

1
00:00:00,000 --> 00:00:05,639
speed and in the background grant who's

2
00:00:03,000 --> 00:00:07,620
sitting probably you know twenty offices

3
00:00:05,639 --> 00:00:09,300
down that way is taking it and sending

4
00:00:07,620 --> 00:00:15,629
out to youtube so let's give grant a

5
00:00:09,300 --> 00:00:17,490
hand and thank him we got the lights you

6
00:00:15,630 --> 00:00:23,550
can bring lights down we'll set and

7
00:00:17,489 --> 00:00:25,618
we'll get ourselves started good evening

8
00:00:23,550 --> 00:00:28,019
ladies and gentlemen and welcome to the

9
00:00:25,618 --> 00:00:30,960
Space Telescope public lecture series it

10
00:00:28,018 --> 00:00:33,030
is my pleasure to host tonight I am dr.

11
00:00:30,960 --> 00:00:43,649
Frank summers of the office of public

12
00:00:33,030 --> 00:00:46,829
outreach and it's so when you come in on

13
00:00:43,649 --> 00:00:47,399
the tables we have lithographs pictures

14
00:00:46,829 --> 00:00:50,009
from Hubble

15
00:00:47,399 --> 00:00:52,259
tonight's picture is Nessie a 104

16
00:00:50,009 --> 00:00:54,479
there's some gray row galaxies and I

17
00:00:52,259 --> 00:00:57,238
chose it because it has a very large

18
00:00:54,479 --> 00:00:59,459
central region that's the Bulge of a

19
00:00:57,238 --> 00:01:02,030
galaxy and you're gonna learn about the

20
00:00:59,460 --> 00:01:04,409
Bulge of the Milky Way galaxy tonight

21
00:01:02,030 --> 00:01:06,810
tonight's speaker is talking on the

22
00:01:04,409 --> 00:01:10,080
Milky Way's bulge from a hypothesized

23
00:01:06,810 --> 00:01:12,570
blob to a remarkably detailed picture

24
00:01:10,079 --> 00:01:14,728
okay so you have an example of a bulge

25
00:01:12,569 --> 00:01:18,929
in front of you to reference while he

26
00:01:14,728 --> 00:01:21,359
gives his talk next month

27
00:01:18,930 --> 00:01:23,520
Greg Sloan will be talking about ashes

28
00:01:21,359 --> 00:01:27,150
to ashes dust to dust

29

00:01:23,519 --> 00:01:28,920
the fate of stars like the Sun so he

30
00:01:27,150 --> 00:01:30,960
specifically said he's not going to talk

31
00:01:28,920 --> 00:01:33,780
about exploding stars and black holes

32
00:01:30,959 --> 00:01:36,209
and neutron stars is that's that's

33
00:01:33,780 --> 00:01:39,509
another talk he's gonna talk about what

34
00:01:36,209 --> 00:01:42,328
happens to medium star sized stars like

35
00:01:39,509 --> 00:01:42,719
our Sun and the ashes to ashes dust to

36
00:01:42,328 --> 00:01:45,449
dust

37
00:01:42,719 --> 00:01:48,868
is a clue okay so come back in August

38
00:01:45,450 --> 00:01:51,629
for that in September we will talk about

39
00:01:48,868 --> 00:01:56,908
more death we're just being morbid here

40
00:01:51,629 --> 00:02:00,259
and our astronomy 100 ways to die in the

41
00:01:56,909 --> 00:02:03,118
universe that's Katie Katie a lot hello

42
00:02:00,259 --> 00:02:05,218
close to be talking about that and in

43
00:02:03,118 --> 00:02:07,349

October then we'll get to those

44

00:02:05,218 --> 00:02:11,269
exploding stars will talk about chasing

45

00:02:07,349 --> 00:02:13,519
supernovae with Kepler from Gotham

46

00:02:11,270 --> 00:02:15,439
here at Space Telescope if you would

47

00:02:13,520 --> 00:02:17,750
like to information about these you can

48

00:02:15,439 --> 00:02:20,000
go to our website go to your favorite

49

00:02:17,750 --> 00:02:21,979
search engine type in Space Telescope

50

00:02:20,000 --> 00:02:25,340
public lectures you should find this

51

00:02:21,979 --> 00:02:28,329
webpage with our upcoming lectures

52

00:02:25,340 --> 00:02:32,990
listed here the links to our live

53

00:02:28,330 --> 00:02:35,540
webcasting as well as our archive the

54

00:02:32,990 --> 00:02:38,420
youtube playlist goes back to 2014 and

55

00:02:35,539 --> 00:02:42,469
the STScI webcast archive goes all the

56

00:02:38,419 --> 00:02:44,329
way back to 2005 so there's an awful lot

57

00:02:42,469 --> 00:02:47,330
if you want to binge-watch astronomy

58
00:02:44,330 --> 00:02:50,810
lectures I got it an entire week of it

59
00:02:47,330 --> 00:02:52,490
for you okay actually I realized that

60
00:02:50,810 --> 00:02:55,610
you know tonight is probably about my

61
00:02:52,490 --> 00:02:58,000
16th anniversary hosting these public

62
00:02:55,610 --> 00:02:58,000
lectures

63
00:03:02,430 --> 00:03:08,460
you know it's been a lot of fun but Wow

64
00:03:05,340 --> 00:03:10,920
sixteen years all right if you would

65
00:03:08,460 --> 00:03:13,020
like to have notice about these public

66
00:03:10,919 --> 00:03:15,780
lectures you can sign up by providing

67
00:03:13,020 --> 00:03:17,880
your email here to our announcements we

68
00:03:15,780 --> 00:03:19,860
send out like two or three announcements

69
00:03:17,879 --> 00:03:21,900
a month

70
00:03:19,860 --> 00:03:25,110
yes announcements sign up at the website

71
00:03:21,900 --> 00:03:26,580
or if you can't handle online technology

72
00:03:25,110 --> 00:03:29,790
what are you doing asking for an email

73
00:03:26,580 --> 00:03:31,170
but anyways just give me your email

74
00:03:29,789 --> 00:03:34,049
address write it down a piece of paper

75
00:03:31,169 --> 00:03:35,909
and I'll make sure to add you okay if

76
00:03:34,050 --> 00:03:38,189
also you have comments or questions you

77
00:03:35,909 --> 00:03:42,599
can send them to our email public

78
00:03:38,189 --> 00:03:45,599
lecture at STScI dot edu if you are into

79
00:03:42,599 --> 00:03:48,449
social media we have a variety for the

80
00:03:45,599 --> 00:03:51,000
hubble web and Space Telescope on

81
00:03:48,449 --> 00:03:53,189
Facebook Twitter YouTube Instagram and

82
00:03:51,000 --> 00:03:56,009
probably a few others that I'm not

83
00:03:53,189 --> 00:03:58,709
listing here I myself am on Facebook

84
00:03:56,009 --> 00:04:01,500
Google+ and Twitter every now and then

85
00:03:58,709 --> 00:04:05,189
if you want to hear more from me

86

00:04:01,500 --> 00:04:09,000
let's see Observatory I had did not get

87
00:04:05,189 --> 00:04:10,909
an email before I started this it was

88
00:04:09,000 --> 00:04:13,590
sort of cloudy and sort of not cloudy

89
00:04:10,909 --> 00:04:14,340
actually when I left my houses to come

90
00:04:13,590 --> 00:04:16,680
in this evening

91
00:04:14,340 --> 00:04:19,680
it was raining but it was sunny while it

92
00:04:16,680 --> 00:04:20,939
was raining so I'm not sure what they

93
00:04:19,680 --> 00:04:24,150
were gonna do so that's still a question

94
00:04:20,939 --> 00:04:25,918
mark I will check with already during the

95
00:04:24,149 --> 00:04:29,699
lecture and I'll have an answer by the

96
00:04:25,918 --> 00:04:31,889
end of the lecture okay but if you are

97
00:04:29,699 --> 00:04:33,899
not if if it doesn't happen tonight

98
00:04:31,889 --> 00:04:36,899
remember there are still open houses on

99
00:04:33,899 --> 00:04:38,879
Friday evenings this webpage of the

100
00:04:36,899 --> 00:04:42,418

Maryland Space Grant observatory will

101

00:04:38,879 --> 00:04:42,959

list the observatory status every Friday

102

00:04:42,418 --> 00:04:45,569

evening

103

00:04:42,959 --> 00:04:46,680

about 5:30 6 o'clock they will list the

104

00:04:45,569 --> 00:04:48,329

status whether or not they're gonna be

105

00:04:46,680 --> 00:04:53,490

open so if you don't get a chance

106

00:04:48,329 --> 00:04:58,189

tonight check back on Friday and now the

107

00:04:53,490 --> 00:05:00,810

news from the universe for July 2018 and

108

00:04:58,189 --> 00:05:01,199

unfortunately I have a repeat story for

109

00:05:00,810 --> 00:05:06,589

you tonight

110

00:05:01,199 --> 00:05:10,279

and it is j DST launched delay ok so

111

00:05:06,589 --> 00:05:13,659

last time back in

112

00:05:10,279 --> 00:05:16,189

let's see when was it it was in March

113

00:05:13,660 --> 00:05:18,950

March or April or May one of those about

114

00:05:16,189 --> 00:05:21,860

three months ago okay the status of it

115
00:05:18,949 --> 00:05:25,279
was that it was being delayed until May

116
00:05:21,860 --> 00:05:27,530
2020 they had formed an independent

117
00:05:25,279 --> 00:05:29,539
review board to look at Jerez t's

118
00:05:27,529 --> 00:05:32,389
construction and really go through the

119
00:05:29,540 --> 00:05:34,610
process rigorously and especially to do

120
00:05:32,389 --> 00:05:36,169
a new cost analysis to make sure that

121
00:05:34,610 --> 00:05:36,740
they really knew what it was going to

122
00:05:36,170 --> 00:05:38,930
cost

123
00:05:36,740 --> 00:05:41,840
well that independent review board has

124
00:05:38,930 --> 00:05:44,980
now finished its study and the press

125
00:05:41,839 --> 00:05:48,169
release from last week was that they

126
00:05:44,980 --> 00:05:51,050
have a new launch date for web of March

127
00:05:48,170 --> 00:05:52,879
30th 2021 so that's almost that's

128
00:05:51,050 --> 00:05:55,879
another ten months of delay for the

129
00:05:52,879 --> 00:05:57,680
James Webb Space Telescope why well

130
00:05:55,879 --> 00:06:00,079
there are changes in the schedule due to

131
00:05:57,680 --> 00:06:02,180
environmental testing and work

132
00:06:00,079 --> 00:06:05,599
performance challenges on the spacecraft

133
00:06:02,180 --> 00:06:07,910
Sun shield and propulsion system okay

134
00:06:05,600 --> 00:06:10,820
that's technical technical language of

135
00:06:07,910 --> 00:06:12,710
the environmental testing I believe is

136
00:06:10,819 --> 00:06:14,959
the vacuum chamber testing that they did

137
00:06:12,709 --> 00:06:17,149
down at Johnson yeah and so they need

138
00:06:14,959 --> 00:06:20,089
more time to pass all of those tests and

139
00:06:17,149 --> 00:06:21,739
get things together but however the

140
00:06:20,089 --> 00:06:23,449
independent review board I mean this is

141
00:06:21,740 --> 00:06:25,910
independent this is not a NASA board

142
00:06:23,449 --> 00:06:27,649
this is independent of NASA it came back

143

00:06:25,910 --> 00:06:30,050
and they also reaffirmed Webb

144
00:06:27,649 --> 00:06:32,629
significant complexity incredible

145
00:06:30,050 --> 00:06:34,790
scientific potential and importance to

146
00:06:32,629 --> 00:06:36,769
astrophysics okay so they didn't say

147
00:06:34,790 --> 00:06:38,540
like oh no no this is a problem no they

148
00:06:36,769 --> 00:06:41,269
said look this is really important and

149
00:06:38,540 --> 00:06:44,090
we gotta get it right okay we do not

150
00:06:41,269 --> 00:06:46,159
have any chance of servicing the James

151
00:06:44,089 --> 00:06:48,228
Webb Space Telescope you're gonna get it

152
00:06:46,160 --> 00:06:50,840
right the first time so that's basically

153
00:06:48,228 --> 00:06:54,560
they said and the new development cost

154
00:06:50,839 --> 00:06:56,000
estimate is 8.8 billion and for those of

155
00:06:54,560 --> 00:06:58,250
you who remember what I said a few

156
00:06:56,000 --> 00:07:00,649
months ago the development cost estimate

157
00:06:58,250 --> 00:07:05,629

originally was eight billion so this in

158

00:07:00,649 --> 00:07:09,228

and a 10% increase in that okay and

159

00:07:05,629 --> 00:07:12,079

that's basically the summary of the the

160

00:07:09,228 --> 00:07:13,909

press release we are of course

161

00:07:12,079 --> 00:07:15,918

disappointed that we'll have to wait

162

00:07:13,910 --> 00:07:18,659

longer for the science from the James

163

00:07:15,918 --> 00:07:21,579

Webb Space Telescope but

164

00:07:18,658 --> 00:07:23,918

it's the next great observatory okay

165

00:07:21,579 --> 00:07:25,810

it's gonna do things that Hubble can't

166

00:07:23,918 --> 00:07:28,718

do that no other Space Telescope has

167

00:07:25,810 --> 00:07:30,939

ever been able to do it's highly

168

00:07:28,718 --> 00:07:31,779

technical and as they say it's gonna be

169

00:07:30,939 --> 00:07:33,669

worth waiting for

170

00:07:31,779 --> 00:07:37,000

okay let's make sure we get it done

171

00:07:33,668 --> 00:07:44,348

right all right our second story tonight

172
00:07:37,000 --> 00:07:51,218
is it came from outer space I am talking

173
00:07:44,348 --> 00:07:56,259
about yet another update the the object

174
00:07:51,218 --> 00:07:59,589
called a 2017 u1 also now called

175
00:07:56,259 --> 00:08:03,280
omoi this is the orbit when it was

176
00:07:59,589 --> 00:08:04,769
discovered in October 25th to actually

177
00:08:03,279 --> 00:08:07,839
discovered a little bit before was in

178
00:08:04,769 --> 00:08:11,079
2017 by the pan-starrs Observatory

179
00:08:07,839 --> 00:08:14,138
alright and if I pull back you can see

180
00:08:11,079 --> 00:08:16,389
this is the full path of it and what

181
00:08:14,139 --> 00:08:22,028
makes this special which makes this u1

182
00:08:16,389 --> 00:08:25,658
okay is that this object path is unbound

183
00:08:22,028 --> 00:08:28,959
to the Sun indicating that it's not part

184
00:08:25,658 --> 00:08:32,408
of our solar system it came from outer

185
00:08:28,959 --> 00:08:36,309
space yes this is the first confirmed

186
00:08:32,408 --> 00:08:38,979
object that trajectory comes from

187
00:08:36,309 --> 00:08:40,478
interstellar space all right and there

188
00:08:38,979 --> 00:08:41,709
probably have been many of these that

189
00:08:40,479 --> 00:08:43,658
come through our solar system this is

190
00:08:41,708 --> 00:08:46,899
the first one we've seen and confirmed

191
00:08:43,658 --> 00:08:49,750
and when I told you about this last fall

192
00:08:46,899 --> 00:08:52,720
I showed you that hey this is all we can

193
00:08:49,750 --> 00:08:54,909
see it yeah that tiny little dot there

194
00:08:52,720 --> 00:08:56,050
that the arrow is pointing to that's

195
00:08:54,909 --> 00:08:59,289
omar Moya

196
00:08:56,049 --> 00:09:02,198
alright so it's really small okay it's

197
00:08:59,289 --> 00:09:05,078
only about half a mile in size and

198
00:09:02,198 --> 00:09:07,299
that's just an estimate okay and we're

199
00:09:05,078 --> 00:09:09,879
looking at and so we really can track it

200

00:09:07,299 --> 00:09:12,429
but you need high precision telescopes

201
00:09:09,879 --> 00:09:15,578
to track it G where would we have a high

202
00:09:12,429 --> 00:09:17,500
precision telescope yes Hubble has

203
00:09:15,578 --> 00:09:20,919
helped the other thing that we noticed

204
00:09:17,500 --> 00:09:22,570
about it is also that it had brightness

205
00:09:20,919 --> 00:09:24,490
variations periodic brightness

206
00:09:22,570 --> 00:09:28,028
variations indicating that it was

207
00:09:24,490 --> 00:09:30,159
rotating and very likely was very

208
00:09:28,028 --> 00:09:32,470
elongated wasn't like a round object

209
00:09:30,159 --> 00:09:33,819
okay if a round object rotates you

210
00:09:32,470 --> 00:09:36,639
don't get these strong brightness

211
00:09:33,820 --> 00:09:38,140
variations but a elongated object

212
00:09:36,639 --> 00:09:41,110
rotates you get these strong brightness

213
00:09:38,139 --> 00:09:42,610
variations so what we knew about it last

214
00:09:41,110 --> 00:09:43,960

time I talked about it is that its orbit

215

00:09:42,610 --> 00:09:46,690

is consistent with an interstellar

216

00:09:43,960 --> 00:09:48,580

origin it rotates about every seven

217

00:09:46,690 --> 00:09:51,610

point three hours and there are these

218

00:09:48,580 --> 00:09:55,420

large brightness variations what we

219

00:09:51,610 --> 00:09:57,909

didn't know back then was it sighs you

220

00:09:55,419 --> 00:10:00,069

know about half a kilometer the axis

221

00:09:57,909 --> 00:10:04,029

ratio was at three to one or was it ten

222

00:10:00,070 --> 00:10:06,100

to one the color and the amount of

223

00:10:04,029 --> 00:10:09,069

reflectivity which is called the albedo

224

00:10:06,100 --> 00:10:10,840

the measurements appeared to disagree we

225

00:10:09,070 --> 00:10:13,410

didn't know it was composed of is it

226

00:10:10,840 --> 00:10:17,290

more asteroid like is it more comet-like

227

00:10:13,409 --> 00:10:18,939

and this is only the first one of this

228

00:10:17,289 --> 00:10:20,889

group what are they what are

229
00:10:18,940 --> 00:10:23,200
interstellar objects generally like and

230
00:10:20,889 --> 00:10:24,009
I finished with this slide to be

231
00:10:23,200 --> 00:10:27,310
continued

232
00:10:24,009 --> 00:10:29,049
tonight we continue the story tonight

233
00:10:27,309 --> 00:10:32,009
I'm going to show you an artist

234
00:10:29,049 --> 00:10:36,639
rendition of what oh mama look like on

235
00:10:32,009 --> 00:10:39,610
January 2nd 2018 so this is the artist

236
00:10:36,639 --> 00:10:43,449
rendition of omoi here on the left on

237
00:10:39,610 --> 00:10:46,539
January second 2018 and how do I know

238
00:10:43,450 --> 00:10:49,090
it's January 2nd 2018 because you see

239
00:10:46,539 --> 00:10:51,879
those positions of those planets yeah I

240
00:10:49,090 --> 00:10:54,910
calculated them okay I made sure that

241
00:10:51,879 --> 00:10:57,820
we're aware more was we got the planets

242
00:10:54,909 --> 00:10:59,049
right in the back I also calculated the

243
00:10:57,820 --> 00:11:02,260
position of the stars in the background

244
00:10:59,049 --> 00:11:04,839
okay so this is the star Spica in the

245
00:11:02,259 --> 00:11:06,519
constellation Virgo okay so not only are

246
00:11:04,840 --> 00:11:09,070
the planets in the right place the stars

247
00:11:06,519 --> 00:11:11,049
are in mostly right place I can't say

248
00:11:09,070 --> 00:11:12,220
it's absolutely the right place okay due

249
00:11:11,049 --> 00:11:14,500
to various things we did with the

250
00:11:12,220 --> 00:11:17,560
artistic aspect of it but you know all

251
00:11:14,500 --> 00:11:20,110
right so this is relatively scientific

252
00:11:17,559 --> 00:11:22,989
in being at art we try to try to combine

253
00:11:20,110 --> 00:11:25,120
science and art here okay and then you

254
00:11:22,990 --> 00:11:27,580
can see that there's all sorts of fuzz

255
00:11:25,120 --> 00:11:32,350
around it okay in these Jay jets coming

256
00:11:27,580 --> 00:11:35,290
out of it and that is the real story so

257

00:11:32,350 --> 00:11:38,560
in watching OMA more over the past

258
00:11:35,289 --> 00:11:41,139
several months Kay and basically the the

259
00:11:38,559 --> 00:11:44,589
observations ended in Jinbo January they

260
00:11:41,139 --> 00:11:46,509
found that its orbit deviated

261
00:11:44,590 --> 00:11:49,420
what would be expected just due to

262
00:11:46,509 --> 00:11:53,110
gravity now gravity is a solved problem

263
00:11:49,419 --> 00:11:56,289
we know how to solve gravity so if an

264
00:11:53,110 --> 00:11:59,350
object moves off of a path that gravity

265
00:11:56,289 --> 00:12:02,139
would predict some other forces involved

266
00:11:59,350 --> 00:12:03,879
okay so there's just a slight

267
00:12:02,139 --> 00:12:06,009
acceleration but we can measure these

268
00:12:03,879 --> 00:12:08,649
slight accelerations and it could be

269
00:12:06,009 --> 00:12:10,539
caused by jets of outgassing all right

270
00:12:08,649 --> 00:12:15,220
and that would be the ices near the

271
00:12:10,539 --> 00:12:18,069

surface spewing out as it passes by the

272

00:12:15,220 --> 00:12:20,050

Sun and heats up okay and so that's why

273

00:12:18,070 --> 00:12:22,270

you can see there are jets here in this

274

00:12:20,049 --> 00:12:25,240

artist's illustration pointing towards

275

00:12:22,269 --> 00:12:27,850

the Sun that would add a small force

276

00:12:25,240 --> 00:12:30,129

that would cause a deviation in the

277

00:12:27,850 --> 00:12:33,279

orbit this is similar to what we see for

278

00:12:30,129 --> 00:12:36,399

comets in our solar system however the

279

00:12:33,279 --> 00:12:39,519

important point to note is that no

280

00:12:36,399 --> 00:12:41,230

outgassing was observed which causes a

281

00:12:39,519 --> 00:12:43,960

little bit of a problem so you need some

282

00:12:41,230 --> 00:12:47,680

outgassing to create the orbit deviation

283

00:12:43,960 --> 00:12:49,450

but not so much outgassing that it would

284

00:12:47,679 --> 00:12:52,179

actually be observed by the telescopes

285

00:12:49,450 --> 00:12:54,670

that looked at it there's still lots of

286
00:12:52,179 --> 00:12:56,500
uncertainty here we still don't have

287
00:12:54,669 --> 00:12:58,659
great estimates we still only have

288
00:12:56,500 --> 00:13:00,970
estimates of the size the shape and the

289
00:12:58,659 --> 00:13:03,069
composition but if this outgassing is

290
00:13:00,970 --> 00:13:06,610
true then it's probably more comet-like

291
00:13:03,070 --> 00:13:08,230
than it is asteroid like and

292
00:13:06,610 --> 00:13:09,909
unfortunately we're not going to get any

293
00:13:08,230 --> 00:13:12,129
more observations because now it's out

294
00:13:09,909 --> 00:13:14,769
past the orbit of Jupiter and heading

295
00:13:12,129 --> 00:13:20,379
out of the solar system never to be seen

296
00:13:14,769 --> 00:13:23,379
again so where do we go from here on

297
00:13:20,379 --> 00:13:26,919
this there should be other interstellar

298
00:13:23,379 --> 00:13:30,189
interlopers in our future if there's one

299
00:13:26,919 --> 00:13:32,769
there's got to be more right and now we

300
00:13:30,190 --> 00:13:34,690
know that there is a population we will

301
00:13:32,769 --> 00:13:36,539
continue to look for them I sort of

302
00:13:34,690 --> 00:13:39,910
think of it like the Kuiper belt objects

303
00:13:36,539 --> 00:13:42,279
when we saw the first recognizable

304
00:13:39,909 --> 00:13:43,809
Kuiper belt objects in 1993 we started

305
00:13:42,279 --> 00:13:45,939
searching and searching for more and

306
00:13:43,809 --> 00:13:47,799
more and we developed a whole family

307
00:13:45,940 --> 00:13:49,870
hopefully over the next year's and

308
00:13:47,799 --> 00:13:51,939
decades will develop a whole family of

309
00:13:49,870 --> 00:13:54,070
these interstellar objects and we'll be

310
00:13:51,940 --> 00:13:56,710
able to understand the characteristics

311
00:13:54,070 --> 00:13:58,110
of a population one is just an

312
00:13:56,710 --> 00:14:00,028
interesting object

313
00:13:58,110 --> 00:14:02,459
until you have a dozen or so then you

314

00:14:00,028 --> 00:14:04,169
can't really make group statements so we

315
00:14:02,458 --> 00:14:04,828
look forward to more interstellar

316
00:14:04,169 --> 00:14:06,659
visitors

317
00:14:04,828 --> 00:14:08,458
I wish they'd hang around a little bit

318
00:14:06,659 --> 00:14:09,539
longer but the nature of their orbits

319
00:14:08,458 --> 00:14:11,639
means that they're gonna come through

320
00:14:09,539 --> 00:14:14,539
BAM we get about six months of observing

321
00:14:11,639 --> 00:14:18,600
and then they're gone forever all right

322
00:14:14,539 --> 00:14:22,588
finally our third story a ten million

323
00:14:18,600 --> 00:14:25,860
year old baby this just hit the news

324
00:14:22,589 --> 00:14:27,690
wires today okay and I could not stop

325
00:14:25,860 --> 00:14:30,000
myself from adding it to the public

326
00:14:27,690 --> 00:14:35,010
lectures the presentation all right so

327
00:14:30,000 --> 00:14:35,970
this somewhere in here is the star PDS

328
00:14:35,009 --> 00:14:38,039

70

329

00:14:35,970 --> 00:14:40,528

I'd love to point out the exact star but

330

00:14:38,039 --> 00:14:41,759

they didn't tell us in when they when

331

00:14:40,528 --> 00:14:43,588

they put out this image they said oh

332

00:14:41,759 --> 00:14:45,870

it's in the center well this is the

333

00:14:43,589 --> 00:14:48,930

center I don't know exactly which one it

334

00:14:45,870 --> 00:14:51,839

is all right and so the star PDS 70 is

335

00:14:48,929 --> 00:14:54,479

special it's you know well first of all

336

00:14:51,839 --> 00:14:56,670

it's an ordinary case five star but it's

337

00:14:54,480 --> 00:14:59,700

only ten million years old it's a young

338

00:14:56,669 --> 00:15:00,899

star it's a recently formed star okay

339

00:14:59,700 --> 00:15:04,800

all right

340

00:15:00,899 --> 00:15:07,409

four PDS 70 all right and in 2006 they

341

00:15:04,799 --> 00:15:09,028

did a study of PDS 70 all right so this

342

00:15:07,409 --> 00:15:10,799

is the star all right and they're

343
00:15:09,028 --> 00:15:13,230
blocking out a little bit of the light

344
00:15:10,799 --> 00:15:15,000
from the Sun with this coal tting spot

345
00:15:13,230 --> 00:15:17,039
you'll notice there'll be a black circle

346
00:15:15,000 --> 00:15:19,049
at the center of all these images that's

347
00:15:17,039 --> 00:15:20,399
not because there's nothing there it's

348
00:15:19,049 --> 00:15:22,409
because we're actually blocking it out

349
00:15:20,399 --> 00:15:25,129
that black circle is blocking the light

350
00:15:22,409 --> 00:15:28,019
from the star okay so here's the star

351
00:15:25,129 --> 00:15:29,070
here's a potential companion that they

352
00:15:28,019 --> 00:15:31,320
identified okay

353
00:15:29,070 --> 00:15:32,730
and when they analyzed this and did all

354
00:15:31,320 --> 00:15:36,060
sorts of computer process you can pulled

355
00:15:32,730 --> 00:15:38,490
it out they found that first of all that

356
00:15:36,059 --> 00:15:41,669
this star was a brown dwarf that could

357
00:15:38,490 --> 00:15:44,730
be a companion all right and then they

358
00:15:41,669 --> 00:15:47,099
found a disk of material orbiting around

359
00:15:44,730 --> 00:15:49,528
the star all right so you're seeing an

360
00:15:47,100 --> 00:15:51,089
disc of material edge on right so you're

361
00:15:49,528 --> 00:15:54,320
seeing material orbiting around the star

362
00:15:51,089 --> 00:15:56,910
plus a jet of material spewing out

363
00:15:54,320 --> 00:15:58,500
perpendicular to the disk and we see

364
00:15:56,909 --> 00:16:00,929
this in other places for example in

365
00:15:58,500 --> 00:16:03,179
Orion when we see newborn stars okay we

366
00:16:00,929 --> 00:16:07,078
have discs and we have jets all right

367
00:16:03,179 --> 00:16:09,359
and so this was interesting and there

368
00:16:07,078 --> 00:16:11,639
were strong hints that a giant planet

369
00:16:09,360 --> 00:16:14,519
could have formed in the interior

370
00:16:11,639 --> 00:16:16,740
and the inner parts of the disc they

371

00:16:14,519 --> 00:16:19,769
went back and studied this again over

372
00:16:16,740 --> 00:16:22,649
time and in 2012 they released this

373
00:16:19,769 --> 00:16:25,319
image again this black spot is just the

374
00:16:22,649 --> 00:16:27,269
occulting circle to get rid of this

375
00:16:25,320 --> 00:16:30,240
flight of the star but you can see how

376
00:16:27,269 --> 00:16:33,179
there's a bright ring here and inside

377
00:16:30,240 --> 00:16:36,690
the ring is an empty region okay there's

378
00:16:33,179 --> 00:16:38,909
a gap that's about 140 astronomical

379
00:16:36,690 --> 00:16:41,400
units across and if you don't remember

380
00:16:38,909 --> 00:16:44,309
an astronomical unit is one the distance

381
00:16:41,399 --> 00:16:47,069
from Earth to the Sun Neptune is about

382
00:16:44,309 --> 00:16:48,929
30 astronomical units and radius so this

383
00:16:47,070 --> 00:16:52,080
is a hundred and forty astronomical

384
00:16:48,929 --> 00:16:54,599
units okay and so there is a gap in

385
00:16:52,080 --> 00:16:57,900

there and that really says hey if

386

00:16:54,600 --> 00:17:00,029

there's a giant planet in there or more

387

00:16:57,899 --> 00:17:02,939

one or more giant planets that can clear

388

00:17:00,029 --> 00:17:06,990

out that gap well that sets the stage

389

00:17:02,940 --> 00:17:08,970

for what was just announced in 2018 they

390

00:17:06,990 --> 00:17:11,279

got a picture from the Very Large

391

00:17:08,970 --> 00:17:13,949

Telescope yes that is its name

392

00:17:11,279 --> 00:17:15,029

the Very Large Telescope we astronomers

393

00:17:13,949 --> 00:17:17,610

are pretty straightforward

394

00:17:15,029 --> 00:17:23,190

from the European Southern Observatory

395

00:17:17,609 --> 00:17:28,769

the VLT got that image you can see the

396

00:17:23,190 --> 00:17:31,580

gap and you can see that ladies and

397

00:17:28,769 --> 00:17:36,859

gentlemen this is the first confirmed

398

00:17:31,579 --> 00:17:36,859

image of a newborn planet

399

00:17:39,230 --> 00:17:45,440

[Music]

400
00:17:40,660 --> 00:17:47,180
this planet is called PDS 70 B the

401
00:17:45,440 --> 00:17:49,549
lowercase B indicating that it's a

402
00:17:47,180 --> 00:17:52,850
planet it's about 20 astronomical units

403
00:17:49,549 --> 00:17:56,119
from its star it is a few Jupiter masses

404
00:17:52,849 --> 00:17:58,039
so only 2 or 3 or 4 Jupiter masses all

405
00:17:56,119 --> 00:18:01,729
right so it's Jupiter size it's a gas

406
00:17:58,039 --> 00:18:05,180
giant planet it's very hot okay

407
00:18:01,730 --> 00:18:07,880
1,800 degrees Fahrenheit all right for

408
00:18:05,180 --> 00:18:09,590
example the the cloud tops of Jupiter or

409
00:18:07,880 --> 00:18:12,410
minus a hundred degrees Fahrenheit as

410
00:18:09,589 --> 00:18:15,859
such all right this is still in

411
00:18:12,410 --> 00:18:18,410
formation okay at 10 million years old

412
00:18:15,859 --> 00:18:21,319
this is the 10 million year old baby I

413
00:18:18,410 --> 00:18:23,779
was talking about in the title ok and

414
00:18:21,319 --> 00:18:25,879
when they do further analysis on it and

415
00:18:23,779 --> 00:18:29,119
they really study it they can tell that

416
00:18:25,880 --> 00:18:30,650
its atmosphere is cloudy I can't tell

417
00:18:29,119 --> 00:18:32,959
you how because I didn't have enough

418
00:18:30,650 --> 00:18:35,240
time to read all the papers today too I

419
00:18:32,960 --> 00:18:38,090
think but as one of the results that

420
00:18:35,240 --> 00:18:41,150
they came out from it so we have had

421
00:18:38,089 --> 00:18:43,579
pictures of planets and such but this is

422
00:18:41,150 --> 00:18:47,420
a newborn planet it takes approximately

423
00:18:43,579 --> 00:18:50,960
10 million years for a gas giant to form

424
00:18:47,420 --> 00:18:54,080
so this is really just a newborn gas

425
00:18:50,960 --> 00:18:57,019
giant and it's a really cool result that

426
00:18:54,079 --> 00:18:59,210
just got announced today all right so I

427
00:18:57,019 --> 00:19:01,190
like to bring you the the really cool

428

00:18:59,210 --> 00:19:03,069
results as they come even though this

429
00:19:01,190 --> 00:19:06,070
isn't a Hubble or a Space Telescope

430
00:19:03,069 --> 00:19:10,629
story it was just too important to skip

431
00:19:06,069 --> 00:19:15,289
and that's our news from the universe

432
00:19:10,630 --> 00:19:18,430
our featured speaker tonight is David

433
00:19:15,289 --> 00:19:23,119
Netto from the Johns Hopkins University

434
00:19:18,430 --> 00:19:26,810
he did his PhD work at the Ohio State

435
00:19:23,119 --> 00:19:28,879
University and then did a postdoc down

436
00:19:26,809 --> 00:19:31,579
in Australia although you he says he

437
00:19:28,880 --> 00:19:34,640
originally hails from Canada came to the

438
00:19:31,579 --> 00:19:36,949
u.s. to do the the PhD went to Australia

439
00:19:34,640 --> 00:19:38,450
to do a postdoc and fortunately came

440
00:19:36,950 --> 00:19:40,730
back to the u.s. to the Johns Hopkins

441
00:19:38,450 --> 00:19:43,819
University and he holds the Davis post

442
00:19:40,730 --> 00:19:46,430

starbuck post doctoral fellowship across

443

00:19:43,819 --> 00:19:50,299
the way he'll tell you about his

444

00:19:46,430 --> 00:19:52,730
research but he says that in his in his

445

00:19:50,299 --> 00:19:55,519
spare time when he's not doing research

446

00:19:52,730 --> 00:19:57,019
he works with the summer interns that

447

00:19:55,519 --> 00:19:58,279
the high school and college students

448

00:19:57,019 --> 00:20:01,039
that come in and work with us over the

449

00:19:58,279 --> 00:20:05,230
summer and he's also can be found down

450

00:20:01,039 --> 00:20:21,349
at the SPCA walking the dogs

451

00:20:05,230 --> 00:20:23,059
ladies gentlemen David natal thank you

452

00:20:21,349 --> 00:20:26,089
for the introduction Frank can everyone

453

00:20:23,059 --> 00:20:27,950
hear me all right good all right so I'll

454

00:20:26,089 --> 00:20:30,349
be speaking about the Milky Way's bulge

455

00:20:27,950 --> 00:20:33,559
and I'll explain what a ball just

456

00:20:30,349 --> 00:20:35,149
shortly but you can see one in the image

457
00:20:33,559 --> 00:20:37,279
that was given out earlier that's the

458
00:20:35,150 --> 00:20:40,550
sombbrero galaxy a relatively famous

459
00:20:37,279 --> 00:20:43,490
galaxy and that is a spectacular image

460
00:20:40,549 --> 00:20:46,730
of a galaxy which is a combination of a

461
00:20:43,490 --> 00:20:51,859
disc and a bulge somewhat similar to the

462
00:20:46,730 --> 00:20:54,289
Milky Way but not quite this is an image

463
00:20:51,859 --> 00:20:58,099
that'll look very familiar to people who

464
00:20:54,289 --> 00:20:59,750
have gone camping and maybe not familiar

465
00:20:58,099 --> 00:21:02,359
to people have never been outside the

466
00:20:59,750 --> 00:21:05,900
city that is what the Milky Way will

467
00:21:02,359 --> 00:21:07,759
look like from the grounds if you don't

468
00:21:05,900 --> 00:21:15,380
have light pollution and if you have

469
00:21:07,759 --> 00:21:16,849
decent night vision oh okay and I heard

470
00:21:15,380 --> 00:21:18,470
an interesting anecdote a few years ago

471
00:21:16,849 --> 00:21:20,629
I don't know if it's true but it sounds

472
00:21:18,470 --> 00:21:22,309
like it could be true apparently many

473
00:21:20,630 --> 00:21:25,190
years ago there was a huge power outage

474
00:21:22,309 --> 00:21:27,559
in Southern California and then people

475
00:21:25,190 --> 00:21:29,450
saw this and they had no idea what was

476
00:21:27,559 --> 00:21:34,029
so they got scared and they called

477
00:21:29,450 --> 00:21:38,720
police there you go

478
00:21:34,029 --> 00:21:41,629
so here's two images of the Milky Way

479
00:21:38,720 --> 00:21:42,700
panoramic Li in optical and

480
00:21:41,630 --> 00:21:45,680
near-infrared

481
00:21:42,700 --> 00:21:49,370
photography I'll explain what so optical

482
00:21:45,680 --> 00:21:51,560
is the type of light that we can see we

483
00:21:49,369 --> 00:21:55,069
can see Li you know it goes from blue

484
00:21:51,559 --> 00:21:59,000
lights - and then you got green light

485

00:21:55,069 --> 00:22:00,500
orange or orange light and red lights

486
00:21:59,000 --> 00:22:03,048
with a bit more detail actually I

487
00:22:00,500 --> 00:22:06,048
skipped purple lights and this is near

488
00:22:03,048 --> 00:22:08,629
infrared lights and can somebody point

489
00:22:06,048 --> 00:22:11,089
out so you can all see that it's kind of

490
00:22:08,630 --> 00:22:12,770
the same but there's some differences

491
00:22:11,089 --> 00:22:15,529
could somebody point out a difference

492
00:22:12,769 --> 00:22:17,629
between the top image and the bottom

493
00:22:15,529 --> 00:22:22,399
image other than the kind of light

494
00:22:17,630 --> 00:22:25,909
they're in yes yeah so there's all these

495
00:22:22,400 --> 00:22:28,130
dust lanes in the top image it looks

496
00:22:25,909 --> 00:22:30,020
like it's black but it's not black

497
00:22:28,130 --> 00:22:32,870
there's a ton of stars there just a lot

498
00:22:30,019 --> 00:22:36,019
of the light is blocked out by

499
00:22:32,869 --> 00:22:38,989

intervening dust particles and dust it

500

00:22:36,019 --> 00:22:42,230

kind of affects all lights but it

501

00:22:38,990 --> 00:22:44,659

affects bluer lights a lot more than

502

00:22:42,230 --> 00:22:46,909

rhetoric or optical light a lot more

503

00:22:44,659 --> 00:22:48,890

than infrared light I learned something

504

00:22:46,909 --> 00:22:51,350

cool when I lived in Australia which is

505

00:22:48,890 --> 00:22:53,330

kind of after it was explained to me it

506

00:22:51,349 --> 00:22:55,308

was obvious so in the southern

507

00:22:53,329 --> 00:22:57,168

hemisphere this do see more of the Milky

508

00:22:55,308 --> 00:22:59,839

Way due to how things are oriented and

509

00:22:57,169 --> 00:23:03,320

for the Australian Aborigines their

510

00:22:59,839 --> 00:23:06,759

constellations weren't just you know

511

00:23:03,319 --> 00:23:09,168

connections of stars the dust lanes

512

00:23:06,759 --> 00:23:11,029

themselves could also be constellations

513

00:23:09,169 --> 00:23:12,740

it would make animals out of that and as

514
00:23:11,029 --> 00:23:14,210
it moved through season it would

515
00:23:12,740 --> 00:23:21,740
correspond to different parts of the

516
00:23:14,210 --> 00:23:24,048
fertility cycle so here's the Milky Way

517
00:23:21,740 --> 00:23:27,048
bulge or rather actions a whole galaxy

518
00:23:24,048 --> 00:23:30,470
including the Bulge as part of an

519
00:23:27,048 --> 00:23:32,569
artist's rendition and some of you may

520
00:23:30,470 --> 00:23:34,730
feel I'm being cheap right now I'm

521
00:23:32,569 --> 00:23:37,250
showing an artist's rendition of our own

522
00:23:34,730 --> 00:23:39,380
galaxy because someone tell me why I

523
00:23:37,250 --> 00:23:47,750
wouldn't be showing a photo of our

524
00:23:39,380 --> 00:23:50,990
galaxy yes in the back thank you that's

525
00:23:47,750 --> 00:23:53,599
exactly right yeah so the previous image

526
00:23:50,990 --> 00:23:55,250
is we're kind of like in the galaxy to

527
00:23:53,599 --> 00:23:57,709
see that right but really we're only

528
00:23:55,250 --> 00:24:00,048
seeing I don't know we're like 70 or 80

529
00:23:57,710 --> 00:24:01,850
percent outwards so in those image we're

530
00:24:00,048 --> 00:24:04,429
kind of seeing the inner 70% of the

531
00:24:01,849 --> 00:24:06,199
galaxy but here it's with somebody yeah

532
00:24:04,429 --> 00:24:08,149
if you've traveled like ten thousand

533
00:24:06,200 --> 00:24:10,190
light-years outwards and it's worse than

534
00:24:08,148 --> 00:24:11,599
that because if you did go out by ten or

535
00:24:10,190 --> 00:24:13,220
50,000 light years

536
00:24:11,599 --> 00:24:16,609
good luck sending this

537
00:24:13,220 --> 00:24:17,269
back you'd be like Oh how did I end up

538
00:24:16,609 --> 00:24:22,519
here

539
00:24:17,269 --> 00:24:24,319
or do I go you'd be screwed and so in

540
00:24:22,519 --> 00:24:26,509
this image of the galaxy the part that's

541
00:24:24,319 --> 00:24:28,519
rel so it's very idealized image the

542

00:24:26,509 --> 00:24:32,509
real galaxy is probably not super

543
00:24:28,519 --> 00:24:34,308
symmetric we kind of all galaxies many

544
00:24:32,509 --> 00:24:37,009
galaxies are symmetric but not perfectly

545
00:24:34,308 --> 00:24:41,119
so but Bryce Raman here the spiral arms

546
00:24:37,009 --> 00:24:43,940
are in blue and the Bulge or bar is in

547
00:24:41,119 --> 00:24:46,699
yellow the reason it's a different color

548
00:24:43,940 --> 00:24:49,009
is that there are fewer young stars in

549
00:24:46,700 --> 00:24:51,950
the Bulge and I'll explain I'll discuss

550
00:24:49,009 --> 00:24:54,379
that at the end so now we're going to

551
00:24:51,950 --> 00:24:55,970
see a video of a forming galaxies

552
00:24:54,380 --> 00:24:57,230
there's so many videos of galaxies

553
00:24:55,970 --> 00:25:01,279
forming out there I didn't know which

554
00:24:57,230 --> 00:25:02,808
ones to take but I took these two well

555
00:25:01,279 --> 00:25:05,089
okay look there's this one and another

556
00:25:02,808 --> 00:25:08,629

one afterwards we're gonna watch this go

557

00:25:05,089 --> 00:25:10,699

it shows Z or Z sorry on the top left

558

00:25:08,630 --> 00:25:13,820

that's the cosmological redshift that

559

00:25:10,700 --> 00:25:16,130

corresponds to time Zetas 15 means about

560

00:25:13,819 --> 00:25:18,889

13 and a half Giga years ago billion

561

00:25:16,130 --> 00:25:20,000

years ago sorry Zetas one means seven

562

00:25:18,890 --> 00:25:23,450

point eight billion years ago and the

563

00:25:20,000 --> 00:25:25,700

way galaxies form over there they're

564

00:25:23,450 --> 00:25:27,590

believed to have formed from tiny proto

565

00:25:25,700 --> 00:25:29,480

galaxies maybe a thousand or ten

566

00:25:27,589 --> 00:25:32,149

thousand times smaller and as the

567

00:25:29,480 --> 00:25:34,490

universe age they all come together and

568

00:25:32,150 --> 00:25:38,059

eventually we have a disk like we have

569

00:25:34,490 --> 00:25:40,279

now this picture is definitely accurate

570

00:25:38,058 --> 00:25:43,038

but the details might be off it's not

571
00:25:40,279 --> 00:25:45,109
it's a matter of controversy and so we

572
00:25:43,038 --> 00:25:47,869
see by this point most of the galaxies

573
00:25:45,109 --> 00:25:49,639
assembled there's kind of fewer big

574
00:25:47,869 --> 00:25:54,048
pieces coming in now there's still a lot

575
00:25:49,640 --> 00:25:56,030
of small pieces like for own galaxy but

576
00:25:54,048 --> 00:26:00,288
you know and the big things are there

577
00:25:56,029 --> 00:26:01,908
and does that thing have slowed down so

578
00:26:00,288 --> 00:26:04,158
it kind of looks like maybe the computer

579
00:26:01,909 --> 00:26:07,010
got slower cuz it's too complicated but

580
00:26:04,159 --> 00:26:09,919
that's not it it's just the ways that is

581
00:26:07,009 --> 00:26:10,788
defines as you go from Z to 15th is out

582
00:26:09,919 --> 00:26:13,580
of 5

583
00:26:10,788 --> 00:26:15,230
you only travel 1 billion years but as

584
00:26:13,579 --> 00:26:17,240
you go from 5 to 1

585
00:26:15,230 --> 00:26:20,298
you try let you go like 8 billion years

586
00:26:17,240 --> 00:26:22,308
it's kind of it's the mapping between

587
00:26:20,298 --> 00:26:26,599
the history of expansion of the universe

588
00:26:22,308 --> 00:26:29,599
and the actual age of things and now

589
00:26:26,599 --> 00:26:31,730
four is about when the Sun formed so

590
00:26:29,599 --> 00:26:33,199
this galaxy here would have a baby son

591
00:26:31,730 --> 00:26:35,569
if that was like the Milky Way we see

592
00:26:33,200 --> 00:26:37,250
that so reasonable spiral it's not

593
00:26:35,569 --> 00:26:40,298
completely symmetric but it's pretty

594
00:26:37,250 --> 00:26:42,349
close right like if this was a flower

595
00:26:40,298 --> 00:26:44,599
okay I mean it doesn't look like a

596
00:26:42,349 --> 00:26:47,990
flower but pretend it does it'd be kind

597
00:26:44,599 --> 00:26:50,058
of a pretty flower and unlike our galaxy

598
00:26:47,990 --> 00:26:52,788
this one has a pretty big merger going

599

00:26:50,058 --> 00:26:55,399
on at the end our galaxy now only has a

600
00:26:52,788 --> 00:26:57,109
has small mergers going on right now

601
00:26:55,400 --> 00:26:59,750
that's still ouch

602
00:26:57,109 --> 00:27:02,599
that's our galaxy into two billion years

603
00:26:59,750 --> 00:27:04,788
when it emerges from Andromeda and now

604
00:27:02,599 --> 00:27:07,639
here's a second galaxy and it already

605
00:27:04,788 --> 00:27:09,558
started it looks the same at first

606
00:27:07,640 --> 00:27:15,950
because they all wait you know I

607
00:27:09,558 --> 00:27:22,009
actually know sorry okay this is

608
00:27:15,950 --> 00:27:25,640
actually what I meant to look at okay

609
00:27:22,009 --> 00:27:28,759
this is just the this galaxy the point

610
00:27:25,640 --> 00:27:31,038
of it is that it's thought to be more

611
00:27:28,759 --> 00:27:32,829
similar to what the Milky Way might have

612
00:27:31,038 --> 00:27:35,029
gone through of course these are random

613
00:27:32,829 --> 00:27:39,168

realizations and go through the trillion

614

00:27:35,029 --> 00:27:41,240

times and never find a match but you'll

615

00:27:39,169 --> 00:27:47,530

get a qualitative match you know which

616

00:27:41,240 --> 00:27:47,529

is similar statistics so to speak right

617

00:27:52,599 --> 00:28:03,379

so in this image the we see the light of

618

00:27:57,440 --> 00:28:06,769

gas and stars stars form from gas what

619

00:28:03,380 --> 00:28:09,830

we're not seeing is the lights from dust

620

00:28:06,769 --> 00:28:11,869

it's it's just turned off in this video

621

00:28:09,829 --> 00:28:13,490

the dust is still active and having

622

00:28:11,869 --> 00:28:15,288

physical effects but it's turned off

623

00:28:13,490 --> 00:28:19,730

because the video is meaning to

624

00:28:15,288 --> 00:28:21,408

emphasize the gas and the stars and what

625

00:28:19,730 --> 00:28:24,048

they bragged about when they made this

626

00:28:21,409 --> 00:28:27,350

is that they're able to make a pretty

627

00:28:24,048 --> 00:28:29,389

thin disc the people simulate these

628
00:28:27,349 --> 00:28:31,399
galaxies have been able to make disks of

629
00:28:29,390 --> 00:28:34,038
galaxies like the Milky Way hasn't shown

630
00:28:31,400 --> 00:28:37,600
you earlier for a long time but to make

631
00:28:34,038 --> 00:28:39,710
thin disks you know crêpes rather than

632
00:28:37,599 --> 00:28:43,908
pancakes from blue moon

633
00:28:39,710 --> 00:28:46,340
is a bit hard and galaxies are small are

634
00:28:43,909 --> 00:28:49,250
some more similar to crepes than to

635
00:28:46,339 --> 00:28:52,250
pancakes from Blue Moon all okay maybe

636
00:28:49,250 --> 00:28:54,319
not in this image but yeah this has a

637
00:28:52,250 --> 00:28:56,509
pretty thin bulge

638
00:28:54,319 --> 00:29:03,139
I ain't thin disc and you can see that

639
00:28:56,509 --> 00:29:05,690
there's a bulge already and so to go

640
00:29:03,140 --> 00:29:08,270
through why ball just matter really the

641
00:29:05,690 --> 00:29:09,830
whole galaxy matters you might come to

642
00:29:08,269 --> 00:29:12,288
another talking year from now they'll be

643
00:29:09,829 --> 00:29:14,750
talking about the disc or the outskirts

644
00:29:12,288 --> 00:29:18,019
or the star clusters every part of the

645
00:29:14,750 --> 00:29:23,058
galaxy matters the reason that the Bulge

646
00:29:18,019 --> 00:29:25,730
now and that the Balch matters is that

647
00:29:23,058 --> 00:29:28,759
it's many of the oldest stars in the

648
00:29:25,730 --> 00:29:30,890
galaxy that's why it's yellow and so by

649
00:29:28,759 --> 00:29:33,859
understanding that we can have a pretty

650
00:29:30,890 --> 00:29:37,159
good idea of how a disproportionate

651
00:29:33,859 --> 00:29:38,538
number of the first stars forms even

652
00:29:37,159 --> 00:29:41,809
though it's only a third of the total

653
00:29:38,538 --> 00:29:44,898
stars it might be like one half to two

654
00:29:41,808 --> 00:29:47,389
thirds of the oldest stars and I make a

655
00:29:44,898 --> 00:29:49,579
lot of analogies with history the field

656

00:29:47,390 --> 00:29:52,370
is now called galactic archaeology maybe

657
00:29:49,579 --> 00:29:55,879
for marketing reasons but imagine in

658
00:29:52,369 --> 00:29:58,879
history like you knew about you know the

659
00:29:55,880 --> 00:30:01,340
American Civil War and the Spanish

660
00:29:58,880 --> 00:30:03,230
Inquisition and that interesting stuff

661
00:30:01,339 --> 00:30:05,298
but you didn't know but the Sumerians

662
00:30:03,230 --> 00:30:07,038
and the Greeks your knowledge would be

663
00:30:05,298 --> 00:30:08,808
very incomplete you need to know that

664
00:30:07,038 --> 00:30:13,190
stuff is interesting as well and it

665
00:30:08,808 --> 00:30:15,859
helps complete the story all right

666
00:30:13,190 --> 00:30:17,870
so part one it's the shortest part it's

667
00:30:15,859 --> 00:30:23,269
the chemical characterization of ball

668
00:30:17,869 --> 00:30:25,028
stars it's it's short because located

669
00:30:23,269 --> 00:30:28,759
three parts in here there's chemistry

670
00:30:25,028 --> 00:30:31,250

there's structure and there's ages and

671

00:30:28,759 --> 00:30:33,470

chemistry might be the simplest in that

672

00:30:31,250 --> 00:30:36,409

it's reasonably solved I don't have as

673

00:30:33,470 --> 00:30:39,679

much controversy to share for you it

674

00:30:36,409 --> 00:30:41,120

wasn't solved maybe 30 years ago but

675

00:30:39,679 --> 00:30:42,798

it's solved now because we have these

676

00:30:41,119 --> 00:30:45,379

great new instruments we could look at

677

00:30:42,798 --> 00:30:50,418

hundreds of stars at a time this was

678

00:30:45,380 --> 00:30:53,510

taken by PhD thesis in Australia who

679

00:30:50,419 --> 00:30:57,350

knows what Fe might be

680

00:30:53,509 --> 00:31:00,410

that's right so the distribution and the

681

00:30:57,349 --> 00:31:02,689

metallicity of stars is usually it could

682

00:31:00,410 --> 00:31:05,540

be any metal you know why not copper or

683

00:31:02,690 --> 00:31:07,308

why not zinc iron is used because it

684

00:31:05,539 --> 00:31:09,470

happens to have a lot of atomic

685
00:31:07,308 --> 00:31:12,109
transitions and so you get a ton of

686
00:31:09,470 --> 00:31:15,919
lines when you look at the atmosphere of

687
00:31:12,109 --> 00:31:18,529
a star absorption lines that are due to

688
00:31:15,919 --> 00:31:21,230
iron and in fact if you go back a

689
00:31:18,529 --> 00:31:23,079
hundred years a lot of astronomers back

690
00:31:21,230 --> 00:31:25,970
then so they didn't have quantum physics

691
00:31:23,079 --> 00:31:27,829
understood but they knew that they

692
00:31:25,970 --> 00:31:29,839
didn't really know what's going on in

693
00:31:27,829 --> 00:31:32,119
the solar atmosphere they thought that

694
00:31:29,839 --> 00:31:34,849
the Sun was made of iron because iron

695
00:31:32,119 --> 00:31:37,939
makes a ton of absorption lines but

696
00:31:34,849 --> 00:31:39,558
that's not it it's just it just happens

697
00:31:37,940 --> 00:31:42,769
that at the typical temperature of a

698
00:31:39,558 --> 00:31:44,660
star a iron has a lot of transitions and

699
00:31:42,769 --> 00:31:46,940
so we use iron to measure things all

700
00:31:44,660 --> 00:31:51,340
right so here it's a logarithmic ratio

701
00:31:46,940 --> 00:31:53,960
of iron to hydrogen minus 1 means

702
00:31:51,339 --> 00:31:58,250
one-tenth the iron to hydrogen ratio of

703
00:31:53,960 --> 00:32:00,079
the Sun and plus 0.4 means about four

704
00:31:58,250 --> 00:32:02,419
times the iron to hydrogen ratio of the

705
00:32:00,079 --> 00:32:05,210
start of the Sun and it turns out that

706
00:32:02,419 --> 00:32:09,620
almost all bulb stars are in that range

707
00:32:05,210 --> 00:32:12,350
and a typical value is zero I always

708
00:32:09,619 --> 00:32:14,928
think that this is a big coincidence but

709
00:32:12,349 --> 00:32:18,500
the iron the metallicity of the Sun is

710
00:32:14,929 --> 00:32:20,210
very typical of the metallicity of most

711
00:32:18,500 --> 00:32:21,829
of the stars in the Balch and indeed

712
00:32:20,210 --> 00:32:23,960
elsewhere in the galaxy it's a little

713

00:32:21,829 --> 00:32:26,629
higher but I don't know I think it's

714
00:32:23,960 --> 00:32:29,630
cool that the Sun is such an all right

715
00:32:26,630 --> 00:32:31,400
an average star in metallicity where

716
00:32:29,630 --> 00:32:33,980
metallicity and chemistry is a thing

717
00:32:31,400 --> 00:32:39,048
that marries the most between different

718
00:32:33,980 --> 00:32:41,750
stars and we can also study other

719
00:32:39,048 --> 00:32:44,000
elements I could go on and on with other

720
00:32:41,750 --> 00:32:45,710
elements but it'd be like too much

721
00:32:44,000 --> 00:32:49,130
information and to be honest the other

722
00:32:45,710 --> 00:32:53,808
elements aren't measured as well so it's

723
00:32:49,130 --> 00:32:57,260
not as informative but here we show OSI

724
00:32:53,808 --> 00:33:00,440
and SIA and see CA calcium so oxygen

725
00:32:57,259 --> 00:33:02,750
silicon and calcium and it's the ratio

726
00:33:00,440 --> 00:33:05,900
relative to iron and what's been

727
00:33:02,750 --> 00:33:06,950

confirmed over most decades of research

728

00:33:05,900 --> 00:33:09,679
the past 20 or 3

729

00:33:06,950 --> 00:33:14,000
years is that the ratios are higher

730

00:33:09,679 --> 00:33:17,480
involved stars than in the Sun so this

731

00:33:14,000 --> 00:33:20,359
is one place in which one area in which

732

00:33:17,480 --> 00:33:23,028
both stars are different they just have

733

00:33:20,359 --> 00:33:24,769
more relative abundances of these

734

00:33:23,028 --> 00:33:27,619
elements and that's kind of cool imagine

735

00:33:24,769 --> 00:33:30,500
you form an earth there right and earth

736

00:33:27,619 --> 00:33:32,989
is I think iron is the second most

737

00:33:30,500 --> 00:33:34,940
abundant element after oxygen and the

738

00:33:32,990 --> 00:33:35,899
earth and so imagine you truncated that

739

00:33:34,940 --> 00:33:38,808
in half it might have a different

740

00:33:35,898 --> 00:33:40,939
evolution of life going on and the

741

00:33:38,808 --> 00:33:43,609
reason for this is thought to be that

742
00:33:40,940 --> 00:33:45,620
the balls formed quickly that's why it

743
00:33:43,609 --> 00:33:50,000
was yellow in the previous images the

744
00:33:45,619 --> 00:33:51,969
stars are older and therefore it says

745
00:33:50,000 --> 00:33:54,380
more of those kinds of supernovae

746
00:33:51,970 --> 00:33:55,990
alright I'll skip this law structure of

747
00:33:54,380 --> 00:34:00,309
the Bulge

748
00:33:55,990 --> 00:34:00,308
has anyone seen an image like this

749
00:34:00,759 --> 00:34:06,788
alright so this is the Hubble tuning

750
00:34:04,069 --> 00:34:10,279
fork diagram and it kind of shows that

751
00:34:06,788 --> 00:34:12,579
galaxies come in a huge variety of

752
00:34:10,280 --> 00:34:14,899
shapes and sizes it was first under

753
00:34:12,579 --> 00:34:17,810
written down by Edwin Hubble

754
00:34:14,898 --> 00:34:19,608
approximately 100 years ago and he had

755
00:34:17,809 --> 00:34:22,429
some story about it about why this

756
00:34:19,608 --> 00:34:23,869
happens it doesn't hold up that's fine

757
00:34:22,429 --> 00:34:25,250
he didn't guess the reason but what's

758
00:34:23,869 --> 00:34:28,519
interesting is that we still don't know

759
00:34:25,250 --> 00:34:31,219
the reason well we know a little bit but

760
00:34:28,519 --> 00:34:34,280
not really fully why galaxies come in

761
00:34:31,219 --> 00:34:38,059
these shapes and when astronomers

762
00:34:34,280 --> 00:34:40,669
realized that there were galaxies there

763
00:34:38,059 --> 00:34:43,269
they didn't realize what kind of galaxy

764
00:34:40,668 --> 00:34:47,658
the Milky Way was is it one like this

765
00:34:43,269 --> 00:34:50,719
like this like this like this of course

766
00:34:47,659 --> 00:34:53,088
you guys might guess because I showed

767
00:34:50,719 --> 00:34:56,328
you an image earlier of an artist's

768
00:34:53,088 --> 00:34:59,088
rendition does anyone want to point to

769
00:34:56,329 --> 00:35:01,519
one of these or I don't know if it's big

770

00:34:59,088 --> 00:35:03,469
enough for everybody see and you say

771
00:35:01,519 --> 00:35:09,858
which one is most similar to the Milky

772
00:35:03,469 --> 00:35:13,578
Way yes who said that yeah down there

773
00:35:09,858 --> 00:35:16,460
probably this one maybe this one so the

774
00:35:13,579 --> 00:35:20,010
bar as I'll explain soon as reasonably

775
00:35:16,460 --> 00:35:23,699
well understood however the spiral arms

776
00:35:20,010 --> 00:35:26,430
are not that well understood and maybe I

777
00:35:23,699 --> 00:35:28,710
will show you great images of the bar

778
00:35:26,429 --> 00:35:30,149
shortly of what it could look like it's

779
00:35:28,710 --> 00:35:32,220
one of the achievement not really my

780
00:35:30,150 --> 00:35:33,720
main five minutes one of the

781
00:35:32,219 --> 00:35:36,419
achievements of astronomy in the past

782
00:35:33,719 --> 00:35:37,399
ten years but there's spiral arms not

783
00:35:36,420 --> 00:35:41,280
yet solved

784
00:35:37,400 --> 00:35:43,980

alright so the Milky Way is not an

785

00:35:41,280 --> 00:35:48,390

unbarred galaxy like the Whirlpool

786

00:35:43,980 --> 00:35:50,490

Galaxy this is an image of a typical

787

00:35:48,389 --> 00:35:52,829

unbarred galaxy it might have a very

788

00:35:50,489 --> 00:35:55,679

very weak bar in here that's possible

789

00:35:52,829 --> 00:35:57,269

but it'll be very weak so whatever if

790

00:35:55,679 --> 00:35:59,129

somebody tell me something else about

791

00:35:57,269 --> 00:36:05,579

the Whirlpool Galaxy that's different

792

00:35:59,130 --> 00:36:07,680

from the Milky Way yes as a companion

793

00:36:05,579 --> 00:36:09,420

right here the Milky Way does have

794

00:36:07,679 --> 00:36:14,069

companions but nothing that's like a

795

00:36:09,420 --> 00:36:18,260

quarter of the size like that the Milky

796

00:36:14,070 --> 00:36:21,780

Way is a barred spiral galaxy like NGC

797

00:36:18,260 --> 00:36:24,390

1559 maybe not quite exactly like this

798

00:36:21,780 --> 00:36:26,040

this is a very strong bar we see there's

799

00:36:24,389 --> 00:36:29,069
a lot of dust lanes just like in our

800

00:36:26,039 --> 00:36:30,420
galaxy and if I could ask another

801

00:36:29,070 --> 00:36:34,650
question for you guys though the

802

00:36:30,420 --> 00:36:36,210
question is on the screen why is it that

803

00:36:34,650 --> 00:36:39,780
this galaxy the one that showed you

804

00:36:36,210 --> 00:36:43,260
before circles but this one here appears

805

00:36:39,780 --> 00:36:45,840
to be longer in one axis and the other

806

00:36:43,260 --> 00:36:47,400
axis it's like twice the length does

807

00:36:45,840 --> 00:36:54,660
anyone have a good guess as to why that

808

00:36:47,400 --> 00:36:57,360
might be yes that's right

809

00:36:54,659 --> 00:36:59,460
of course it could actually be that it

810

00:36:57,360 --> 00:37:01,590
is slightly asymmetric that does happen

811

00:36:59,460 --> 00:37:04,110
there could be a companion just off

812

00:37:01,590 --> 00:37:06,090
that's torquing it but the most likely

813
00:37:04,110 --> 00:37:10,050
explanation you take something that's

814
00:37:06,090 --> 00:37:14,220
flat you tilt it and then it will appear

815
00:37:10,050 --> 00:37:16,860
longer in one axis then the other the

816
00:37:14,219 --> 00:37:19,109
Milky Way is the only galaxy that we can

817
00:37:16,860 --> 00:37:21,360
study in three dimensions all other

818
00:37:19,110 --> 00:37:25,890
galaxies appears two-dimensional

819
00:37:21,360 --> 00:37:28,079
projections and another image this one

820
00:37:25,889 --> 00:37:32,339
is more plausible the Milky Way is a

821
00:37:28,079 --> 00:37:33,889
barred spiral galaxy like NGC 43 94 this

822
00:37:32,340 --> 00:37:35,660
one's 54 million light years

823
00:37:33,889 --> 00:37:38,239
away in the constellation Coma Berenices

824
00:37:35,659 --> 00:37:41,179
no one's gonna remember that that's okay

825
00:37:38,239 --> 00:37:44,569
what's cool about this one this is such

826
00:37:41,179 --> 00:37:47,719
a strong bar this is like really strong

827

00:37:44,570 --> 00:37:50,300
and it's actually kind of similar to the

828
00:37:47,719 --> 00:37:51,949
Milky Way's bar yeah we're gonna see in

829
00:37:50,300 --> 00:37:58,640
a few screens somebody said something

830
00:37:51,949 --> 00:38:01,699
yes oh sorry okay so let's go back here

831
00:37:58,639 --> 00:38:03,199
so bulge is like the central part if you

832
00:38:01,699 --> 00:38:05,509
think of a disk of the galaxy as a

833
00:38:03,199 --> 00:38:07,039
pancake in the middle of the pancake you

834
00:38:05,510 --> 00:38:16,910
can have like a pile of whipped cream or

835
00:38:07,039 --> 00:38:19,940
butter or I don't know spinach so that

836
00:38:16,909 --> 00:38:22,460
can take on different shapes apparent

837
00:38:19,940 --> 00:38:23,960
shapes depending on the dynamics and the

838
00:38:22,460 --> 00:38:26,960
gravity and the interactions of

839
00:38:23,960 --> 00:38:28,909
neighboring galaxies and sometimes it's

840
00:38:26,960 --> 00:38:33,309
just a big blob in the middle like in

841
00:38:28,909 --> 00:38:36,639

these or in fact like right here and

842

00:38:33,309 --> 00:38:41,750

sometimes you end up with a barred shape

843

00:38:36,639 --> 00:38:43,190

like this in different contexts and it

844

00:38:41,750 --> 00:38:45,679

really depends on the history of the

845

00:38:43,190 --> 00:38:49,250

interaction so I'll get to that soon but

846

00:38:45,679 --> 00:38:53,119

thank you for asking that all right

847

00:38:49,250 --> 00:38:55,250

where we were on this one and okay so we

848

00:38:53,119 --> 00:38:57,980

didn't we didn't always know if the

849

00:38:55,250 --> 00:39:03,559

Milky Way's Bulge was a Bart shaped like

850

00:38:57,980 --> 00:39:07,940

a bar like this right or if it was

851

00:39:03,559 --> 00:39:10,549

shaped as a spheroid like this it's hard

852

00:39:07,940 --> 00:39:12,710

to guess and you go back thirty years

853

00:39:10,550 --> 00:39:15,440

and everything was less precise and it

854

00:39:12,710 --> 00:39:20,059

was less data the first really good

855

00:39:15,440 --> 00:39:21,740

evidence came from Stan akin all 1994

856
00:39:20,059 --> 00:39:24,320
Chris Stanek then he was a graduate

857
00:39:21,739 --> 00:39:26,929
student at Princeton and imagine that

858
00:39:24,320 --> 00:39:29,420
we're in this artist rendition if you

859
00:39:26,929 --> 00:39:32,029
look at the stars here and then you look

860
00:39:29,420 --> 00:39:34,550
at the stars here the ones that are here

861
00:39:32,030 --> 00:39:37,340
because they're closer are going to be

862
00:39:34,550 --> 00:39:40,400
brighter let's say they're like thirty

863
00:39:37,340 --> 00:39:42,110
percent after twenty percent closer then

864
00:39:40,400 --> 00:39:46,309
there'll be about forty percent brighter

865
00:39:42,110 --> 00:39:47,010
and that's what he found when he looked

866
00:39:46,309 --> 00:39:49,340
at

867
00:39:47,010 --> 00:39:51,780
a tiny what is comparatively

868
00:39:49,340 --> 00:39:54,390
comparatively to now a tiny amount of

869
00:39:51,780 --> 00:39:57,450
data he was able to discern this these

870
00:39:54,389 --> 00:39:59,489
three histograms are meant to show that

871
00:39:57,449 --> 00:40:04,139
stars are slightly brighter over here

872
00:39:59,489 --> 00:40:06,059
than over here and from that he infer he

873
00:40:04,139 --> 00:40:08,969
called it evidence for the Galactic Bar

874
00:40:06,059 --> 00:40:11,429
this was done of Polish astronomers here

875
00:40:08,969 --> 00:40:13,409
I show a photo of him it's an

876
00:40:11,429 --> 00:40:15,089
interesting anecdote about the referee

877
00:40:13,409 --> 00:40:16,889
process in science this was somewhat

878
00:40:15,090 --> 00:40:19,079
controversial people thought the Milky

879
00:40:16,889 --> 00:40:22,230
Way had more of a balls like this a

880
00:40:19,079 --> 00:40:24,599
spheroid and I think the first referee

881
00:40:22,230 --> 00:40:27,480
either challenged it or rejected the

882
00:40:24,599 --> 00:40:29,579
paper he said you cannot submit a paper

883
00:40:27,480 --> 00:40:35,300
on the evidence for the Galactic Bar

884

00:40:29,579 --> 00:40:38,309
because there is no Galactic bar so ok

885
00:40:35,300 --> 00:40:39,750
the process of peer review which we hear

886
00:40:38,309 --> 00:40:42,809
about in the media in the newspaper

887
00:40:39,750 --> 00:40:46,050
sometimes is making science sacred it's

888
00:40:42,809 --> 00:40:48,840
really good it does help things but it's

889
00:40:46,050 --> 00:40:51,960
not perfect something that helps in

890
00:40:48,840 --> 00:40:55,050
general will have instances where it

891
00:40:51,960 --> 00:40:57,990
either helps something bad or blocks

892
00:40:55,050 --> 00:41:00,030
something good though in this case they

893
00:40:57,989 --> 00:41:02,849
were able to get to another referee and

894
00:41:00,030 --> 00:41:04,440
that's fine you do get second chances

895
00:41:02,849 --> 00:41:07,829
because it's realized that this can

896
00:41:04,440 --> 00:41:11,220
happen but you know that was kind of a

897
00:41:07,829 --> 00:41:13,049
course image that static God right he

898
00:41:11,219 --> 00:41:14,759

said evidence for the Galactic Bar

899

00:41:13,050 --> 00:41:17,280

that's great but if we want to know what

900

00:41:14,760 --> 00:41:19,230

the Milky Way looks like right we need a

901

00:41:17,280 --> 00:41:21,210

lot more than evidence right I mean both

902

00:41:19,230 --> 00:41:24,510

of these have evidence they're different

903

00:41:21,210 --> 00:41:27,480

which one's the accurate representation

904

00:41:24,510 --> 00:41:29,520

we'd like to know and one thing that's

905

00:41:27,480 --> 00:41:32,849

helped is the improvements in CCD

906

00:41:29,519 --> 00:41:35,130

technology I remember when digital

907

00:41:32,849 --> 00:41:37,199

cameras first went on sale or maybe when

908

00:41:35,130 --> 00:41:40,769

ii went on sale at prime that's at first

909

00:41:37,199 --> 00:41:42,629

you had like 3 or 4 megapixels and that

910

00:41:40,769 --> 00:41:47,639

was good and it was like five hundred

911

00:41:42,630 --> 00:41:49,380

dollars no now you could get i don't

912

00:41:47,639 --> 00:41:51,929

even know what it's up to now maybe like

913
00:41:49,380 --> 00:41:55,289
20 megapixels for \$200 or something it's

914
00:41:51,929 --> 00:41:57,980
just improved very rapidly and the same

915
00:41:55,289 --> 00:41:59,489
thing is true of astronomy observatories

916
00:41:57,980 --> 00:42:02,670
the

917
00:41:59,489 --> 00:42:07,049
whereas they used to use the data that

918
00:42:02,670 --> 00:42:09,809
Stanek used was five megapixels it was

919
00:42:07,050 --> 00:42:13,170
from me the Warsaw observatory located

920
00:42:09,809 --> 00:42:14,429
in Chile in South America a few hours

921
00:42:13,170 --> 00:42:16,920
north of Santiago

922
00:42:14,429 --> 00:42:18,179
now we regularly use cameras and

923
00:42:16,920 --> 00:42:22,530
astronomy that are a few hundred

924
00:42:18,179 --> 00:42:26,819
megapixels this is a CCD charge-coupled

925
00:42:22,530 --> 00:42:30,150
device a single one of these has more

926
00:42:26,820 --> 00:42:31,769
pixels on it actually this is the CCD

927
00:42:30,150 --> 00:42:33,360
charge-coupled device you see there's

928
00:42:31,769 --> 00:42:34,800
many of them together it's hollow many

929
00:42:33,360 --> 00:42:37,019
of them together because it's easier to

930
00:42:34,800 --> 00:42:40,260
do it that way than to make one big one

931
00:42:37,019 --> 00:42:43,110
and a single one of these has more

932
00:42:40,260 --> 00:42:44,850
pixels on it than the camera that was

933
00:42:43,110 --> 00:42:46,650
used to confirm the existence to the bar

934
00:42:44,849 --> 00:42:49,049
in the 1990s it's really improved

935
00:42:46,650 --> 00:42:51,539
rapidly and here we have an image of the

936
00:42:49,050 --> 00:42:53,610
sky here it's great and then there's

937
00:42:51,539 --> 00:42:57,599
another coincidence that as much as

938
00:42:53,610 --> 00:43:01,050
cameras have gotten bigger right at

939
00:42:57,599 --> 00:43:03,139
about the same speed hard drives have

940
00:43:01,050 --> 00:43:06,090
gone in bigger as well right I remember

941

00:43:03,139 --> 00:43:08,000
playing computer games and their 90s if

942
00:43:06,090 --> 00:43:10,410
you wanted to play one game

943
00:43:08,000 --> 00:43:14,130
you'd have to delete the other game

944
00:43:10,409 --> 00:43:16,710
first hard drives are really small and I

945
00:43:14,130 --> 00:43:23,099
think the teenagers here have any of you

946
00:43:16,710 --> 00:43:25,710
ever done that Wow okay well I had to do

947
00:43:23,099 --> 00:43:26,569
that all the time and you know climbing

948
00:43:25,710 --> 00:43:29,670
back here

949
00:43:26,570 --> 00:43:32,730
imagine CCDs had grown much much faster

950
00:43:29,670 --> 00:43:34,108
than hard drives that would totally suck

951
00:43:32,730 --> 00:43:36,179
for astronomy because we would take

952
00:43:34,108 --> 00:43:38,279
these great pictures and we wouldn't be

953
00:43:36,179 --> 00:43:41,279
able to store it ok so there's like 100

954
00:43:38,280 --> 00:43:44,460
times more data now and people have used

955
00:43:41,280 --> 00:43:48,769

it properly and this is from Christopher

956

00:43:44,460 --> 00:43:54,358

Wegg who did a postdoc in Germany and

957

00:43:48,769 --> 00:43:56,250

but grew up in the UK and it's a deep

958

00:43:54,358 --> 00:43:58,679

rejected model so same methodology of

959

00:43:56,250 --> 00:44:01,219

static slightly more sophisticated but

960

00:43:58,679 --> 00:44:04,169

just hundreds of times more data and

961

00:44:01,219 --> 00:44:05,849

this is a deep rejected model this is

962

00:44:04,170 --> 00:44:09,210

what the Milky Way's bar would look like

963

00:44:05,849 --> 00:44:11,789

face on this is what it look like slide

964

00:44:09,210 --> 00:44:12,900

on and this is kind of what it looks

965

00:44:11,789 --> 00:44:18,239

like

966

00:44:12,900 --> 00:44:21,028

from the Sun what happens is here okay

967

00:44:18,239 --> 00:44:23,159

so if the Sun is here we see this and

968

00:44:21,028 --> 00:44:25,980

then like this side here is taller than

969

00:44:23,159 --> 00:44:28,348

that side because it's closer but this

970
00:44:25,980 --> 00:44:30,179
here the second image is what you would

971
00:44:28,349 --> 00:44:31,859
see if you were living right here if the

972
00:44:30,179 --> 00:44:33,538
Sun was there it see both sides

973
00:44:31,858 --> 00:44:36,150
symmetrically and it kind of has like an

974
00:44:33,539 --> 00:44:39,690
X shape or a peanut shape it's a really

975
00:44:36,150 --> 00:44:42,900
remarkable image in 20 years we've gone

976
00:44:39,690 --> 00:44:45,568
from rejecting papers that said that the

977
00:44:42,900 --> 00:44:49,139
galaxy might have a bar to having a

978
00:44:45,568 --> 00:44:51,298
really precisely projection of what the

979
00:44:49,139 --> 00:44:53,879
bar looks like I think that's a great

980
00:44:51,298 --> 00:44:56,009
achievement and then you might be say

981
00:44:53,880 --> 00:44:57,809
okay that's from a model there's a lot

982
00:44:56,009 --> 00:44:59,429
of analysis going on

983
00:44:57,809 --> 00:45:01,109
I don't trust it's too complicated

984
00:44:59,429 --> 00:45:04,379
computer models will give you whatever

985
00:45:01,108 --> 00:45:06,179
you want okay well sometimes true in

986
00:45:04,380 --> 00:45:09,450
this case I don't agree because I know

987
00:45:06,179 --> 00:45:13,669
what went into the model but here is an

988
00:45:09,449 --> 00:45:16,048
image not taken in the near-infrared

989
00:45:13,670 --> 00:45:20,068
data like this but from mid-infrared

990
00:45:16,048 --> 00:45:22,768
data like that so maybe 5,000 nanometers

991
00:45:20,068 --> 00:45:24,568
or light that's about eight times longer

992
00:45:22,768 --> 00:45:27,568
than the reddest lights that we can see

993
00:45:24,568 --> 00:45:30,778
and at those wavelengths thus there's

994
00:45:27,568 --> 00:45:34,949
almost nothing and young stars don't

995
00:45:30,778 --> 00:45:38,639
contribute much so we only see sorry we

996
00:45:34,949 --> 00:45:41,608
only see old red stars and if you look

997
00:45:38,639 --> 00:45:45,528
at in those image the Milky Way has an X

998

00:45:41,608 --> 00:45:47,969
shape in its bar when if you slide on

999
00:45:45,528 --> 00:45:49,170
which is very very prominent I don't

1000
00:45:47,969 --> 00:45:50,399
know if you guys could see it because

1001
00:45:49,170 --> 00:45:52,309
there's a lot of light in this room can

1002
00:45:50,400 --> 00:45:54,568
you guys see that there's an X in here

1003
00:45:52,309 --> 00:45:59,130
okay great

1004
00:45:54,568 --> 00:46:02,759
oh okay actually there's this better

1005
00:45:59,130 --> 00:46:05,068
image here and you see like the disc

1006
00:46:02,759 --> 00:46:07,710
right I said it was thin earlier look at

1007
00:46:05,068 --> 00:46:10,528
how thin that is relative to its length

1008
00:46:07,710 --> 00:46:18,389
right it's like 50 times longer than its

1009
00:46:10,528 --> 00:46:20,248
tall that is a type of a class of orbits

1010
00:46:18,389 --> 00:46:21,929
happening so the X you might think it's

1011
00:46:20,248 --> 00:46:24,058
one thing it's actually two things I'm

1012
00:46:21,929 --> 00:46:26,399

gonna try and hold my hand really steady

1013

00:46:24,059 --> 00:46:29,730

over here to get this right you've got

1014

00:46:26,400 --> 00:46:31,559

some orbits that are like this right and

1015

00:46:29,730 --> 00:46:34,469

then you've got some other orbits that

1016

00:46:31,559 --> 00:46:35,910

are like this and they're even there's

1017

00:46:34,469 --> 00:46:37,649

an even number of them because the

1018

00:46:35,909 --> 00:46:39,778

galaxy is symmetric between the north

1019

00:46:37,650 --> 00:46:45,539

and south and when you view them

1020

00:46:39,778 --> 00:46:48,809

together you end up with an X in

1021

00:46:45,539 --> 00:46:51,599

combination and now that's an

1022

00:46:48,809 --> 00:46:52,019

explanation but why do we care I'll

1023

00:46:51,599 --> 00:46:54,710

answer

1024

00:46:52,019 --> 00:46:57,829

oh sorry do you want to ask something

1025

00:46:54,710 --> 00:46:57,829

[Music]

1026

00:47:02,838 --> 00:47:16,078

that is I think so that's a very good

1027
00:47:13,199 --> 00:47:18,088
question actually I think it kind of

1028
00:47:16,079 --> 00:47:21,778
looks like a funnel but like a weak one

1029
00:47:18,088 --> 00:47:26,308
in the middle of it and then as you move

1030
00:47:21,778 --> 00:47:29,338
to the side there isn't going on here

1031
00:47:26,309 --> 00:47:31,500
it's okay sorry I'm not sure actually

1032
00:47:29,338 --> 00:47:40,048
but that's that's actually a very good

1033
00:47:31,500 --> 00:47:41,760
question yes they come in a variety

1034
00:47:40,048 --> 00:47:44,190
there actually so some of them are

1035
00:47:41,760 --> 00:47:46,799
circular or elliptical Ammar completely

1036
00:47:44,190 --> 00:47:49,318
chaotic I I don't have pictures of balls

1037
00:47:46,798 --> 00:47:50,969
orbits in here why are give an

1038
00:47:49,318 --> 00:47:53,880
explanation of why orbits are

1039
00:47:50,969 --> 00:47:56,759
complicated in the solar system orbits

1040
00:47:53,880 --> 00:47:59,670
are circle circle sorry they're circles

1041
00:47:56,760 --> 00:48:01,619
or ellipses and the reason that

1042
00:47:59,670 --> 00:48:03,838
simplicity happens is that no matter

1043
00:48:01,619 --> 00:48:08,068
where you are in the solar system all of

1044
00:48:03,838 --> 00:48:10,199
the mass is within you because 99.9% of

1045
00:48:08,068 --> 00:48:12,298
the mass is due to the Sun but in a

1046
00:48:10,199 --> 00:48:14,868
galaxy let's say you start off on an

1047
00:48:12,298 --> 00:48:17,338
eccentric orbit as you move outwards

1048
00:48:14,869 --> 00:48:19,019
then there's more mass within you

1049
00:48:17,338 --> 00:48:21,808
there's no point mass at the center it's

1050
00:48:19,019 --> 00:48:23,429
a distribution of mass and that causes

1051
00:48:21,809 --> 00:48:29,250
the orbits to take on really weird

1052
00:48:23,429 --> 00:48:31,649
shapes really good question - so I

1053
00:48:29,250 --> 00:48:33,599
notice why do we care that there's an X

1054
00:48:31,650 --> 00:48:37,470
I show three different things here this

1055

00:48:33,599 --> 00:48:39,510
is NGC 4710 another similar galaxy with

1056
00:48:37,469 --> 00:48:41,609
a very strong X

1057
00:48:39,510 --> 00:48:43,470
this is the D projection shown below and

1058
00:48:41,610 --> 00:48:46,140
this is an n body simulation with like

1059
00:48:43,469 --> 00:48:50,059
500,000 particles that evolve and we see

1060
00:48:46,139 --> 00:48:52,789
that an X emerges in the bar over time

1061
00:48:50,059 --> 00:48:56,070
so bars are kind of generic in

1062
00:48:52,789 --> 00:48:58,469
simulations of galaxy formation pretty

1063
00:48:56,070 --> 00:49:02,309
much anything can form a bar but

1064
00:48:58,469 --> 00:49:05,669
typically to have a very strong X not

1065
00:49:02,309 --> 00:49:10,139
always but usually you need to have a

1066
00:49:05,670 --> 00:49:12,300
very quiet galaxy if you have a merger

1067
00:49:10,139 --> 00:49:15,869
it'll jumble up the orbits and you'll

1068
00:49:12,300 --> 00:49:18,360
get a spheroid usually and so for the X

1069
00:49:15,869 --> 00:49:20,940

in the Milky Way to be so strong that

1070

00:49:18,360 --> 00:49:22,800

means that there probably hasn't been a

1071

00:49:20,940 --> 00:49:26,940

major merger in a long time do you have

1072

00:49:22,800 --> 00:49:30,030

your hand up okay all right so that's

1073

00:49:26,940 --> 00:49:32,639

the global picture of the bar it solved

1074

00:49:30,030 --> 00:49:35,220

that I think that's really cool what's

1075

00:49:32,639 --> 00:49:37,440

not solved well the detailed picture is

1076

00:49:35,219 --> 00:49:40,199

not solved if you look at all the stars

1077

00:49:37,440 --> 00:49:42,300

together there's an X but if you break

1078

00:49:40,199 --> 00:49:46,379

up the Stars into different ethnicities

1079

00:49:42,300 --> 00:49:49,530

let's say they're really so at the

1080

00:49:46,380 --> 00:49:51,599

metal-rich stars that yeah it's pretty

1081

00:49:49,530 --> 00:49:54,180

prominent this is an analysis done by

1082

00:49:51,599 --> 00:49:56,130

Matt apartheid he was a graduate student

1083

00:49:54,179 --> 00:49:58,349

in Germany where the brilliant thesis

1084
00:49:56,130 --> 00:50:00,150
but for more metal-poor stars the ones

1085
00:49:58,349 --> 00:50:01,860
that are more metal form in a Sun it's

1086
00:50:00,150 --> 00:50:05,190
much weaker it's still there but it's

1087
00:50:01,860 --> 00:50:09,210
far weaker and you might wonder why that

1088
00:50:05,190 --> 00:50:10,260
is and the answer is don't know that's

1089
00:50:09,210 --> 00:50:15,449
the next step

1090
00:50:10,260 --> 00:50:17,390
in bolts research ok part 3 the ages of

1091
00:50:15,449 --> 00:50:20,099
all stars

1092
00:50:17,389 --> 00:50:23,069
so galactic archaeology and the

1093
00:50:20,099 --> 00:50:25,170
challenge of age dating I used that term

1094
00:50:23,070 --> 00:50:27,510
before so historical archaeology has

1095
00:50:25,170 --> 00:50:30,450
been revolutionized by carbon dating

1096
00:50:27,510 --> 00:50:32,250
methods no such luck for galactic

1097
00:50:30,449 --> 00:50:34,919
archaeology we're not successful at

1098
00:50:32,250 --> 00:50:36,480
least so far when we estimate the ages

1099
00:50:34,920 --> 00:50:39,269
of stars to try and figure out which

1100
00:50:36,480 --> 00:50:42,360
group of stars came first for usually

1101
00:50:39,269 --> 00:50:45,690
off by like 10 or 15% unfortunately and

1102
00:50:42,360 --> 00:50:48,990
that and often more actually I think 10%

1103
00:50:45,690 --> 00:50:51,450
is an optimistic estimate of the error

1104
00:50:48,989 --> 00:50:53,239
in estimating the ages of stars because

1105
00:50:51,449 --> 00:50:55,909
there's no equivalent to carbon dating

1106
00:50:53,239 --> 00:50:57,529
that could give you a 1% age and you

1107
00:50:55,909 --> 00:50:59,868
might imagine that we'd have more

1108
00:50:57,530 --> 00:51:02,780
uncertainty in our books on the history

1109
00:50:59,869 --> 00:51:05,210
of civilization if we didn't know who

1110
00:51:02,780 --> 00:51:07,070
came first we might be able to

1111
00:51:05,210 --> 00:51:10,909
reconstruct it from improvements in

1112

00:51:07,070 --> 00:51:15,019
pottery or written history when we have

1113
00:51:10,909 --> 00:51:17,029
it but sometimes it wouldn't be all

1114
00:51:15,019 --> 00:51:20,719
right so the first evidence that the

1115
00:51:17,030 --> 00:51:24,800
Stars and the balls were older came from

1116
00:51:20,719 --> 00:51:26,449
Nassau and Blanco they looked at red

1117
00:51:24,800 --> 00:51:28,310
variables towards the center of the

1118
00:51:26,449 --> 00:51:31,629
Milky Way and they found that those

1119
00:51:28,309 --> 00:51:34,610
variables had shorter periods of

1120
00:51:31,630 --> 00:51:37,369
oscillation so typically they or they

1121
00:51:34,610 --> 00:51:40,130
they so these are variables they get

1122
00:51:37,369 --> 00:51:42,019
bigger bigger bigger smaller smaller

1123
00:51:40,130 --> 00:51:44,150
smaller bigger bigger bigger smaller

1124
00:51:42,019 --> 00:51:45,440
smaller smaller big differences in

1125
00:51:44,150 --> 00:51:47,840
variations it could be two or three

1126
00:51:45,440 --> 00:51:50,539

times brighter at the end the periods

1127

00:51:47,840 --> 00:51:52,070

were like a couple hundred days and in

1128

00:51:50,539 --> 00:51:54,170

the solar neighborhood we get such

1129

00:51:52,070 --> 00:51:57,530

within like a thousand light years at a

1130

00:51:54,170 --> 00:51:59,599

Sun we get such variables but we also

1131

00:51:57,530 --> 00:52:03,980

get variables that take thousands of

1132

00:51:59,599 --> 00:52:06,409

days to oscillate and so they observed

1133

00:52:03,980 --> 00:52:09,559

that difference and they didn't and they

1134

00:52:06,409 --> 00:52:13,118

actually did not know that this was due

1135

00:52:09,559 --> 00:52:15,019

to an age effect but it's the first

1136

00:52:13,119 --> 00:52:17,358

within the literature it's when the

1137

00:52:15,019 --> 00:52:19,309

first statements that's explicitly

1138

00:52:17,358 --> 00:52:20,989

written down which now with what we know

1139

00:52:19,309 --> 00:52:23,358

now about astronomy and how in variable

1140

00:52:20,989 --> 00:52:26,269

stars can be interpreted as new to an

1141
00:52:23,358 --> 00:52:28,489
age difference a distribution and a

1142
00:52:26,269 --> 00:52:31,730
difference in the distribution of Ages

1143
00:52:28,489 --> 00:52:36,579
in the galaxy okay I'm gonna skip this

1144
00:52:31,730 --> 00:52:39,079
and this actually so how do we know that

1145
00:52:36,579 --> 00:52:42,108
stars in the center of the galaxy are

1146
00:52:39,079 --> 00:52:44,900
older there's a few arguments probably

1147
00:52:42,108 --> 00:52:46,219
the the strongest argument I think is

1148
00:52:44,900 --> 00:52:48,920
this one which has been through many

1149
00:52:46,219 --> 00:52:52,549
iterations but it was done really really

1150
00:52:48,920 --> 00:52:55,250
well by my noella luckily she is an

1151
00:52:52,550 --> 00:52:57,890
Italian astronomer who now works in

1152
00:52:55,250 --> 00:53:02,059
Chile in South America and she's

1153
00:52:57,889 --> 00:53:03,500
probably contributed either the most or

1154
00:53:02,059 --> 00:53:06,320
among the most that people have

1155
00:53:03,500 --> 00:53:07,340
contributed to this field in the past 20

1156
00:53:06,320 --> 00:53:08,539
years

1157
00:53:07,340 --> 00:53:12,769
and so now we're going to look at

1158
00:53:08,539 --> 00:53:14,900
distributions of stars this is stars in

1159
00:53:12,769 --> 00:53:18,530
the solar neighborhood so you got

1160
00:53:14,900 --> 00:53:21,680
brightness here and color here we have

1161
00:53:18,530 --> 00:53:26,720
faint red stars we have bright red stars

1162
00:53:21,679 --> 00:53:30,199
and we have bright blue stars right now

1163
00:53:26,719 --> 00:53:33,109
in the balls faint red stars bright red

1164
00:53:30,199 --> 00:53:36,829
stars and four bright blue stars there's

1165
00:53:33,110 --> 00:53:41,019
nothing can anybody tell me why there

1166
00:53:36,829 --> 00:53:44,360
are no bright blue stars there yes

1167
00:53:41,019 --> 00:53:47,449
that's right so bright blue stars those

1168
00:53:44,360 --> 00:53:51,140
are a really massive stars they don't

1169

00:53:47,449 --> 00:53:55,009
live a long life right so they die

1170
00:53:51,139 --> 00:53:57,109
within like hundreds of millions of

1171
00:53:55,010 --> 00:53:59,720
years and there's just very few of them

1172
00:53:57,110 --> 00:54:04,480
in the Bulge just might be a sprinkling

1173
00:53:59,719 --> 00:54:08,389
of them but it's a tiny amount and so

1174
00:54:04,480 --> 00:54:09,980
right there's a shortage of younger

1175
00:54:08,389 --> 00:54:11,269
stars I'll skip those cool actually this

1176
00:54:09,980 --> 00:54:14,090
is just meant to show that there was a

1177
00:54:11,269 --> 00:54:16,730
consensus from various experts I'll just

1178
00:54:14,090 --> 00:54:20,180
quote mine wallows locally there since I

1179
00:54:16,730 --> 00:54:22,730
showed her work the Balch age which was

1180
00:54:20,179 --> 00:54:24,379
found to be as large of that as the

1181
00:54:22,730 --> 00:54:27,019
Galactic globular clusters were at least

1182
00:54:24,380 --> 00:54:30,320
10 billion years old so twice as old as

1183
00:54:27,019 --> 00:54:32,869

the Sun no train no trace sorry

1184

00:54:30,320 --> 00:54:36,590
not not no train it's found for any

1185

00:54:32,869 --> 00:54:40,279
younger stellar population here's a more

1186

00:54:36,590 --> 00:54:43,460
recent analysis it's a histogram done by

1187

00:54:40,280 --> 00:54:45,650
astronomers based in Sweden they use the

1188

00:54:43,460 --> 00:54:49,730
same method to look at stars near the

1189

00:54:45,650 --> 00:54:52,700
Sun here and in the Bulge here and four

1190

00:54:49,730 --> 00:54:54,710
stars near the Sun they find all ages

1191

00:54:52,699 --> 00:54:56,779
their stars of all ages which has been

1192

00:54:54,710 --> 00:54:59,269
known for a very long time but the most

1193

00:54:56,780 --> 00:55:01,550
common age is four and a half billion

1194

00:54:59,269 --> 00:55:03,199
years do you guys can think you guys

1195

00:55:01,550 --> 00:55:05,440
think of another star that's about

1196

00:55:03,199 --> 00:55:08,689
four-and-a-half billion years old

1197

00:55:05,440 --> 00:55:10,700
yeah so that's another coincidence here

1198
00:55:08,690 --> 00:55:13,700
the Sun is very typical in metallicity

1199
00:55:10,699 --> 00:55:16,219
as I mentioned earlier and it's also

1200
00:55:13,699 --> 00:55:19,639
very typical in age of the stars near it

1201
00:55:16,219 --> 00:55:20,989
it's kind of weird and for the Bulge

1202
00:55:19,639 --> 00:55:22,940
they also see

1203
00:55:20,989 --> 00:55:25,669
stars of all ages the sample is smaller

1204
00:55:22,940 --> 00:55:30,019
because it's hard harder to measure

1205
00:55:25,670 --> 00:55:32,720
those stars but there isn't as big a

1206
00:55:30,019 --> 00:55:58,610
peak at 4 Giga years it's kind of like

1207
00:55:32,719 --> 00:56:02,959
flat from 4 to 12 yes sorry can you see

1208
00:55:58,610 --> 00:56:06,760
that again oh they wouldn't have time to

1209
00:56:02,960 --> 00:56:09,110
move out for a star in a typical orbit

1210
00:56:06,760 --> 00:56:11,720
it would take several hundred million

1211
00:56:09,110 --> 00:56:13,460
years well for a Sun for example it

1212
00:56:11,719 --> 00:56:16,099
takes 200 million years to go around the

1213
00:56:13,460 --> 00:56:17,809
galaxy and that's a small and then it

1214
00:56:16,099 --> 00:56:19,339
ends up at the same spot right if you

1215
00:56:17,809 --> 00:56:21,920
want a big change you'll need a lot more

1216
00:56:19,340 --> 00:56:24,320
time than that so relative to the

1217
00:56:21,920 --> 00:56:31,519
lifetime of a blue star that's actually

1218
00:56:24,320 --> 00:56:37,010
pretty big now okay I get it

1219
00:56:31,519 --> 00:56:39,619
thank you so originally there was a lot

1220
00:56:37,010 --> 00:56:42,050
of gas there and the center of the

1221
00:56:39,619 --> 00:56:44,750
galaxy I think that's what you said had

1222
00:56:42,050 --> 00:56:46,340
a higher density of gas and it does

1223
00:56:44,750 --> 00:56:49,940
happen that when you have a higher

1224
00:56:46,340 --> 00:56:52,550
density of gas physically it gets

1225
00:56:49,940 --> 00:56:55,220
converted to stars much more efficiently

1226

00:56:52,550 --> 00:56:58,160
the more gas you have if you have like

1227
00:56:55,219 --> 00:57:00,500
three times as much gas you might form 9

1228
00:56:58,159 --> 00:57:02,929
times as many stars in a certain amount

1229
00:57:00,500 --> 00:57:04,989
of time so you do run out of gas more

1230
00:57:02,929 --> 00:57:08,149
rapidly once you run out of gas you

1231
00:57:04,989 --> 00:57:10,159
can't form stars anymore there's other

1232
00:57:08,150 --> 00:57:16,789
ways to stop forming stars but that's

1233
00:57:10,159 --> 00:57:19,460
the simplest one and all right so

1234
00:57:16,789 --> 00:57:21,980
perhaps the ages are even older I want

1235
00:57:19,460 --> 00:57:24,170
it to stop there but there was a wrinkle

1236
00:57:21,980 --> 00:57:26,840
published today and so I decided to add

1237
00:57:24,170 --> 00:57:32,108
it because it does inform our science we

1238
00:57:26,840 --> 00:57:32,108
go back to this figure here boy okay

1239
00:57:33,018 --> 00:57:37,158
and it's kind of flats between 4 and 12

1240
00:57:35,268 --> 00:57:39,798

Giga years right so there's already a

1241
00:57:37,159 --> 00:57:42,169
story and that it's different than what

1242
00:57:39,798 --> 00:57:45,498
we have near the Sun but how different

1243
00:57:42,168 --> 00:57:47,028
and it might be even more different than

1244
00:57:45,498 --> 00:57:50,268
they think and I happen to agree

1245
00:57:47,028 --> 00:57:52,130
personally there was a new analysis that

1246
00:57:50,268 --> 00:57:53,748
came out I think it was yesterday or the

1247
00:57:52,130 --> 00:57:55,999
day before not not yesterday I have

1248
00:57:53,748 --> 00:57:58,308
Friday or Thursday by an Italian

1249
00:57:55,998 --> 00:57:59,898
astronomer alveolar and Zini Italians

1250
00:57:58,309 --> 00:58:01,669
have contributed a lot to astronomy and

1251
00:57:59,898 --> 00:58:06,048
particularly this to this astronomy of

1252
00:58:01,668 --> 00:58:09,168
the galaxy and he says stars that are

1253
00:58:06,048 --> 00:58:12,288
less than 5 billion years old exist in

1254
00:58:09,168 --> 00:58:15,679
at most a trace amounts or not at all no

1255
00:58:12,289 --> 00:58:18,559
more than 3% of the stars and this

1256
00:58:15,679 --> 00:58:21,709
contradicts this image who's right who's

1257
00:58:18,559 --> 00:58:24,649
wrong so I think that they're wrong and

1258
00:58:21,708 --> 00:58:27,168
he's right but I cannot prove it right

1259
00:58:24,648 --> 00:58:29,739
now it's an ongoing controversy and

1260
00:58:27,168 --> 00:58:34,578
people have been going back and forth on

1261
00:58:29,739 --> 00:58:36,108
this controversy for a few years so

1262
00:58:34,579 --> 00:58:39,349
conclusions asked to the

1263
00:58:36,108 --> 00:58:43,699
characterization of the Bulge right I

1264
00:58:39,349 --> 00:58:46,759
should have brought more water sorry the

1265
00:58:43,699 --> 00:58:49,369
ball stars have a broad range in metals

1266
00:58:46,759 --> 00:58:51,559
abundance you know or you have stars

1267
00:58:49,369 --> 00:58:54,108
with very few metals stars and are like

1268
00:58:51,559 --> 00:58:56,630
the Sun and stars that have four or five

1269
00:58:54,108 --> 00:58:59,989
times more metals in the Sun it's a big

1270
00:58:56,630 --> 00:59:01,759
range and the typical value is about the

1271
00:58:59,989 --> 00:59:04,818
same iron to hydrogen ratio as a Sun

1272
00:59:01,759 --> 00:59:06,918
which is a cool coincidence but they

1273
00:59:04,818 --> 00:59:10,699
have somewhat more oxygen silicon

1274
00:59:06,918 --> 00:59:14,388
calcium relative to iron then the Sun

1275
00:59:10,699 --> 00:59:16,999
has almost all the stars in the Bulge

1276
00:59:14,389 --> 00:59:19,429
are distributed as an exceptionally

1277
00:59:16,998 --> 00:59:21,588
strong bar and my exceptionally strong I

1278
00:59:19,429 --> 00:59:24,699
mean relative to other spiral galaxies

1279
00:59:21,588 --> 00:59:27,528
in the sky half of spirals have bars

1280
00:59:24,699 --> 00:59:29,630
approximately but already it's stronger

1281
00:59:27,528 --> 00:59:31,728
than half of them but even among the

1282
00:59:29,630 --> 00:59:34,130
half that have bars very few of them

1283

00:59:31,728 --> 00:59:36,259
have a bar which is as strong as the

1284
00:59:34,130 --> 00:59:38,659
Milky Way's bar it's not clear why that

1285
00:59:36,259 --> 00:59:40,668
is on the one hand I've been telling you

1286
00:59:38,659 --> 00:59:42,318
that the Sun is typical within the Milky

1287
00:59:40,668 --> 00:59:45,558
Way but on the other hand the Milky Way

1288
00:59:42,318 --> 00:59:46,608
is a typical among galaxies should we

1289
00:59:45,559 --> 00:59:49,670
interpret that

1290
00:59:46,608 --> 00:59:51,588
or should we not I'm not sure and this

1291
00:59:49,670 --> 00:59:53,599
effect is strongest among the most

1292
00:59:51,588 --> 00:59:55,009
metal-rich stars it does suggest that

1293
00:59:53,599 --> 01:00:01,009
there hasn't been a merger here in a

1294
00:59:55,009 --> 01:00:04,298
long time a merger of galaxies and the

1295
01:00:01,009 --> 01:00:10,219
stars in the Bulge are typically older

1296
01:00:04,298 --> 01:00:34,338
than most of the stars near the Sun all

1297
01:00:10,219 --> 01:00:36,738

right that's all thank you yes okay so

1298

01:00:34,338 --> 01:00:38,179

the question is what is in the center of

1299

01:00:36,739 --> 01:00:40,970

the galaxy that causes everything to

1300

01:00:38,179 --> 01:00:43,568

spin around it yeah I'm just repeating

1301

01:00:40,969 --> 01:00:47,929

questions for the online audience there

1302

01:00:43,568 --> 01:00:51,380

so okay why do galaxies spin and have

1303

01:00:47,929 --> 01:00:52,489

angular momentum so if you spin

1304

01:00:51,380 --> 01:00:55,789

something on earth

1305

01:00:52,489 --> 01:00:59,179

it'll stop spinning do the drag but if

1306

01:00:55,789 --> 01:01:04,249

you spin something in space it will keep

1307

01:00:59,179 --> 01:01:06,798

spinning forever so if you're asking why

1308

01:01:04,248 --> 01:01:09,858

does the galaxy have angular momentum

1309

01:01:06,798 --> 01:01:11,630

it's kind of a random thing some

1310

01:01:09,858 --> 01:01:14,268

galaxies have very little angular

1311

01:01:11,630 --> 01:01:17,480

momentum some have a lot in one

1312
01:01:14,268 --> 01:01:21,018
direction and some have a lot in the

1313
01:01:17,480 --> 01:01:23,960
other direction and so it just happens

1314
01:01:21,018 --> 01:01:25,459
that we live in one that has a lot in

1315
01:01:23,960 --> 01:01:29,449
its current direction but if you take

1316
01:01:25,460 --> 01:01:33,170
the sum of spin of all the galaxies it

1317
01:01:29,449 --> 01:01:36,018
has to add up to zero kurz Goodell who's

1318
01:01:33,170 --> 01:01:37,608
a mathematician who contribute a lot to

1319
01:01:36,018 --> 01:01:39,889
our understanding of logic actually

1320
01:01:37,608 --> 01:01:43,690
showed in the mid twentieth century that

1321
01:01:39,889 --> 01:01:46,730
if the universe as a whole was spinning

1322
01:01:43,690 --> 01:01:48,889
then not only would time-travel be

1323
01:01:46,730 --> 01:01:51,440
possible but it would be necessary and

1324
01:01:48,889 --> 01:01:54,920
happening all the time and we'd have

1325
01:01:51,440 --> 01:01:56,358
causal loops going on maybe that's true

1326
01:01:54,920 --> 01:01:58,159
and we don't realize it for pi the

1327
01:01:56,358 --> 01:01:59,788
universe as a whole is not spinning oh

1328
01:01:58,159 --> 01:02:15,208
yeah

1329
01:01:59,789 --> 01:02:17,579
okay so many questions so there is this

1330
01:02:15,208 --> 01:02:19,618
gentleman there was a there's a black

1331
01:02:17,579 --> 01:02:21,839
hole in the center of these galaxies how

1332
01:02:19,619 --> 01:02:23,338
does that affect the Bulge I'm sorry I

1333
01:02:21,838 --> 01:02:24,538
didn't repeat the last question thank

1334
01:02:23,338 --> 01:02:29,578
you

1335
01:02:24,539 --> 01:02:31,739
so that is you know that's like a major

1336
01:02:29,579 --> 01:02:34,318
major topic of research in astronomy

1337
01:02:31,739 --> 01:02:36,929
it's probably 10% of the papers that are

1338
01:02:34,318 --> 01:02:39,898
published debating that point so I

1339
01:02:36,929 --> 01:02:42,059
cannot give you an answer I can give you

1340

01:02:39,898 --> 01:02:45,088
some of the answers that people have

1341
01:02:42,059 --> 01:02:48,449
suggested so the Milky Way does have a

1342
01:02:45,088 --> 01:02:51,139
black hole in its center it's about four

1343
01:02:48,449 --> 01:02:53,938
million times more massive than the Sun

1344
01:02:51,139 --> 01:02:56,608
it's pretty big and it does turn out

1345
01:02:53,938 --> 01:02:59,278
that four galaxies the properties of

1346
01:02:56,608 --> 01:03:02,058
black hole are tightly correlated with

1347
01:02:59,278 --> 01:03:04,768
the properties of the galaxy as a whole

1348
01:03:02,059 --> 01:03:07,889
some people say that's a coincidence and

1349
01:03:04,768 --> 01:03:10,678
some people say that's a causal link

1350
01:03:07,889 --> 01:03:12,989
it's not clear who's right and who's

1351
01:03:10,679 --> 01:03:15,898
wrong what could be the case for example

1352
01:03:12,989 --> 01:03:17,969
is that maybe you go back to the movie

1353
01:03:15,898 --> 01:03:20,518
at the start of the prudhoe galaxies

1354
01:03:17,969 --> 01:03:22,949

merging maybe all proto galaxies

1355

01:03:20,518 --> 01:03:25,318

themselves have black holes and so when

1356

01:03:22,949 --> 01:03:28,918

they merge their black holes Cora last

1357

01:03:25,318 --> 01:03:31,079

is center and that's and so and then

1358

01:03:28,918 --> 01:03:33,328

eventually the bigger galaxies which

1359

01:03:31,079 --> 01:03:35,219

were formed from more mergers also have

1360

01:03:33,329 --> 01:03:38,759

big or black holes at their center but

1361

01:03:35,219 --> 01:03:40,648

there's huge scatter there but there

1362

01:03:38,759 --> 01:03:43,139

will be much better measurements of that

1363

01:03:40,648 --> 01:03:44,909

this year the way that's measured there

1364

01:03:43,139 --> 01:03:46,858

happens to be we're very lucky there's a

1365

01:03:44,909 --> 01:03:50,130

star that passes very close to the black

1366

01:03:46,858 --> 01:03:53,489

hole it's on an elliptical orbit and so

1367

01:03:50,130 --> 01:03:55,318

it passes closest sometime this year and

1368

01:03:53,489 --> 01:03:55,798

they're taking a lot of images of it

1369
01:03:55,318 --> 01:03:57,599
right now

1370
01:03:55,798 --> 01:03:59,489
and we'll have much more detail on the

1371
01:03:57,599 --> 01:04:01,380
black hole that will probably be one of

1372
01:03:59,489 --> 01:04:02,608
the next year's public talks it

1373
01:04:01,380 --> 01:04:07,189
certainly hope so yeah that's an

1374
01:04:02,608 --> 01:04:07,188
exciting observation going up yes

1375
01:04:10,170 --> 01:04:15,440
see how do they relate to each of it

1376
01:04:11,818 --> 01:04:18,389
this is the black hole inside the bar

1377
01:04:15,440 --> 01:04:20,099
yes how does the black hole at the

1378
01:04:18,389 --> 01:04:21,449
center of the galaxy and the bar the

1379
01:04:20,099 --> 01:04:25,200
center of the galaxy relate to each

1380
01:04:21,449 --> 01:04:26,879
other so geometrically the black hole is

1381
01:04:25,199 --> 01:04:29,669
approximately the size of the solar

1382
01:04:26,880 --> 01:04:32,670
system and it's four million times more

1383
01:04:29,670 --> 01:04:38,068
mass in the Sun it defines the center of

1384
01:04:32,670 --> 01:04:41,430
the galaxy the bar itself is not the

1385
01:04:38,068 --> 01:04:43,528
size or source system it's maybe so half

1386
01:04:41,429 --> 01:04:47,548
the length the bar as in from the middle

1387
01:04:43,528 --> 01:04:50,548
to the end is about thirteen thousand

1388
01:04:47,548 --> 01:04:54,809
light-years so it's far bigger and the

1389
01:04:50,548 --> 01:04:57,599
bar as a whole is about twenty billion

1390
01:04:54,809 --> 01:05:01,440
solar masses so it's a totally different

1391
01:04:57,599 --> 01:05:03,599
scale but the the supermassive black

1392
01:05:01,440 --> 01:05:05,369
hole should be at the center that said

1393
01:05:03,599 --> 01:05:07,880
you can always define the center of a

1394
01:05:05,369 --> 01:05:10,559
circle or the center of a square a

1395
01:05:07,880 --> 01:05:13,380
galaxy doesn't have a very precise shape

1396
01:05:10,559 --> 01:05:16,950
so this the meaning of the center isn't

1397

01:05:13,380 --> 01:05:32,009
perfect when yes way back in the corner

1398
01:05:16,949 --> 01:05:33,719
there I say the question was you said

1399
01:05:32,009 --> 01:05:35,369
that a black hole of a supermassive

1400
01:05:33,719 --> 01:05:36,028
black hole is about the size of a solar

1401
01:05:35,369 --> 01:05:38,220
system

1402
01:05:36,028 --> 01:05:40,259
he thinks that black holes don't take up

1403
01:05:38,219 --> 01:05:41,818
any space can you clarify that

1404
01:05:40,259 --> 01:05:45,449
all right that's a very good question

1405
01:05:41,818 --> 01:05:50,068
thank you and so it depends how you

1406
01:05:45,449 --> 01:05:54,419
define it so black holes in pop culture

1407
01:05:50,068 --> 01:05:56,608
and also in a lot of physics are just a

1408
01:05:54,420 --> 01:06:00,450
single arity at the center which is

1409
01:05:56,608 --> 01:06:03,389
exactly it's a point of no space and the

1410
01:06:00,449 --> 01:06:06,000
point of infinite density another way to

1411
01:06:03,389 --> 01:06:09,239

define a black hole is in terms of an

1412

01:06:06,000 --> 01:06:10,980

event horizon and that's where if you

1413

01:06:09,239 --> 01:06:13,258

get close enough to the black hole

1414

01:06:10,980 --> 01:06:13,588

nobody is ever going to hear from you

1415

01:06:13,259 --> 01:06:16,289

again

1416

01:06:13,588 --> 01:06:19,440

and you're done it's the point of no

1417

01:06:16,289 --> 01:06:21,420

turning back and so that defines a

1418

01:06:19,440 --> 01:06:23,159

radius which for the black hole the

1419

01:06:21,420 --> 01:06:23,750

center of the galaxy is about the size

1420

01:06:23,159 --> 01:06:27,109

of the source

1421

01:06:23,750 --> 01:06:29,150

if the Sun was a black hole that radius

1422

01:06:27,110 --> 01:06:30,890

would be three kilometers I think or is

1423

01:06:29,150 --> 01:06:33,950

it one and a half kilometers I think

1424

01:06:30,889 --> 01:06:34,909

three kilometers okay the other question

1425

01:06:33,949 --> 01:06:38,480

in the back there

1426
01:06:34,909 --> 01:06:44,269
yes you so you said that starts in the

1427
01:06:38,480 --> 01:06:46,909
bolger RM in average older than those we

1428
01:06:44,269 --> 01:06:49,909
have at next door yes does that mean

1429
01:06:46,909 --> 01:06:52,549
that when in the far future when those

1430
01:06:49,909 --> 01:06:54,589
stars in the boobs will have died there

1431
01:06:52,550 --> 01:07:03,200
will be a mostly empty space in the

1432
01:06:54,590 --> 01:07:05,360
middle it'll look like empty space but

1433
01:07:03,199 --> 01:07:09,079
when stars die they leave behind

1434
01:07:05,360 --> 01:07:12,050
remnants typically called white dwarfs a

1435
01:07:09,079 --> 01:07:15,110
white dwarf might be like typically half

1436
01:07:12,050 --> 01:07:18,530
the mass of the original star but it's

1437
01:07:15,110 --> 01:07:20,900
the old core of the star and it's about

1438
01:07:18,530 --> 01:07:24,050
the size of the earth and it's very

1439
01:07:20,900 --> 01:07:26,240
faint so you'll have a bunch of dark

1440
01:07:24,050 --> 01:07:27,680
remnants and aside from the white dwarfs

1441
01:07:26,239 --> 01:07:30,079
there will be like millions or billions

1442
01:07:27,679 --> 01:07:31,609
of black holes that are much smaller

1443
01:07:30,079 --> 01:07:33,110
than a supermassive black hole at the

1444
01:07:31,610 --> 01:07:36,380
center of galaxies but still pretty big

1445
01:07:33,110 --> 01:07:37,550
so it'll look like empty space that's a

1446
01:07:36,380 --> 01:07:39,680
great question actually I'll go back to

1447
01:07:37,550 --> 01:07:42,380
the beginning oh where is it where's

1448
01:07:39,679 --> 01:07:44,960
that photo artist's rendition instead of

1449
01:07:42,380 --> 01:07:47,180
this being yellow it'll look black but

1450
01:07:44,960 --> 01:07:55,250
there will be a ton of objects down I

1451
01:07:47,179 --> 01:07:58,599
have about the same amount of mass what

1452
01:07:55,250 --> 01:07:58,599
defines the edge of a galaxy

1453
01:08:04,099 --> 01:08:08,989
I'm not sure if there is a precise

1454

01:08:06,650 --> 01:08:10,910
definition of the edge and I know for

1455
01:08:08,989 --> 01:08:13,579
example at a conference that I went to a

1456
01:08:10,909 --> 01:08:16,039
couple years ago they debated what is

1457
01:08:13,579 --> 01:08:18,619
the mass of the galaxy and that depends

1458
01:08:16,039 --> 01:08:20,449
how far out you go because it just keeps

1459
01:08:18,619 --> 01:08:22,519
adding more mass as you go further out

1460
01:08:20,449 --> 01:08:24,199
and eventually you're like an

1461
01:08:22,520 --> 01:08:25,790
intergalactic space and you have one

1462
01:08:24,199 --> 01:08:27,829
point that might be closer to another

1463
01:08:25,789 --> 01:08:30,350
galaxy and then you move in some other

1464
01:08:27,829 --> 01:08:34,039
direction and it's not clear there's no

1465
01:08:30,350 --> 01:08:36,680
border so in Star Trek

1466
01:08:34,039 --> 01:08:39,829
for example there's like borders and

1467
01:08:36,680 --> 01:08:42,770
interstellar space and they police them

1468
01:08:39,829 --> 01:08:47,180

or even in did anyone watch Battlestar

1469

01:08:42,770 --> 01:08:49,640

Galactica it was a Cylon armistice line

1470

01:08:47,180 --> 01:08:52,369

and that was brought back so it's like a

1471

01:08:49,640 --> 01:08:54,619

line in space but I'm not sure how that

1472

01:08:52,369 --> 01:08:58,579

would work and that'd be like a huge

1473

01:08:54,619 --> 01:09:00,319

area to patrol this audience learned a

1474

01:08:58,579 --> 01:09:02,420

few months ago the size of the

1475

01:09:00,319 --> 01:09:04,699

Federation space and Star Trek is only

1476

01:09:02,420 --> 01:09:07,460

like 200 light-years across I thought it

1477

01:09:04,699 --> 01:09:10,460

was a whole awful hundred light-years

1478

01:09:07,460 --> 01:09:13,069

it's really crazy and I would also add

1479

01:09:10,460 --> 01:09:14,689

that the edge of the galaxy is defined

1480

01:09:13,069 --> 01:09:17,000

differently by different astronomers

1481

01:09:14,689 --> 01:09:20,089

visible light astronomers might do one

1482

01:09:17,000 --> 01:09:21,829

thing h1 astronomers radio astronomers

1483
01:09:20,090 --> 01:09:23,900
would do another thing in terms of the

1484
01:09:21,829 --> 01:09:25,670
edge yeah he's right there's just a lot

1485
01:09:23,899 --> 01:09:29,899
of different variations we have a

1486
01:09:25,670 --> 01:09:32,960
question from online let's see what the

1487
01:09:29,899 --> 01:09:37,219
ramifications are two bulges colliding

1488
01:09:32,960 --> 01:09:40,850
reclining galaxies that's a great

1489
01:09:37,220 --> 01:09:44,150
question and its relevance but one of

1490
01:09:40,850 --> 01:09:46,850
the reasons it's relevant is that it may

1491
01:09:44,149 --> 01:09:49,339
happen in a few billion years here when

1492
01:09:46,850 --> 01:09:52,329
the Milky Way and Andromeda are very

1493
01:09:49,340 --> 01:09:54,949
likely to merge so it does depend on the

1494
01:09:52,329 --> 01:09:57,710
configuration that they have and whether

1495
01:09:54,949 --> 01:09:59,210
it's like head-on or just like skidding

1496
01:09:57,710 --> 01:10:01,340
each other because it could be any

1497
01:09:59,210 --> 01:10:04,329
configuration but typically they will

1498
01:10:01,340 --> 01:10:07,250
end up forming a bigger bulge and

1499
01:10:04,329 --> 01:10:09,439
statistically what happens is that stars

1500
01:10:07,250 --> 01:10:11,899
that were in the center of their

1501
01:10:09,439 --> 01:10:14,479
respective bulges will also be in the

1502
01:10:11,899 --> 01:10:15,889
center of the combined bulge and stars

1503
01:10:14,479 --> 01:10:16,439
that were in the outskirts of the

1504
01:10:15,890 --> 01:10:19,140
respect

1505
01:10:16,439 --> 01:10:20,729
we'll also be in the outskirts of their

1506
01:10:19,140 --> 01:10:23,969
combined ball just need how that works

1507
01:10:20,729 --> 01:10:30,419
out all right other questions from here

1508
01:10:23,969 --> 01:10:32,069
is there any evidence is there any

1509
01:10:30,420 --> 01:10:37,130
evidence that our galaxy is already

1510
01:10:32,069 --> 01:10:39,750
collided with another galaxy yes so I

1511

01:10:37,130 --> 01:10:42,090
showed you the movies to start so you

1512
01:10:39,750 --> 01:10:44,640
could argue that's evidence because

1513
01:10:42,090 --> 01:10:45,900
within cosmological simulations that

1514
01:10:44,640 --> 01:10:47,730
start with our understanding of the

1515
01:10:45,899 --> 01:10:50,129
universe galaxies are formed from

1516
01:10:47,729 --> 01:10:51,659
mergers of proto galaxies but maybe you

1517
01:10:50,130 --> 01:10:55,170
want more evidence to that and so the

1518
01:10:51,659 --> 01:10:58,559
best evidence we have is that we do see

1519
01:10:55,170 --> 01:11:00,449
a few small streams around the Milky Way

1520
01:10:58,560 --> 01:11:02,550
which are they're not shown in this

1521
01:11:00,448 --> 01:11:08,579
image I don't know if they're shown in

1522
01:11:02,550 --> 01:11:14,100
any of the other images see I'll try and

1523
01:11:08,579 --> 01:11:21,988
see if there's one somewhere okay and

1524
01:11:14,100 --> 01:11:23,550
HAP may be actually okay so it happens

1525
01:11:21,988 --> 01:11:25,709

that there's no streams anywhere but

1526

01:11:23,550 --> 01:11:28,199

around the Milky Way we actually do see

1527

01:11:25,710 --> 01:11:30,689

a few weak streams which are due to

1528

01:11:28,198 --> 01:11:32,789

active accretion of smaller galaxies but

1529

01:11:30,689 --> 01:11:36,988

these are very minor mergers happening

1530

01:11:32,789 --> 01:11:38,698

it's like a 100 to 1 ratio and whereas

1531

01:11:36,988 --> 01:11:40,500

in simulations we expect that at some

1532

01:11:38,698 --> 01:11:43,259

point there should be two to one ratio

1533

01:11:40,500 --> 01:11:45,000

mergers 3 to 1 ratio mergers and so on

1534

01:11:43,260 --> 01:11:48,090

the mergers that we're seeing in the

1535

01:11:45,000 --> 01:11:52,590

Milky Way now are in the very very minor

1536

01:11:48,090 --> 01:11:56,219

merger regime as it's called ok and we

1537

01:11:52,590 --> 01:11:58,680

have one last question from online how

1538

01:11:56,219 --> 01:12:00,600

old is the oldest star in the Milky Way

1539

01:11:58,680 --> 01:12:05,340

and how does that compare to the age of

1540
01:12:00,600 --> 01:12:08,160
the universe so that is a very good

1541
01:12:05,340 --> 01:12:11,430
question as well and the answer is that

1542
01:12:08,159 --> 01:12:13,559
we can't know that that well because

1543
01:12:11,430 --> 01:12:16,500
ages of stars are only measured to about

1544
01:12:13,560 --> 01:12:18,690
10% precision or so and because of that

1545
01:12:16,500 --> 01:12:21,930
we actually have stars for which the

1546
01:12:18,689 --> 01:12:24,629
best estimate of the age is older than

1547
01:12:21,930 --> 01:12:27,150
the age of the universe but that's fine

1548
01:12:24,630 --> 01:12:28,930
because we know that's what the

1549
01:12:27,149 --> 01:12:31,299
measurement error is

1550
01:12:28,930 --> 01:12:34,480
and so we're okay with that but

1551
01:12:31,300 --> 01:12:35,980
eventually as ages improve we should not

1552
01:12:34,479 --> 01:12:37,839
have any stars older in the age of

1553
01:12:35,979 --> 01:12:40,209
universe and one thing that we'd like to

1554
01:12:37,840 --> 01:12:42,250
find out and for which Baltimore

1555
01:12:40,210 --> 01:12:44,500
astronomers will take a leading role is

1556
01:12:42,250 --> 01:12:46,390
when did the first stars in the universe

1557
01:12:44,500 --> 01:12:48,279
form was it a hundred million years

1558
01:12:46,390 --> 01:12:50,770
after the Big Bang two hundred million

1559
01:12:48,279 --> 01:12:55,869
years after the Big Bang that is an open

1560
01:12:50,770 --> 01:12:57,820
topic which may be the James Webb Space

1561
01:12:55,869 --> 01:13:00,159
Telescope mentioned by Frank earlier

1562
01:12:57,819 --> 01:13:02,170
will help us solve within a year or two

1563
01:13:00,159 --> 01:13:05,619
it's one of the points of the James Webb

1564
01:13:02,170 --> 01:13:17,470
Space Telescope okay and in the back

1565
01:13:05,619 --> 01:13:18,869
corner so if Andromeda look we're gonna

1566
01:13:17,470 --> 01:13:21,039
combine does that mean that the

1567
01:13:18,869 --> 01:13:21,729
Andromeda has a blue shift relative to

1568

01:13:21,039 --> 01:13:24,220
the Milky Way

1569
01:13:21,729 --> 01:13:26,769
yeah it does it's one of the few blue

1570
01:13:24,220 --> 01:13:39,670
shifted galaxies we have one more

1571
01:13:26,770 --> 01:13:43,900
question here typically they will end up

1572
01:13:39,670 --> 01:13:46,090
sinking faster too because they're more

1573
01:13:43,899 --> 01:13:47,889
massive they will end up sinking faster

1574
01:13:46,090 --> 01:13:52,000
and then you'll also have a merger of

1575
01:13:47,890 --> 01:13:53,980
your black holes eventually and that'll

1576
01:13:52,000 --> 01:13:57,399
make big gravitational waves the most

1577
01:13:53,979 --> 01:13:59,649
energetic events in the universe within

1578
01:13:57,399 --> 01:14:01,479
pop-culture knowledge it might be

1579
01:13:59,649 --> 01:14:03,099
believed to be supernova but it's

1580
01:14:01,479 --> 01:14:05,439
actually the mergers of supermassive

1581
01:14:03,100 --> 01:14:08,470
black holes where the energy comes down

1582
01:14:05,439 --> 01:14:10,719

in gravitational waves and eventually

1583

01:14:08,470 --> 01:14:13,060

they merge but I might be like some

1584

01:14:10,720 --> 01:14:14,650

billion years after the galaxies

1585

01:14:13,060 --> 01:14:16,960

themselves approached because it'll take

1586

01:14:14,649 --> 01:14:19,149

time for the smaller black hole to make

1587

01:14:16,960 --> 01:14:21,760

it to the center of gravity and

1588

01:14:19,149 --> 01:14:24,309

encounter the bigger black hole all

1589

01:14:21,760 --> 01:14:26,470

right we're gonna end it there ireenie

1590

01:14:24,310 --> 01:14:28,180

are you here anybody from the Maryland

1591

01:14:26,470 --> 01:14:30,940

Space Grant Observatory here to take

1592

01:14:28,180 --> 01:14:32,710

people across the street I guess not so

1593

01:14:30,939 --> 01:14:33,789

there will be no observing across the

1594

01:14:32,710 --> 01:14:34,600

street with the Maryland Space Grant

1595

01:14:33,789 --> 01:14:36,279

observatory

1596

01:14:34,600 --> 01:14:38,950

please check their website for their

1597
01:14:36,279 --> 01:14:41,229
Friday night open houses next month

1598
01:14:38,949 --> 01:14:43,569
August 7th ashes to

1599
01:14:41,229 --> 01:14:45,909
ashes dust to dust the fate of stars

1600
01:14:43,569 --> 01:14:48,369
like the Sun you want to know how the

1601
01:14:45,909 --> 01:14:50,590
story ends for our Sun you got to come

1602
01:14:48,369 --> 01:14:50,979
next month let's give another great big

1603
01:14:50,590 --> 01:14:53,340
hand

1604
01:14:50,979 --> 01:14:53,339
thank you

1605
01:14:58,109 --> 01:15:02,659
[Applause]