910 --> 01:01:39,839
and i just want to show you where this

1697
01:01:44,150 --> 01:01:41,920
is uh quickly another scientific slide

1698
01:01:45,829 --> 01:01:44,160
this is our measurement here

1699
01:01:47,670 --> 01:01:45,839
and the the thing without you know the

1700
01:01:49,510 --> 01:01:47,680
zodiacal light

1701
01:01:50,950 --> 01:01:49,520
we have much smaller error bars that has

1702
01:01:52,470 --> 01:01:50,960
ever been done before people have tried

1703
01:01:55,190 --> 01:01:52,480
this over and over again

1704
01:01:56,390 --> 01:01:55,200
but they get very large error bars and

1705
01:01:57,670 --> 01:01:56,400
even just the detection of the

1706
01:01:59,109 --> 01:01:57,680
background is not particularly

1707
01:02:00,309 --> 01:01:59,119
significant with these measurements we

1708
01:02:01,430 --> 01:02:00,319
have a very good detection of the

1709
01:02:03,270 --> 01:02:01,440
background

1710
01:02:08,549 --> 01:02:03,280
and we take it off we have you know an

1711
01:02:11,589 --> 01:02:09,910
so i don't know if this will work with

1712
01:02:13,589 --> 01:02:11,599
you but i will try to talk your way

1713
01:02:15,430 --> 01:02:13,599

around it so the best guess what are we

1714
01:02:17,190 --> 01:02:15,440
looking at

1715
01:02:19,430 --> 01:02:17,200
you know have we counted our galaxies

1716
01:02:21,109 --> 01:02:19,440
right you know that's something which is

1717
01:02:23,190 --> 01:02:21,119
frontier research adding up all the

1718
01:02:26,309 --> 01:02:23,200
galaxy universe

1719
01:02:28,230 --> 01:02:26,319
uh the yellow line is a range of plus or

1720
01:02:29,750 --> 01:02:28,240
minus where we think it is that's the

1721
01:02:31,270 --> 01:02:29,760
yellow

1722
01:02:32,710 --> 01:02:31,280
and here's our measurements up here and

1723
01:02:35,270 --> 01:02:32,720
that's why we think there's something

1724
01:02:37,109 --> 01:02:35,280
unknown but

1725
01:02:38,470 --> 01:02:37,119
even the hubble space telescope can't

1726
01:02:40,870 --> 01:02:38,480
see everything

1727
01:02:43,430 --> 01:02:40,880
and we have to extrapolate those counts

1728
01:02:45,670 --> 01:02:43,440
that i showed you to what you can't see

1729
01:02:47,510 --> 01:02:45,680
and that's what this is and if

1730
01:02:50,150 --> 01:02:47,520
there's a black line if we extrapolate

1731
01:02:52,230 --> 01:02:50,160
by just how it looks for the brighter

1732
01:02:54,630 --> 01:02:52,240
galaxies you know we extrapolate to the

1733
01:02:55,829 --> 01:02:54,640
faintest possible galaxies and doesn't

1734
01:02:58,230 --> 01:02:55,839
change

1735
01:03:00,549 --> 01:02:58,240
you know then we can't explain it

1736
01:03:02,309 --> 01:03:00,559
but let's say all of a sudden these

1737
01:03:04,230 --> 01:03:02,319
faint galaxies you can see there's more

1738
01:03:05,910 --> 01:03:04,240

than you expect from extrapolation maybe

1739
01:03:08,230 --> 01:03:05,920
you know it comes up and there's you

1740
01:03:10,390 --> 01:03:08,240
know gobs and gobs of faint galaxies and

1741
01:03:12,789 --> 01:03:10,400
so that's called a steep slope that

1742
01:03:15,029 --> 01:03:12,799
there's more than you expect and so if

1743
01:03:17,029 --> 01:03:15,039
there is an unknown population of faint

1744
01:03:19,510 --> 01:03:17,039
galaxies that could explain the light

1745
01:03:20,470 --> 01:03:19,520
light that we see

1746
01:03:22,470 --> 01:03:20,480
and so

1747
01:03:25,270 --> 01:03:22,480
this is the exercise

1748
01:03:27,029 --> 01:03:25,280
we think this is this is useful

1749
01:03:28,789 --> 01:03:27,039
because it pushes against what we

1750
01:03:32,390 --> 01:03:28,799
understand as the population of faint

1751
01:03:34,549 --> 01:03:32,400
galaxies it gives us something to check

1752
01:03:35,910 --> 01:03:34,559
that is add up all the light add up the

1753
01:03:37,990 --> 01:03:35,920
galaxy you can't see if there's a

1754
01:03:40,870 --> 01:03:38,000
difference it means something is new

1755
01:03:42,470 --> 01:03:40,880
either it's galaxies you can't see or

1756
01:03:45,190 --> 01:03:42,480
you know something that you haven't seen

1757
01:03:47,510 --> 01:03:45,200
and they say the bet is that what we are

1758
01:03:50,470 --> 01:03:47,520
seeing

1759
01:03:52,470 --> 01:03:50,480
is just parts of galaxies

1760
01:03:54,069 --> 01:03:52,480
that have come off or haven't been

1761
01:03:55,349 --> 01:03:54,079
counted yet

1762
01:03:57,349 --> 01:03:55,359
but

1763
01:03:59,990 --> 01:03:57,359

it's something unknown and we leave open

1764
01:04:02,870 --> 01:04:00,000
the possibility that it's something not

1765
01:04:05,430 --> 01:04:02,880
to do with galaxies something unexpected

1766
01:04:07,910 --> 01:04:05,440
perhaps something even closer in than

1767
01:04:10,710 --> 01:04:07,920
the distant universe which will be

1768
01:04:12,390 --> 01:04:10,720
a surprise to us

1769
01:04:15,270 --> 01:04:12,400
and so with that

1770
01:04:17,670 --> 01:04:15,280
i should probably wisely um

1771
01:04:20,150 --> 01:04:17,680
fade to black

1772
01:04:21,670 --> 01:04:20,160
but as they say in the um

1773
01:04:23,829 --> 01:04:21,680
in the old

1774
01:04:24,829 --> 01:04:23,839
advertisements uh you know but wait

1775
01:04:27,670 --> 01:04:24,839
there's

1776
01:04:30,230 --> 01:04:27,680
more and let's see if i can

1777
01:04:31,910 --> 01:04:30,240
do this i was about to leave my talk

1778
01:04:33,510 --> 01:04:31,920
which would be bad

1779
01:04:35,190 --> 01:04:33,520
oh now i see what i need to do i need to

1780
01:04:40,470 --> 01:04:35,200
stop sharing

1781
01:04:46,309 --> 01:04:42,630
so what i told you

1782
01:04:48,390 --> 01:04:46,319
was that we used observations um that

1783
01:04:49,910 --> 01:04:48,400
were taken uh with new horizons for

1784
01:04:51,589 --> 01:04:49,920
something else so in archive we actually

1785
01:04:55,109 --> 01:04:51,599
didn't point to spacecraft that did this

1786
01:04:57,750 --> 01:04:55,119
we used data that already been taken

1787
01:04:59,589 --> 01:04:57,760
and as a result we couldn't be picky

1788
01:05:01,190 --> 01:04:59,599

about you know what we had and i showed

1789
01:05:03,270 --> 01:05:01,200
you that we had to take care of

1790
01:05:05,589 --> 01:05:03,280
scattered light from other stars and we

1791
01:05:07,270 --> 01:05:05,599
had to account for light coming from our

1792
01:05:09,510 --> 01:05:07,280
own you know scattering off the cirrus

1793
01:05:10,309 --> 01:05:09,520
around our galaxy

1794
01:05:13,029 --> 01:05:10,319
but

1795
01:05:16,390 --> 01:05:13,039
if we can pick and choose if we can plan

1796
01:05:18,390 --> 01:05:16,400
the observations in advance um we can

1797
01:05:20,150 --> 01:05:18,400
find darker places to look and we can

1798
01:05:22,470 --> 01:05:20,160
make our air bars smaller to make it

1799
01:05:23,670 --> 01:05:22,480
unequivocal that we've seen something

1800
01:05:28,390 --> 01:05:23,680
unknown

1801
01:05:32,549 --> 01:05:30,710
that possibility

1802
01:05:34,309 --> 01:05:32,559
and one thing that we were able to do

1803
01:05:36,870 --> 01:05:34,319
because we're looking at how well the

1804
01:05:38,069 --> 01:05:36,880
spacecraft performs for future research

1805
01:05:40,309 --> 01:05:38,079
ideas

1806
01:05:42,390 --> 01:05:40,319
uh this year we set up we picked a field

1807
01:05:43,910 --> 01:05:42,400
that was extremely dark

1808
01:05:45,270 --> 01:05:43,920
it should be much much darker than

1809
01:05:47,430 --> 01:05:45,280
anything where we've seen before should

1810
01:05:49,109 --> 01:05:47,440
have no contribution from scout light

1811
01:05:52,069 --> 01:05:49,119
off the milky way at all

1812
01:05:54,470 --> 01:05:52,079
it has much less skylight than we saw

1813
01:05:56,390 --> 01:05:54,480

we developed i should say the whole team

1814
01:05:58,950 --> 01:05:56,400
you saw there with the engineers working

1815
01:06:01,270 --> 01:05:58,960
develop this command sequences for the

1816
01:06:02,870 --> 01:06:01,280
spacecraft they were verified tested to

1817
01:06:04,710 --> 01:06:02,880
make sure they'd be safe and lots of

1818
01:06:08,150 --> 01:06:04,720
plan going into that

1819
01:06:10,950 --> 01:06:08,160
they were uploaded into the spacecraft

1820
01:06:13,349 --> 01:06:10,960
in the middle of september

1821
01:06:16,309 --> 01:06:13,359
and this is done every few weeks for the

1822
01:06:19,349 --> 01:06:16,319
spacecraft to run commands

1823
01:06:22,390 --> 01:06:19,359
a friday ago uh our observations were

1824
01:06:24,549 --> 01:06:22,400
taken on the spacecraft

1825
01:06:27,270 --> 01:06:24,559
and they sit in the image store waiting

1826
01:06:29,910 --> 01:06:27,280
until they're coming down

1827
01:06:32,630 --> 01:06:29,920
and so tonight um i'm looking here at

1828
01:06:34,630 --> 01:06:32,640
this wonderful website you can go to

1829
01:06:36,630 --> 01:06:34,640
we get data from everything off the

1830
01:06:38,390 --> 01:06:36,640
earth planets and the moon from with

1831
01:06:40,150 --> 01:06:38,400
deep space network it goes back to the

1832
01:06:41,990 --> 01:06:40,160
times of apollo it's how we could see

1833
01:06:43,430 --> 01:06:42,000
the astronauts walking down the moon

1834
01:06:45,510 --> 01:06:43,440
that's how we get pictures back from

1835
01:06:49,029 --> 01:06:45,520
pluto it's how we got pictures back from

1836
01:06:52,230 --> 01:06:49,039
mars mercury and venus all the planets

1837
01:06:53,670 --> 01:06:52,240
come back with a deep space network

1838
01:06:55,670 --> 01:06:53,680

and

1839
01:06:57,029 --> 01:06:55,680
these passes are programmed very

1840
01:06:59,510 --> 01:06:57,039
carefully

1841
01:07:03,270 --> 01:06:59,520
they get data from the spacecraft

1842
01:07:04,870 --> 01:07:03,280
and if you look over here you can see

1843
01:07:06,630 --> 01:07:04,880
goldstone

1844
01:07:08,230 --> 01:07:06,640
that's one of three stations spanning

1845
01:07:10,710 --> 01:07:08,240
the world there are three stations one

1846
01:07:13,270 --> 01:07:10,720
in madrid one in goldstone and canberra

1847
01:07:15,109 --> 01:07:13,280
this is the biggest this is goldstone

1848
01:07:17,349 --> 01:07:15,119
and you look here the telemetry is

1849
01:07:19,349 --> 01:07:17,359
active

1850
01:07:21,430 --> 01:07:19,359
data's going up this spacecraft data is

1851
01:07:23,829 --> 01:07:21,440
coming down from the spacecraft and

1852
01:07:27,589 --> 01:07:23,839
here's the acronym and hpc that's the

1853
01:07:29,510 --> 01:07:27,599
dsn code for the new horizon spacecraft

1854
01:07:32,390 --> 01:07:29,520
and so right now

1855
01:07:34,549 --> 01:07:32,400
the large 70 meter dish at goldstone

1856
01:07:36,309 --> 01:07:34,559
which is in the mojave is talking to the

1857
01:07:38,870 --> 01:07:36,319
spacecraft and is getting data from the

1858
01:07:40,710 --> 01:07:38,880
spacecraft

1859
01:07:42,549 --> 01:07:40,720
and i happen to know that that's our

1860
01:07:44,549 --> 01:07:42,559
data that we took for a trial so as i've

1861
01:07:47,109 --> 01:07:44,559
been talking to you

1862
01:07:48,630 --> 01:07:47,119
uh new horizons light travel time is

1863
01:07:50,630 --> 01:07:48,640

seven hours

1864
01:07:52,150 --> 01:07:50,640
that our data from these images is

1865
01:07:54,230 --> 01:07:52,160
beaming across

1866
01:07:56,470 --> 01:07:54,240
the solar system

1867
01:07:58,870 --> 01:07:56,480
down to earth through the dsn

1868
01:08:01,029 --> 01:07:58,880
and so um after i'm done talking to you

1869
01:08:02,309 --> 01:08:01,039
i can get rid of the zoom and other

1870
01:08:03,910 --> 01:08:02,319
things and i can bring it up and i can

1871
01:08:08,829 --> 01:08:03,920
see what we got

1872
01:08:13,829 --> 01:08:11,109
talking all right

1873
01:08:15,430 --> 01:08:13,839
thank you todd that was a wonderful

1874
01:08:18,070 --> 01:08:15,440
talking with a great little finish in

1875
01:08:20,070 --> 01:08:18,080
that you know there will be more because

1876
01:08:23,269 --> 01:08:20,080
the data's coming down right now wait

1877
01:08:25,910 --> 01:08:23,279
wait there's more yes

1878
01:08:27,990 --> 01:08:25,920
still not satisfied yes

1879
01:08:30,870 --> 01:08:28,000
i will have to say i sort of took a riff

1880
01:08:34,149 --> 01:08:30,880
off of one of the comments on the

1881
01:08:35,669 --> 01:08:34,159
uh the chat on on youtube uh and it

1882
01:08:37,590 --> 01:08:35,679
turns out that you went

1883
01:08:40,470 --> 01:08:37,600
you joined the new horizons team and you

1884
01:08:43,510 --> 01:08:40,480
went over to the dark side

1885
01:08:45,590 --> 01:08:43,520
well i i i can tell you so so i i can't

1886
01:08:47,189 --> 01:08:45,600
resist telling you this so i did this

1887
01:08:50,070 --> 01:08:47,199
and um

1888
01:08:52,390 --> 01:08:50,080

a paper that just got accepted is was

1889
01:08:54,630 --> 01:08:52,400
using the light of caron

1890
01:08:55,669 --> 01:08:54,640
to light up the dark side of pluto and

1891
01:09:00,709 --> 01:08:55,679
so

1892
01:09:05,110 --> 01:09:03,349
i kind of like that dr dark i don't know

1893
01:09:06,709 --> 01:09:05,120
maybe i get a license plate printed that

1894
01:09:09,269 --> 01:09:06,719
up okay

1895
01:09:10,229 --> 01:09:09,279
so one of the questions from our our

1896
01:09:14,390 --> 01:09:10,239
audience

1897
01:09:16,070 --> 01:09:14,400
was about darkness and the expansion of

1898
01:09:17,030 --> 01:09:16,080
the universe

1899
01:09:19,749 --> 01:09:17,040
that

1900
01:09:22,870 --> 01:09:19,759
is the universe also dark due to the

1901
01:09:24,550 --> 01:09:22,880
expansion of the universe

1902
01:09:26,550 --> 01:09:24,560
yeah and that that in fact is correct

1903
01:09:29,590 --> 01:09:26,560
that's that's a very good question and

1904
01:09:31,510 --> 01:09:29,600
it's easy to answer

1905
01:09:33,590 --> 01:09:31,520
uh i mean there's part of the darkness

1906
01:09:35,269 --> 01:09:33,600
is the fact that it's taken so long for

1907
01:09:38,390 --> 01:09:35,279
light to get us even from the start that

1908
01:09:40,550 --> 01:09:38,400
would limit the brightness but the fact

1909
01:09:42,950 --> 01:09:40,560
that you know distant galaxies are

1910
01:09:45,030 --> 01:09:42,960
red-shifted you know uh that's why we

1911
01:09:46,470 --> 01:09:45,040
have the james webb telescope uh the

1912
01:09:47,829 --> 01:09:46,480
forming galaxies right at the start of

1913
01:09:49,910 --> 01:09:47,839

the universe we can't see with an

1914
01:09:52,309 --> 01:09:49,920
ordinary telescope their light is

1915
01:09:54,630 --> 01:09:52,319
shifted into the infrared so yeah that

1916
01:09:56,070 --> 01:09:54,640
that is also part of the factor for

1917
01:09:56,790 --> 01:09:56,080
white you know why we can only see so

1918
01:09:59,110 --> 01:09:56,800
far

1919
01:10:00,950 --> 01:09:59,120
so see so much

1920
01:10:02,470 --> 01:10:00,960
all right well i'm sure there were other

1921
01:10:04,310 --> 01:10:02,480
questions that i didn't have a chance to

1922
01:10:06,950 --> 01:10:04,320
write down but

1923
01:10:09,189 --> 01:10:06,960
grant justice has been following the uh

1924
01:10:11,830 --> 01:10:09,199
chat more closely than i grant why don't

1925
01:10:13,830 --> 01:10:11,840
you turn on your video and uh tell us

1926
01:10:15,110 --> 01:10:13,840
what questions you found in the youtube

1927
01:10:17,110 --> 01:10:15,120
chat

1928
01:10:20,229 --> 01:10:17,120
absolutely

1929
01:10:22,070 --> 01:10:20,239
all right so let's uh get us started off

1930
01:10:24,310 --> 01:10:22,080
here

1931
01:10:25,350 --> 01:10:24,320
and this is one that i i feel like a lot

1932
01:10:27,910 --> 01:10:25,360
of people

1933
01:10:29,350 --> 01:10:27,920
think but don't necessarily ask kind of

1934
01:10:31,669 --> 01:10:29,360
what we were talking about question

1935
01:10:32,630 --> 01:10:31,679
there cannot be asked yes go ahead

1936
01:10:33,510 --> 01:10:32,640
yes

1937
01:10:34,310 --> 01:10:33,520
um

1938
01:10:36,070 --> 01:10:34,320

so

1939
01:10:39,030 --> 01:10:36,080
and this is one of the big things with

1940
01:10:40,790 --> 01:10:39,040
james webb and especially with space and

1941
01:10:42,310 --> 01:10:40,800
darkness as well is

1942
01:10:44,790 --> 01:10:42,320
when you're looking for things that are

1943
01:10:47,510 --> 01:10:44,800
so far away things that have

1944
01:10:49,030 --> 01:10:47,520
such small photonic signatures you have

1945
01:10:50,630 --> 01:10:49,040
to collect so much light and be able to

1946
01:10:52,870 --> 01:10:50,640
see it what exactly is it that you're

1947
01:10:54,630 --> 01:10:52,880
looking for there not necessarily what

1948
01:10:56,630 --> 01:10:54,640
heavenly body but what is it that you're

1949
01:11:00,070 --> 01:10:56,640
detecting

1950
01:11:03,270 --> 01:11:00,080
well it's with um

1951
01:11:04,630 --> 01:11:03,280
not quite sure um

1952
01:11:07,430 --> 01:11:04,640
there's a technical thing let me give

1953
01:11:10,470 --> 01:11:07,440
you the technical answer bring it on it

1954
01:11:12,870 --> 01:11:10,480
is light it's uh for optical light we

1955
01:11:15,510 --> 01:11:12,880
have a ccd and those are once exotic

1956
01:11:17,430 --> 01:11:15,520
devices i did my thesis with one of the

1957
01:11:19,590 --> 01:11:17,440
first ccds around

1958
01:11:21,030 --> 01:11:19,600
but you know you probably have two of

1959
01:11:22,390 --> 01:11:21,040
them you can't see that with my

1960
01:11:25,189 --> 01:11:22,400
background coming in but you have two of

1961
01:11:27,270 --> 01:11:25,199
them with you in your phone right back

1962
01:11:30,149 --> 01:11:27,280
side front side and that's the ccd and

1963
01:11:32,310 --> 01:11:30,159

the sensors are not that different

1964
01:11:33,830 --> 01:11:32,320
the james webb telescope sees the

1965
01:11:36,390 --> 01:11:33,840
infrared so you need a different kind

1966
01:11:38,830 --> 01:11:36,400
but it's a solid state thing photon

1967
01:11:41,270 --> 01:11:38,840
comes in makes an electron

1968
01:11:43,030 --> 01:11:41,280
electron uh you know builds up for a bit

1969
01:11:44,790 --> 01:11:43,040
and then after a while you quote read it

1970
01:11:46,070 --> 01:11:44,800
out you count them and that gets turned

1971
01:11:48,149 --> 01:11:46,080
into a number

1972
01:11:49,750 --> 01:11:48,159
and so everything is if you want light

1973
01:11:51,350 --> 01:11:49,760
being turned into numbers and that's

1974
01:11:53,430 --> 01:11:51,360
what's coming down with deep space

1975
01:11:55,750 --> 01:11:53,440
network right now the space network is

1976
01:11:57,350 --> 01:11:55,760
sending us numbers

1977
01:11:58,709 --> 01:11:57,360
saying how bright is it in this pixel

1978
01:12:02,630 --> 01:11:58,719
how bright is it in that pixel and

1979
01:12:06,550 --> 01:12:04,390
okay um

1980
01:12:09,830 --> 01:12:06,560
kind of building on that as well

1981
01:12:12,229 --> 01:12:09,840
what efforts were previously made to

1982
01:12:14,229 --> 01:12:12,239
measure blackness like

1983
01:12:15,990 --> 01:12:14,239
what what kind of instrumentation would

1984
01:12:18,310 --> 01:12:16,000
you use previously before we had

1985
01:12:20,070 --> 01:12:18,320
infrared and a lot of a lot of the more

1986
01:12:21,510 --> 01:12:20,080
advanced stuff we have now

1987
01:12:23,030 --> 01:12:21,520
well uh

1988
01:12:24,310 --> 01:12:23,040

you use some of the advanced stuff

1989
01:12:27,350 --> 01:12:24,320
people have tried this with the hubble

1990
01:12:29,189 --> 01:12:27,360
space telescope and th this is this is

1991
01:12:30,870 --> 01:12:29,199
the thing i mean just because

1992
01:12:33,510 --> 01:12:30,880
something's hard

1993
01:12:35,910 --> 01:12:33,520
um doesn't mean you don't try it

1994
01:12:37,990 --> 01:12:35,920
and in fact i'm being a little cavalier

1995
01:12:40,550 --> 01:12:38,000
is the yoy's trihard stuff it's always

1996
01:12:42,550 --> 01:12:40,560
at the frontier and so this question has

1997
01:12:43,990 --> 01:12:42,560
been around for decades and people have

1998
01:12:45,350 --> 01:12:44,000
tried a different way it's hard from the

1999
01:12:48,310 --> 01:12:45,360
earth because the earth's atmosphere

2000
01:12:49,669 --> 01:12:48,320
puts out yet more glow you know that

2001
01:12:52,229 --> 01:12:49,679
gets in the way

2002
01:12:53,990 --> 01:12:52,239
but work was done oh gosh i'm trying to

2003
01:12:57,110 --> 01:12:54,000
remember when this was in the late 90s

2004
01:12:59,750 --> 01:12:57,120
with the hubble space telescope

2005
01:13:01,590 --> 01:12:59,760
and you know it was bothered by zodiacal

2006
01:13:03,510 --> 01:13:01,600
light but the clever people say well you

2007
01:13:05,590 --> 01:13:03,520
know i think it looks like this and i

2008
01:13:06,790 --> 01:13:05,600
can take it out if it has this

2009
01:13:08,149 --> 01:13:06,800
distribution

2010
01:13:10,709 --> 01:13:08,159
and and they're completely right they

2011
01:13:12,870 --> 01:13:10,719
can do that but it puts noise in and

2012
01:13:14,870 --> 01:13:12,880
there's uncertainties and

2013
01:13:16,470 --> 01:13:14,880

the thing that's a little bit hard for

2014
01:13:18,229 --> 01:13:16,480
people to put their head around is we

2015
01:13:19,350 --> 01:13:18,239
often are not so much interested in the

2016
01:13:21,110 --> 01:13:19,360
measurement

2017
01:13:22,709 --> 01:13:21,120
but the errors

2018
01:13:24,470 --> 01:13:22,719
you know there's i don't really care

2019
01:13:26,229 --> 01:13:24,480
what the number is but i do care if the

2020
01:13:28,070 --> 01:13:26,239
errors are small and so people made the

2021
01:13:29,189 --> 01:13:28,080
measurements but the errors were just

2022
01:13:30,790 --> 01:13:29,199
very big

2023
01:13:33,510 --> 01:13:30,800
and they were honest about the errors

2024
01:13:36,149 --> 01:13:33,520
and so we tried this there's a

2025
01:13:37,669 --> 01:13:36,159
japanese probe rocket called cyber which

2026
01:13:40,550 --> 01:13:37,679
is for this thing

2027
01:13:42,310 --> 01:13:40,560
uh you know it's it's suborbital and so

2028
01:13:43,750 --> 01:13:42,320
they had to take care of zodiac light as

2029
01:13:46,950 --> 01:13:43,760
well and they had ways of doing that but

2030
01:13:48,390 --> 01:13:46,960
again you get large errors and so a lot

2031
01:13:50,310 --> 01:13:48,400
of the measurements and i had that in

2032
01:13:51,910 --> 01:13:50,320
the figure said yeah maybe something's

2033
01:13:53,590 --> 01:13:51,920
there but they weren't the errors

2034
01:13:55,990 --> 01:13:53,600
weren't you know small enough that you

2035
01:13:58,870 --> 01:13:56,000
could be completely sure about that

2036
01:14:01,110 --> 01:13:58,880
in our case um yeah diacolite was always

2037
01:14:02,709 --> 01:14:01,120
the the major fact that you couldn't

2038
01:14:04,470 --> 01:14:02,719

gauge perfectly you couldn't you

2039
01:14:06,550 --> 01:14:04,480
couldn't get around that and so we're

2040
01:14:08,310 --> 01:14:06,560
not clever we're actually lazy you know

2041
01:14:09,910 --> 01:14:08,320
we're we

2042
01:14:11,750 --> 01:14:09,920
right we're so lazy we put the

2043
01:14:13,669 --> 01:14:11,760
spacecraft that is this whole soulism

2044
01:14:15,430 --> 01:14:13,679
but it has no zodiacal light so i don't

2045
01:14:16,550 --> 01:14:15,440
have to do the fancy stuff i have to

2046
01:14:18,149 --> 01:14:16,560
worry about other things but i don't

2047
01:14:24,950 --> 01:14:18,159
have to worry about that

2048
01:14:24,960 --> 01:14:29,350
okay

2049
01:14:33,350 --> 01:14:31,270
it's basically if you if you produce

2050
01:14:36,149 --> 01:14:33,360
your background noise but i'm sorry

2051
01:14:38,709 --> 01:14:36,159
by a vector of 10 it's you know

2052
01:14:40,630 --> 01:14:38,719
that's quote quote easy and then you

2053
01:14:42,310 --> 01:14:40,640
worry about all the really really small

2054
01:14:43,750 --> 01:14:42,320
things you looked a little stunned there

2055
01:14:45,830 --> 01:14:43,760
frank that's why i was like oh my god oh

2056
01:14:46,870 --> 01:14:45,840
no i was just sort of expecting grant to

2057
01:14:47,750 --> 01:14:46,880
jump in and

2058
01:14:51,030 --> 01:14:47,760
okay

2059
01:14:54,870 --> 01:14:53,189
jump in jump in

2060
01:14:57,270 --> 01:14:54,880
i was too busy listening i was waiting

2061
01:14:59,510 --> 01:14:57,280
for the next the next sentence to start

2062
01:15:00,790 --> 01:14:59,520
all right um here we go i won't let you

2063
01:15:02,149 --> 01:15:00,800

start your sins so we're gonna give you

2064
01:15:04,310 --> 01:15:02,159
more but go ahead

2065
01:15:07,189 --> 01:15:04,320
bring it on

2066
01:15:08,950 --> 01:15:07,199
um one of our returning guys um what's

2067
01:15:12,550 --> 01:15:08,960
the darkest place in the universe that

2068
01:15:16,229 --> 01:15:13,590
well

2069
01:15:19,590 --> 01:15:17,990
the darkest place

2070
01:15:21,270 --> 01:15:19,600
you know it's funny if you if you just

2071
01:15:23,669 --> 01:15:21,280
you know the old dark room is right if

2072
01:15:25,270 --> 01:15:23,679
you uh just went in you know to develop

2073
01:15:26,870 --> 01:15:25,280
film you seal up everything that's is

2074
01:15:28,390 --> 01:15:26,880
probably as dark as anything no light

2075
01:15:30,870 --> 01:15:28,400
whatsoever

2076
01:15:32,630 --> 01:15:30,880
um but no i you know that's that's not

2077
01:15:35,110 --> 01:15:32,640
that that's i can't answer that question

2078
01:15:36,470 --> 01:15:35,120
very well because what i said so far is

2079
01:15:38,550 --> 01:15:36,480
you know i just took what was off the

2080
01:15:41,270 --> 01:15:38,560
spacecraft what i would say is those

2081
01:15:43,270 --> 01:15:41,280
images were the darkest sky ever seen by

2082
01:15:46,470 --> 01:15:43,280
any spacecraft so i would say what you

2083
01:15:48,390 --> 01:15:46,480
have seen there is the darkest

2084
01:15:50,229 --> 01:15:48,400
things they've looked at and

2085
01:15:51,910 --> 01:15:50,239
the data i'm getting down right now that

2086
01:15:53,510 --> 01:15:51,920
while we're talking that may be darker

2087
01:15:54,709 --> 01:15:53,520
yet that would actually be a record

2088
01:15:56,550 --> 01:15:54,719

breaker so there was a little

2089
01:15:59,830 --> 01:15:56,560
speculation about what about a black

2090
01:16:01,590 --> 01:15:59,840
hole would that be an absolute dark like

2091
01:16:03,830 --> 01:16:01,600
reference calibration source or

2092
01:16:06,390 --> 01:16:03,840
something not that new horizons could

2093
01:16:08,550 --> 01:16:06,400
see a black hole but um yeah

2094
01:16:10,390 --> 01:16:08,560
well boy

2095
01:16:11,990 --> 01:16:10,400
i'll tell you i wouldn't want to do that

2096
01:16:14,950 --> 01:16:12,000
because

2097
01:16:16,550 --> 01:16:14,960
right you say well we need a black hole

2098
01:16:20,070 --> 01:16:16,560
well points not going to be oh let's get

2099
01:16:22,149 --> 01:16:20,080
close enough to the black hole

2100
01:16:23,669 --> 01:16:22,159
yeah so it fills the sky like the moon

2101
01:16:25,350 --> 01:16:23,679
or something like that no i you wouldn't

2102
01:16:27,030 --> 01:16:25,360
want to be anywhere near that so and

2103
01:16:28,950 --> 01:16:27,040
plus you know you how could you avoid

2104
01:16:30,630 --> 01:16:28,960
the photon sphere around the black hole

2105
01:16:32,630 --> 01:16:30,640
right no i mean there's things falling

2106
01:16:35,189 --> 01:16:32,640
in the black holes giving off light and

2107
01:16:37,110 --> 01:16:35,199
so even black holes you know well yes

2108
01:16:38,310 --> 01:16:37,120
nothing can come up a lot goes in when

2109
01:16:39,990 --> 01:16:38,320
all this stuff goes there's so much

2110
01:16:41,669 --> 01:16:40,000
there's so much light around the black

2111
01:16:43,110 --> 01:16:41,679
around the black that would contaminate

2112
01:16:45,030 --> 01:16:43,120
all your observations

2113
01:16:46,709 --> 01:16:45,040

exactly i mean it's a great idea i

2114
01:16:49,990 --> 01:16:46,719
thought it was a very inventive idea

2115
01:16:53,590 --> 01:16:51,669
okay well i actually have a question

2116
01:16:56,470 --> 01:16:53,600
myself did you sit there and do the

2117
01:16:59,030 --> 01:16:56,480
calculation that uh like a 25 watt light

2118
01:17:00,630 --> 01:16:59,040
bulb in a refrigerator is at one

2119
01:17:03,750 --> 01:17:00,640
kilometer is equal to the light from

2120
01:17:05,910 --> 01:17:03,760
sirius at what series is 8.8 to light

2121
01:17:07,500 --> 01:17:05,920
years away no i just looked it up on the

2122
01:17:10,709 --> 01:17:07,510
web you know you have these everything

2123
01:17:12,709 --> 01:17:10,719
[Laughter]

2124
01:17:14,390 --> 01:17:12,719
google google light bulb refrigerator

2125
01:17:16,390 --> 01:17:14,400
seriously somebody asked that question

2126
01:17:18,950 --> 01:17:16,400
you know five years ago

2127
01:17:21,350 --> 01:17:18,960
absolutely yes no i i

2128
01:17:22,709 --> 01:17:21,360
no i i did that um

2129
01:17:25,270 --> 01:17:22,719
i went because i really wanted to

2130
01:17:27,510 --> 01:17:25,280
visualize what the light was like and uh

2131
01:17:29,590 --> 01:17:27,520
mark postman also

2132
01:17:31,830 --> 01:17:29,600
did that and we got we got the same

2133
01:17:33,990 --> 01:17:31,840
answer and yes the refrigerator lights

2134
01:17:36,470 --> 01:17:34,000
is 25 watts how far do you have to put

2135
01:17:38,550 --> 01:17:36,480
it away it's about a kilometer and it

2136
01:17:40,550 --> 01:17:38,560
turns out i want to do it like a star

2137
01:17:42,310 --> 01:17:40,560
and sirius is the same thing so you know

2138
01:17:44,709 --> 01:17:42,320

there there you go

2139
01:17:46,550 --> 01:17:44,719
so yes i did do that calculation myself

2140
01:17:49,350 --> 01:17:46,560
for ourselves and we had our math

2141
01:17:50,950 --> 01:17:49,360
checked and and so sirius is is one

2142
01:17:53,110 --> 01:17:50,960
fridge of

2143
01:17:55,189 --> 01:17:53,120
seriousness one period provides only one

2144
01:17:56,070 --> 01:17:55,199
fridge of light like one fridge of light

2145
01:17:58,870 --> 01:17:56,080
yes

2146
01:18:03,430 --> 01:18:01,350
into my next talk okay yeah i i want the

2147
01:18:05,110 --> 01:18:03,440
iau to define this to define this thing

2148
01:18:06,709 --> 01:18:05,120
but yes a fridge of light is an open

2149
01:18:09,030 --> 01:18:06,719
refrigerator or climate that's the

2150
01:18:10,709 --> 01:18:09,040
background radiation all right fantastic

2151
01:18:12,550 --> 01:18:10,719
anything but the metric system we're

2152
01:18:14,870 --> 01:18:12,560
using refrigerators of light to measure

2153
01:18:17,189 --> 01:18:14,880
distance well a kilometer a kilometer is

2154
01:18:18,870 --> 01:18:17,199
in there but that yeah we'll ignore that

2155
01:18:20,630 --> 01:18:18,880
i know it's just

2156
01:18:23,030 --> 01:18:20,640
it's too good it's too good

2157
01:18:27,430 --> 01:18:23,040
all right what else we got grant all

2158
01:18:32,390 --> 01:18:27,440
right so let's see um

2159
01:18:38,070 --> 01:18:35,189
all right um so given your field of

2160
01:18:41,189 --> 01:18:38,080
study and the specific conditions that

2161
01:18:43,510 --> 01:18:41,199
you use and you have to work in

2162
01:18:45,750 --> 01:18:43,520
where would be the ideal place for us to

2163
01:18:48,950 --> 01:18:45,760

place either a telescope or a spacecraft

2164
01:18:51,750 --> 01:18:48,960
for your type of observations

2165
01:18:53,990 --> 01:18:51,760
well um where new horizons is right now

2166
01:18:55,430 --> 01:18:54,000
is pretty ideal

2167
01:18:56,550 --> 01:18:55,440
that that's what that's hard that's hard

2168
01:18:58,630 --> 01:18:56,560
to beat

2169
01:19:00,149 --> 01:18:58,640
um

2170
01:19:02,390 --> 01:19:00,159
you you wouldn't send you probably

2171
01:19:04,470 --> 01:19:02,400
wouldn't send a spacecraft out for just

2172
01:19:06,630 --> 01:19:04,480
this measurement um now what's

2173
01:19:08,630 --> 01:19:06,640
interesting is that if you put you know

2174
01:19:10,550 --> 01:19:08,640
the james webb telescope out there or

2175
01:19:12,790 --> 01:19:10,560
the hubble space telescope

2176
01:19:15,830 --> 01:19:12,800
with a darker background boy they were a

2177
01:19:17,430 --> 01:19:15,840
lot more sensitive to galaxies

2178
01:19:19,270 --> 01:19:17,440
it's a funny kind of thing right you

2179
01:19:21,030 --> 01:19:19,280
know you know that the stars are there

2180
01:19:22,310 --> 01:19:21,040
during daylight

2181
01:19:24,709 --> 01:19:22,320
you know you just can't see them because

2182
01:19:25,910 --> 01:19:24,719
the sky is too bright well the zodiacal

2183
01:19:28,149 --> 01:19:25,920
light for

2184
01:19:29,669 --> 01:19:28,159
hubble space telescope that interferes

2185
01:19:31,189 --> 01:19:29,679
with its ability to see the famous

2186
01:19:33,030 --> 01:19:31,199
galaxies and the same thing for the

2187
01:19:35,750 --> 01:19:33,040
james webb telescope

2188
01:19:37,590 --> 01:19:35,760

and so if you were to put them way out

2189
01:19:39,990 --> 01:19:37,600
in the solar system they'd be much more

2190
01:19:41,350 --> 01:19:40,000
superb for faint galaxies to be very

2191
01:19:43,430 --> 01:19:41,360
very nice

2192
01:19:45,910 --> 01:19:43,440
but you know the telemetry the expense

2193
01:19:48,550 --> 01:19:45,920
of operating at enormous distances it

2194
01:19:50,550 --> 01:19:48,560
makes it extremely difficult and it's

2195
01:19:52,310 --> 01:19:50,560
very difficult operating new horizons so

2196
01:19:53,590 --> 01:19:52,320
you probably wouldn't do you know you

2197
01:19:54,950 --> 01:19:53,600
probably wouldn't mount the mission just

2198
01:19:57,430 --> 01:19:54,960
for this

2199
01:20:00,390 --> 01:19:57,440
so that brings up a question um we've

2200
01:20:02,870 --> 01:20:00,400
been able to contact voyager out to

2201
01:20:06,470 --> 01:20:02,880
about 120 au

2202
01:20:08,950 --> 01:20:06,480
yeah 100 it's 120 yeah yeah yeah and so

2203
01:20:11,110 --> 01:20:08,960
new horizons is at 50 a.u right now

2204
01:20:13,350 --> 01:20:11,120
right and it's moving much faster how

2205
01:20:15,750 --> 01:20:13,360
many more years do we have that where we

2206
01:20:17,990 --> 01:20:15,760
can still talk to new horizons

2207
01:20:20,229 --> 01:20:18,000
um yeah actually it's not moving faster

2208
01:20:23,030 --> 01:20:20,239
it turns out that the voyagers are

2209
01:20:25,189 --> 01:20:23,040
you know given where they went um but we

2210
01:20:26,790 --> 01:20:25,199
always say new horizons had the fastest

2211
01:20:29,430 --> 01:20:26,800
as fastest move

2212
01:20:31,270 --> 01:20:29,440
of any space a spacecraft we've launched

2213
01:20:33,270 --> 01:20:31,280

when we launched it it was true oh when

2214
01:20:35,270 --> 01:20:33,280
we launched it you got to read the fine

2215
01:20:38,229 --> 01:20:35,280
print

2216
01:20:38,950 --> 01:20:38,239
you know

2217
01:20:40,870 --> 01:20:38,960
so

2218
01:20:41,990 --> 01:20:40,880
voyager got the sliding shots and got

2219
01:20:43,990 --> 01:20:42,000
faster

2220
01:20:45,030 --> 01:20:44,000
the slingshots yeah voyagers it's you

2221
01:20:46,709 --> 01:20:45,040
know

2222
01:20:48,390 --> 01:20:46,719
no we're i'm no one's going to catch me

2223
01:20:50,790 --> 01:20:48,400
and new horizons didn't try to catch it

2224
01:20:52,790 --> 01:20:50,800
but but your question is and and one of

2225
01:20:54,550 --> 01:20:52,800
the things is funny new horizons was was

2226
01:20:56,950 --> 01:20:54,560
compared the voyager was made on the

2227
01:20:59,110 --> 01:20:56,960
cheap and we had a small dish

2228
01:21:01,270 --> 01:20:59,120
and so the answer is uh

2229
01:21:02,709 --> 01:21:01,280
you know we're looking to get out to 100

2230
01:21:05,110 --> 01:21:02,719
au

2231
01:21:06,550 --> 01:21:05,120
and you know we may be able to make to

2232
01:21:09,590 --> 01:21:06,560
make that

2233
01:21:12,229 --> 01:21:09,600
uh and that will be in the late 30s and

2234
01:21:14,390 --> 01:21:12,239
so that's probably about

2235
01:21:17,270 --> 01:21:14,400
probably about where we'll go so

2236
01:21:18,950 --> 01:21:17,280
um where voyagers are now we will

2237
01:21:20,790 --> 01:21:18,960
probably not be able to talk to new

2238
01:21:22,629 --> 01:21:20,800

horizons as far as the voyagers have

2239
01:21:24,790 --> 01:21:22,639
gotten out we just don't have the

2240
01:21:27,110 --> 01:21:24,800
transmitter the dish and the power

2241
01:21:29,189 --> 01:21:27,120
reserves to do that

2242
01:21:30,149 --> 01:21:29,199
so in the direction that new horizons is

2243
01:21:35,510 --> 01:21:30,159
going

2244
01:21:37,590 --> 01:21:35,520
heliopause uh is it before uh we won't

2245
01:21:40,070 --> 01:21:37,600
be able to no unfortunately yeah we we

2246
01:21:42,070 --> 01:21:40,080
should we should not see the heliopause

2247
01:21:45,189 --> 01:21:42,080
before while we can still talk to them

2248
01:21:47,270 --> 01:21:45,199
okay because that would be a fantastic

2249
01:21:48,550 --> 01:21:47,280
a wonderful verification it would be

2250
01:21:49,669 --> 01:21:48,560
great you know if you have somebody we

2251
01:21:51,669 --> 01:21:49,679
could go there you know if you have some

2252
01:21:53,270 --> 01:21:51,679
plutonium in your pocket you know you go

2253
01:21:55,750 --> 01:21:53,280
out there and pass up the you know the

2254
01:21:57,110 --> 01:21:55,760
rtgs right refill that

2255
01:21:59,030 --> 01:21:57,120
you know buff it up a little bit give it

2256
01:22:00,149 --> 01:21:59,040
a bigger dish than we're talking

2257
01:22:01,270 --> 01:22:00,159
refuel it by the way while it's

2258
01:22:03,430 --> 01:22:01,280
something that we could really do

2259
01:22:07,189 --> 01:22:03,440
something so

2260
01:22:10,629 --> 01:22:08,830
all

2261
01:22:12,390 --> 01:22:10,639
right i've got to find two more

2262
01:22:14,229 --> 01:22:12,400
questions i've got two more to finish

2263
01:22:19,430 --> 01:22:14,239

this up if that's okay

2264
01:22:23,990 --> 01:22:22,070
first one off here um

2265
01:22:26,550 --> 01:22:24,000
is it possible that there are objects in

2266
01:22:30,310 --> 01:22:26,560
the universe that are beyond what we can

2267
01:22:31,510 --> 01:22:30,320
see now and if true well realistically

2268
01:22:34,709 --> 01:22:31,520
we know that there are things that we

2269
01:22:35,910 --> 01:22:34,719
can't see and can't observe um but

2270
01:22:38,470 --> 01:22:35,920
is there anything that you think we will

2271
01:22:40,470 --> 01:22:38,480
not be able to observe just based on

2272
01:22:44,229 --> 01:22:40,480
location based on

2273
01:22:47,430 --> 01:22:44,239
obstruction based on uh like being near

2274
01:22:48,550 --> 01:22:47,440
a black hole radiation being

2275
01:22:50,229 --> 01:22:48,560
pulled from is there anything that you

2276
01:22:51,510 --> 01:22:50,239
think we won't be able to actually

2277
01:22:53,750 --> 01:22:51,520
observe

2278
01:22:57,270 --> 01:22:53,760
i let me let me answer that question a

2279
01:22:59,350 --> 01:22:57,280
little bit differently um

2280
01:23:00,390 --> 01:22:59,360
i think you know that's very hard to

2281
01:23:02,229 --> 01:23:00,400
answer so i'm going to answer a

2282
01:23:05,030 --> 01:23:02,239
different question that you didn't ask

2283
01:23:07,510 --> 01:23:06,390
i have a great answer to a different

2284
01:23:09,189 --> 01:23:07,520
question

2285
01:23:10,470 --> 01:23:09,199
it's very it's very political of me it's

2286
01:23:12,149 --> 01:23:10,480
a style yes i know what you asked but

2287
01:23:13,350 --> 01:23:12,159
i'm going to answer something else

2288
01:23:18,870 --> 01:23:13,360

um

2289
01:23:20,870 --> 01:23:18,880
a picture of the galaxy in the plane

2290
01:23:22,390 --> 01:23:20,880
and we know already that you know being

2291
01:23:25,030 --> 01:23:22,400
in the planet of our galaxy makes it

2292
01:23:26,550 --> 01:23:25,040
very difficult for us to see what's not

2293
01:23:28,149 --> 01:23:26,560
you know what is what we're actually

2294
01:23:30,229 --> 01:23:28,159
blocking

2295
01:23:31,590 --> 01:23:30,239
and you saw there's dust in the galaxy

2296
01:23:33,510 --> 01:23:31,600
they're parts of the galaxy very

2297
01:23:35,270 --> 01:23:33,520
difficult to see

2298
01:23:36,470 --> 01:23:35,280
and you know you think you know if

2299
01:23:38,070 --> 01:23:36,480
you're in the center of the galaxy

2300
01:23:39,669 --> 01:23:38,080
around all those stars boy you would

2301
01:23:42,070 --> 01:23:39,679
have trouble seeing a distant universe

2302
01:23:43,750 --> 01:23:42,080
astronomy be very difficult

2303
01:23:46,229 --> 01:23:43,760
and so it's an interesting question to

2304
01:23:48,229 --> 01:23:46,239
play a parlor game you know astronomers

2305
01:23:49,830 --> 01:23:48,239
if i know i've never been to an

2306
01:23:51,910 --> 01:23:49,840
astronomer parlor but you know if you

2307
01:23:53,830 --> 01:23:51,920
imagine there is such a thing

2308
01:23:55,430 --> 01:23:53,840
you know and and are you

2309
01:23:57,910 --> 01:23:55,440
sorry sorry

2310
01:23:58,709 --> 01:23:57,920
in in the late evening at the double ass

2311
01:24:00,310 --> 01:23:58,719
meeting

2312
01:24:03,750 --> 01:24:00,320
yeah i guess that's as close to his

2313
01:24:05,669 --> 01:24:03,760

astronomers parlor yes and

2314
01:24:07,189 --> 01:24:05,679
there has to be some good drink involved

2315
01:24:08,790 --> 01:24:07,199
for this but it's you know a great

2316
01:24:10,550 --> 01:24:08,800
question is what's wrong with where we

2317
01:24:12,310 --> 01:24:10,560
are what are we missing because you can

2318
01:24:13,830 --> 01:24:12,320
say boy i'm glad i'm not at the center

2319
01:24:15,910 --> 01:24:13,840
of the galaxy because i wouldn't know

2320
01:24:18,229 --> 01:24:15,920
this or what if i was in between

2321
01:24:20,229 --> 01:24:18,239
andromeda you know our galaxy and i

2322
01:24:21,830 --> 01:24:20,239
couldn't get parallaxes to figure out

2323
01:24:23,189 --> 01:24:21,840
distances i wouldn't know what they were

2324
01:24:24,870 --> 01:24:23,199
you know

2325
01:24:27,270 --> 01:24:24,880
what if our sun was in the globular

2326
01:24:29,510 --> 01:24:27,280
cluster right yeah exactly the sky would

2327
01:24:32,229 --> 01:24:29,520
be just so bright with stars and just

2328
01:24:33,910 --> 01:24:32,239
don't destroy our no you you'd have

2329
01:24:35,910 --> 01:24:33,920
trouble you'd have trouble understanding

2330
01:24:36,870 --> 01:24:35,920
what you know what you're looking at

2331
01:24:38,870 --> 01:24:36,880
but

2332
01:24:41,189 --> 01:24:38,880
there is some ways which we you know

2333
01:24:42,310 --> 01:24:41,199
which limit our view and i suggest a few

2334
01:24:44,470 --> 01:24:42,320
of them that were in the plane of our

2335
01:24:46,149 --> 01:24:44,480
galaxy and so it's asking what is it

2336
01:24:48,550 --> 01:24:46,159
that we don't know

2337
01:24:50,470 --> 01:24:48,560
what is wrong with our vantage point

2338
01:24:52,950 --> 01:24:50,480

that is limiting our ability to do this

2339
01:24:54,390 --> 01:24:52,960
it's like you know the unknown unknown

2340
01:24:55,750 --> 01:24:54,400
you know maybe some of the things we

2341
01:24:57,510 --> 01:24:55,760
think are because there's something

2342
01:24:59,189 --> 01:24:57,520
limiting what we can see and that's an

2343
01:25:00,550 --> 01:24:59,199
interesting question to say what could

2344
01:25:03,510 --> 01:25:00,560
that be

2345
01:25:05,270 --> 01:25:03,520
so if that's an okay answer to that your

2346
01:25:06,950 --> 01:25:05,280
question

2347
01:25:08,310 --> 01:25:06,960
i feel like that was

2348
01:25:09,990 --> 01:25:08,320
that was a reason

2349
01:25:14,790 --> 01:25:10,000
i know he asked the person to see if the

2350
01:25:18,709 --> 01:25:17,110
plausibility scale you know

2351
01:25:21,189 --> 01:25:18,719
frank do you have any more before i ask

2352
01:25:22,709 --> 01:25:21,199
the last one ask the last question i'll

2353
01:25:23,750 --> 01:25:22,719
have a final comment

2354
01:25:25,350 --> 01:25:23,760
okay

2355
01:25:26,550 --> 01:25:25,360
this is one i'm going to bring it back a

2356
01:25:28,070 --> 01:25:26,560
little bit because we're getting a

2357
01:25:30,470 --> 01:25:28,080
little bit into the weeds here this is

2358
01:25:33,830 --> 01:25:30,480
one that i've seen a parlor game

2359
01:25:37,110 --> 01:25:35,270
maybe she would go into the weeds that

2360
01:25:38,950 --> 01:25:37,120
could be just as good but it could it

2361
01:25:40,790 --> 01:25:38,960
could some of the chat would definitely

2362
01:25:42,229 --> 01:25:40,800
like us to go into the weeds but just

2363
01:25:43,350 --> 01:25:42,239

given the amount of times i've seen this

2364
01:25:45,830 --> 01:25:43,360
repeated

2365
01:25:48,629 --> 01:25:45,840
what is it that causes galaxies to

2366
01:25:51,030 --> 01:25:48,639
appear to be closer together or in

2367
01:25:54,550 --> 01:25:51,040
like tighter formations the further away

2368
01:25:56,310 --> 01:25:54,560
that we are observing them

2369
01:25:58,149 --> 01:25:56,320
i'm not sure i can answer i don't i

2370
01:25:59,750 --> 01:25:58,159
don't know that that is so

2371
01:26:01,110 --> 01:25:59,760
um

2372
01:26:02,790 --> 01:26:01,120
i've seen it repeated in the chat like

2373
01:26:04,390 --> 01:26:02,800
four or five times i wanted to get your

2374
01:26:05,510 --> 01:26:04,400
input here

2375
01:26:08,070 --> 01:26:05,520
um

2376
01:26:09,510 --> 01:26:08,080
i i you i'm afraid i'm baffled because i

2377
01:26:11,590 --> 01:26:09,520
i don't think they don't i don't

2378
01:26:13,350 --> 01:26:11,600
understand that that is so yeah the

2379
01:26:17,590 --> 01:26:13,360
two-point correlation function of

2380
01:26:19,270 --> 01:26:17,600
galaxies as you with increasing redshift

2381
01:26:21,110 --> 01:26:19,280
um

2382
01:26:22,709 --> 01:26:21,120
well i mean

2383
01:26:24,550 --> 01:26:22,719
no i mean what we can say you know the

2384
01:26:26,229 --> 01:26:24,560
only thing i'd say is galaxies do like

2385
01:26:28,870 --> 01:26:26,239
the company of other galaxies they're

2386
01:26:29,590 --> 01:26:28,880
not spread flat or randomly in fact

2387
01:26:33,430 --> 01:26:29,600
right

2388
01:26:35,750 --> 01:26:33,440

perfect that's a cluster of galaxies

2389
01:26:37,590 --> 01:26:35,760
where the galaxies are very dense and

2390
01:26:39,750 --> 01:26:37,600
closely associated with each other so

2391
01:26:41,430 --> 01:26:39,760
there is that you know gravity pulls

2392
01:26:43,669 --> 01:26:41,440
that develops over time it doesn't

2393
01:26:46,310 --> 01:26:43,679
develop back and it it it decreases back

2394
01:26:48,149 --> 01:26:46,320
in time no yeah back in time galaxies

2395
01:26:49,430 --> 01:26:48,159
are are if anything less clustered

2396
01:26:50,790 --> 01:26:49,440
together that's that's how i would

2397
01:26:51,990 --> 01:26:50,800
answer that

2398
01:26:55,990 --> 01:26:52,000
okay

2399
01:26:59,110 --> 01:26:56,000
astronomical parlor and i was

2400
01:27:01,910 --> 01:26:59,120
remembering 25 years ago

2401
01:27:03,830 --> 01:27:01,920
um when we were at the double a s that

2402
01:27:04,629 --> 01:27:03,840
we were talking about in san antonio

2403
01:27:07,830 --> 01:27:04,639
yeah

2404
01:27:10,629 --> 01:27:07,840
and neil tyson had a bottle of wine out

2405
01:27:11,430 --> 01:27:10,639
yes he did um yes and uh we were sitting

2406
01:27:13,350 --> 01:27:11,440
around

2407
01:27:14,950 --> 01:27:13,360
chatting and touching i actually

2408
01:27:17,510 --> 01:27:14,960
remember that conversation i remember

2409
01:27:19,910 --> 01:27:17,520
that conversation and i remember

2410
01:27:23,110 --> 01:27:19,920
particular because you said billions

2411
01:27:26,470 --> 01:27:23,120
tonight uh a certain person doing a very

2412
01:27:29,030 --> 01:27:26,480
interesting carl sagan impersonation

2413
01:27:30,790 --> 01:27:29,040

at that me at that astronomical parlor

2414
01:27:31,990 --> 01:27:30,800
somebody somebody might have done that i

2415
01:27:34,790 --> 01:27:32,000
don't know who would have done that i

2416
01:27:36,149 --> 01:27:34,800
don't know who would have done that yeah

2417
01:27:38,629 --> 01:27:36,159
but i was waiting for you to do the

2418
01:27:40,870 --> 01:27:38,639
billions and billions here

2419
01:27:43,030 --> 01:27:40,880
raising the 400 billion stars the

2420
01:27:45,430 --> 01:27:43,040
innumerable bounty of human existence

2421
01:27:47,189 --> 01:27:45,440
yes sorry

2422
01:27:49,750 --> 01:27:47,199
well thank you very much thank you for

2423
01:27:51,350 --> 01:27:49,760
that for doing that all right all right

2424
01:27:53,350 --> 01:27:51,360
you better give me a little wine for

2425
01:27:55,750 --> 01:27:53,360
yourself uh thank you

2426
01:27:57,910 --> 01:27:55,760
thank you so much for being here todd

2427
01:27:59,189 --> 01:27:57,920
really appreciated having you thank you

2428
01:28:02,229 --> 01:27:59,199
this is fun

2429
01:28:03,270 --> 01:28:02,239
thank you to everyone who's watching um

2430
01:28:05,510 --> 01:28:03,280
next

2431
01:28:08,629 --> 01:28:05,520
public lecture series will be november

2432
01:28:10,870 --> 01:28:08,639
2nd com please join us thank you all and