PUBLIC LECTURE SERIES

The Milky Way's Bulge: From a Hypothesized Blob to a Remarkably Detailed Picture

Featuring Guest Speaker:

David Nataf

1
00:00:05,630 --> 00:00:02,990
speed and in the background grant who's

2
00:00:07,610 --> 00:00:05,640
sitting probably you know twenty offices

3
00:00:09,290 --> 00:00:07,620
down that way is taking it and sending

4
00:00:15,620 --> 00:00:09,300
out to youtube so let's give grant a

5
00:00:17,480 --> 00:00:15,630
hand and thank him we got the lights you

6
00:00:23,540 --> 00:00:17,490
can bring lights down we'll set and

7
00:00:25,609 --> 00:00:23,550
we'll get ourselves started good evening

8
00:00:28,009 --> 00:00:25,619
ladies and gentlemen and welcome to the

9
00:00:30,950 --> 00:00:28,019
Space Telescope public lecture series it

10
00:00:33,020 --> 00:00:30,960
is my pleasure to host tonight I am dr.

11
00:00:43,639 --> 00:00:33,030
Frank summers of the office of public

12
00:00:46,819 --> 00:00:43,649
outreach and it's so when you come in on

13
00:00:47,389 --> 00:00:46,829

the tables we have lithographs pictures

14
00:00:50,000 --> 00:00:47,399
from Hubble

15
00:00:52,250 --> 00:00:50,010
tonight's picture is Nessie a 104

16
00:00:54,470 --> 00:00:52,260
there's some gray row galaxies and I

17
00:00:57,229 --> 00:00:54,480
chose it because it has a very large

18
00:00:59,450 --> 00:00:57,239
central region that's the Bulge of a

19
00:01:02,020 --> 00:00:59,460
galaxy and you're gonna learn about the

20
00:01:04,399 --> 00:01:02,030
Bulge of the Milky Way galaxy tonight

21
00:01:06,800 --> 00:01:04,409
tonight's speaker is talking on the

22
00:01:10,070 --> 00:01:06,810
Milky Way's bulge from a hypothesized

23
00:01:12,560 --> 00:01:10,080
blob to a remarkably detailed picture

24
00:01:14,719 --> 00:01:12,570
okay so you have an example of a bulge

25
00:01:18,920 --> 00:01:14,729
in front of you to reference while he

26
00:01:21,350 --> 00:01:18,930
gives his talk next month

27
00:01:23,510 --> 00:01:21,360
Greg Sloan will be talking about ashes

28
00:01:27,140 --> 00:01:23,520
to ashes dust to dust

29
00:01:28,910 --> 00:01:27,150
the fate of stars like the Sun so he

30
00:01:30,950 --> 00:01:28,920
specifically said he's not going to talk

31
00:01:33,770 --> 00:01:30,960
about exploding stars and black holes

32
00:01:36,200 --> 00:01:33,780
and neutron stars is that's that's

33
00:01:39,499 --> 00:01:36,210
another talk he's gonna talk about what

34
00:01:42,319 --> 00:01:39,509
happens to medium star sized stars like

35
00:01:42,710 --> 00:01:42,329
our Sun and the ashes to ashes dust to

36
00:01:45,440 --> 00:01:42,720
dust

37
00:01:48,859 --> 00:01:45,450
is a clue okay so come back in August

38
00:01:51,620 --> 00:01:48,869

for that in September we will talk about

39
00:01:56,899 --> 00:01:51,630
more death we're just being morbid here

40
00:02:00,249 --> 00:01:56,909
and our astronomy 100 ways to die in the

41
00:02:03,109 --> 00:02:00,259
universe that's Katie Katie a lot hello

42
00:02:05,209 --> 00:02:03,119
close to be talking about that and in

43
00:02:07,340 --> 00:02:05,219
October then we'll get to those

44
00:02:11,260 --> 00:02:07,350
exploding stars will talk about chasing

45
00:02:13,510 --> 00:02:11,270
supernovae with Kepler from Gotham

46
00:02:15,430 --> 00:02:13,520
here at Space Telescope if you would

47
00:02:17,740 --> 00:02:15,440
like to information about these you can

48
00:02:19,990 --> 00:02:17,750
go to our website go to your favorite

49
00:02:21,970 --> 00:02:20,000
search engine type in Space Telescope

50
00:02:25,330 --> 00:02:21,980
public lectures you should find this

51
00:02:28,320 --> 00:02:25,340
webpage with our upcoming lectures

52
00:02:32,980 --> 00:02:28,330
listed here the links to our live

53
00:02:35,530 --> 00:02:32,990
webcasting as well as our archive the

54
00:02:38,410 --> 00:02:35,540
youtube playlist goes back to 2014 and

55
00:02:42,460 --> 00:02:38,420
the STScI webcast archive goes all the

56
00:02:44,320 --> 00:02:42,470
way back to 2005 so there's an awful lot

57
00:02:47,320 --> 00:02:44,330
if you want to binge-watch astronomy

58
00:02:50,800 --> 00:02:47,330
lectures I got it an entire week of it

59
00:02:52,480 --> 00:02:50,810
for you okay actually I realized that

60
00:02:55,600 --> 00:02:52,490
you know tonight is probably about my

61
00:03:02,420 --> 00:02:55,610
16th anniversary hosting these public

62
00:03:08,450 --> 00:03:05,330
you know it's been a lot of fun but Wow

63
00:03:10,910 --> 00:03:08,460

sixteen years all right if you would

64
00:03:13,010 --> 00:03:10,920
like to have notice about these public

65
00:03:15,770 --> 00:03:13,020
lectures you can sign up by providing

66
00:03:17,870 --> 00:03:15,780
your email here to our announcements we

67
00:03:19,850 --> 00:03:17,880
send out like two or three announcements

68
00:03:21,890 --> 00:03:19,860
a month

69
00:03:25,100 --> 00:03:21,900
yes announcements sign up at the website

70
00:03:26,570 --> 00:03:25,110
or if you can't handle online technology

71
00:03:29,780 --> 00:03:26,580
what are you doing asking for an email

72
00:03:31,160 --> 00:03:29,790
but anyways just give me your email

73
00:03:34,040 --> 00:03:31,170
address write it down a piece of paper

74
00:03:35,900 --> 00:03:34,050
and I'll make sure to add you okay if

75
00:03:38,180 --> 00:03:35,910
also you have comments or questions you

76
00:03:42,590 --> 00:03:38,190
can send them to our email public

77
00:03:45,590 --> 00:03:42,600
lecture at STScI dot edu if you are into

78
00:03:48,440 --> 00:03:45,600
social media we have a variety for the

79
00:03:50,990 --> 00:03:48,450
hubble web and Space Telescope on

80
00:03:53,180 --> 00:03:51,000
Facebook Twitter YouTube Instagram and

81
00:03:56,000 --> 00:03:53,190
probably a few others that I'm not

82
00:03:58,699 --> 00:03:56,010
listing here I myself am on Facebook

83
00:04:01,490 --> 00:03:58,709
Google+ and Twitter every now and then

84
00:04:05,180 --> 00:04:01,500
if you want to hear more from me

85
00:04:08,990 --> 00:04:05,190
let's see Observatory I had did not get

86
00:04:10,900 --> 00:04:09,000
an email before I started this it was

87
00:04:13,580 --> 00:04:10,910
sort of cloudy and sort of not cloudy

88
00:04:14,330 --> 00:04:13,590

actually when I left my houses to come

89
00:04:16,670 --> 00:04:14,340
in this evening

90
00:04:19,670 --> 00:04:16,680
it was raining but it was sunny while it

91
00:04:20,930 --> 00:04:19,680
was raining so I'm not sure what they

92
00:04:24,140 --> 00:04:20,940
were gonna do so that's still a question

93
00:04:25,909 --> 00:04:24,150
mark I will check with aready during the

94
00:04:29,690 --> 00:04:25,919
lecture and I'll have an answer by the

95
00:04:31,880 --> 00:04:29,700
end of the lecture okay but if you are

96
00:04:33,890 --> 00:04:31,890
not if if it doesn't happen tonight

97
00:04:36,890 --> 00:04:33,900
remember there are still open houses on

98
00:04:38,870 --> 00:04:36,900
Friday evenings this webpage of the

99
00:04:42,409 --> 00:04:38,880
Maryland Space Grant observatory will

100
00:04:42,950 --> 00:04:42,419
list the observatory status every Friday

101
00:04:45,560 --> 00:04:42,960
evening

102
00:04:46,670 --> 00:04:45,570
about 5:30 6 o'clock they will list the

103
00:04:48,320 --> 00:04:46,680
status whether or not they're gonna be

104
00:04:53,480 --> 00:04:48,330
open so if you don't get a chance

105
00:04:58,180 --> 00:04:53,490
tonight check back on Friday and now the

106
00:05:00,800 --> 00:04:58,190
news from the universe for July 2018 and

107
00:05:01,190 --> 00:05:00,810
unfortunately I have a repeat story for

108
00:05:06,580 --> 00:05:01,200
you tonight

109
00:05:10,270 --> 00:05:06,590
and it is j DST launched delay ok so

110
00:05:13,650 --> 00:05:10,280
last time back in

111
00:05:16,180 --> 00:05:13,660
let's see when was it it was in March

112
00:05:18,940 --> 00:05:16,190
March or April or May one of those about

113
00:05:21,850 --> 00:05:18,950

three months ago okay the status of it

114
00:05:25,270 --> 00:05:21,860
was that it was being delayed until May

115
00:05:27,520 --> 00:05:25,280
2020 they had formed an independent

116
00:05:29,530 --> 00:05:27,530
review board to look at Jerez t's

117
00:05:32,380 --> 00:05:29,540
construction and really go through the

118
00:05:34,600 --> 00:05:32,390
process rigorously and especially to do

119
00:05:36,160 --> 00:05:34,610
a new cost analysis to make sure that

120
00:05:36,730 --> 00:05:36,170
they really knew what it was going to

121
00:05:38,920 --> 00:05:36,740
cost

122
00:05:41,830 --> 00:05:38,930
well that independent review board has

123
00:05:44,970 --> 00:05:41,840
now finished its study and the press

124
00:05:48,160 --> 00:05:44,980
release from last week was that they

125
00:05:51,040 --> 00:05:48,170
have a new launch date for web of March

126
00:05:52,870 --> 00:05:51,050
30th 2021 so that's almost that's

127
00:05:55,870 --> 00:05:52,880
another ten months of delay for the

128
00:05:57,670 --> 00:05:55,880
James Webb Space Telescope why well

129
00:06:00,070 --> 00:05:57,680
there are changes in the schedule due to

130
00:06:02,170 --> 00:06:00,080
environmental testing and work

131
00:06:05,590 --> 00:06:02,180
performance challenges on the spacecraft

132
00:06:07,900 --> 00:06:05,600
Sun shield and propulsion system okay

133
00:06:10,810 --> 00:06:07,910
that's technical technical language of

134
00:06:12,700 --> 00:06:10,820
the environmental testing I believe is

135
00:06:14,950 --> 00:06:12,710
the vacuum chamber testing that they did

136
00:06:17,140 --> 00:06:14,960
down at Johnson yeah and so they need

137
00:06:20,080 --> 00:06:17,150
more time to pass all of those tests and

138
00:06:21,730 --> 00:06:20,090

get things together but however the

139
00:06:23,440 --> 00:06:21,740
independent review board I mean this is

140
00:06:25,900 --> 00:06:23,450
independent this is not a NASA board

141
00:06:27,640 --> 00:06:25,910
this is independent of NASA it came back

142
00:06:30,040 --> 00:06:27,650
and they also reaffirmed Webb

143
00:06:32,620 --> 00:06:30,050
significant complexity incredible

144
00:06:34,780 --> 00:06:32,630
scientific potential and importance to

145
00:06:36,760 --> 00:06:34,790
astrophysics okay so they didn't say

146
00:06:38,530 --> 00:06:36,770
like oh no no this is a problem no they

147
00:06:41,260 --> 00:06:38,540
said look this is really important and

148
00:06:44,080 --> 00:06:41,270
we gotta get it right okay we do not

149
00:06:46,150 --> 00:06:44,090
have any chance of servicing the James

150
00:06:48,219 --> 00:06:46,160
Webb Space Telescope you're gonna get it

151
00:06:50,830 --> 00:06:48,229
right the first time so that's basically

152
00:06:54,550 --> 00:06:50,840
they said and the new development cost

153
00:06:55,990 --> 00:06:54,560
estimate is 8.8 billion and for those of

154
00:06:58,240 --> 00:06:56,000
you who remember what I said a few

155
00:07:00,640 --> 00:06:58,250
months ago the development cost estimate

156
00:07:05,620 --> 00:07:00,650
originally was eight billion so this in

157
00:07:09,219 --> 00:07:05,630
and a 10% increase in that okay and

158
00:07:12,070 --> 00:07:09,229
that's basically the summary of the the

159
00:07:13,900 --> 00:07:12,080
press release we are of course

160
00:07:15,909 --> 00:07:13,910
disappointed that we'll have to wait

161
00:07:18,649 --> 00:07:15,919
longer for the science from the James

162
00:07:21,570 --> 00:07:18,659
Webb Space Telescope but

163
00:07:23,909 --> 00:07:21,580

it's the next great observatory okay

164
00:07:25,800 --> 00:07:23,919
it's gonna do things that Hubble can't

165
00:07:28,709 --> 00:07:25,810
do that no other Space Telescope has

166
00:07:30,929 --> 00:07:28,719
ever been able to do it's highly

167
00:07:31,770 --> 00:07:30,939
technical and as they say it's gonna be

168
00:07:33,659 --> 00:07:31,780
worth waiting for

169
00:07:36,990 --> 00:07:33,669
okay let's make sure we get it done

170
00:07:44,339 --> 00:07:37,000
right all right our second story tonight

171
00:07:51,209 --> 00:07:44,349
is it came from outer space I am talking

172
00:07:56,249 --> 00:07:51,219
about yet another update the the object

173
00:07:59,580 --> 00:07:56,259
called a 2017 u1 also now called

174
00:08:03,270 --> 00:07:59,590
omoi this is the orbit when it was

175
00:08:04,760 --> 00:08:03,280
discovered in October 25th to actually

176
00:08:07,830 --> 00:08:04,770
discovered a little bit before was in

177
00:08:11,070 --> 00:08:07,840
2017 by the pan-starrs Observatory

178
00:08:14,129 --> 00:08:11,080
alright and if I pull back you can see

179
00:08:16,379 --> 00:08:14,139
this is the full path of it and what

180
00:08:22,019 --> 00:08:16,389
makes this special which makes this u1

181
00:08:25,649 --> 00:08:22,029
okay is that this object path is unbound

182
00:08:28,950 --> 00:08:25,659
to the Sun indicating that it's not part

183
00:08:32,399 --> 00:08:28,960
of our solar system it came from outer

184
00:08:36,300 --> 00:08:32,409
space yes this is the first confirmed

185
00:08:38,969 --> 00:08:36,310
object that trajectory comes from

186
00:08:40,469 --> 00:08:38,979
interstellar space all right and there

187
00:08:41,699 --> 00:08:40,479
probably have been many of these that

188
00:08:43,649 --> 00:08:41,709

come through our solar system this is

189
00:08:46,889 --> 00:08:43,659
the first one we've seen and confirmed

190
00:08:49,740 --> 00:08:46,899
and when I told you about this last fall

191
00:08:52,710 --> 00:08:49,750
I showed you that hey this is all we can

192
00:08:54,900 --> 00:08:52,720
see it yeah that tiny little dot there

193
00:08:56,040 --> 00:08:54,910
that the arrow is pointing to that's

194
00:08:59,280 --> 00:08:56,050
omar Moya

195
00:09:02,189 --> 00:08:59,290
alright so it's really small okay it's

196
00:09:05,069 --> 00:09:02,199
only about half a mile in size and

197
00:09:07,290 --> 00:09:05,079
that's just an estimate okay and we're

198
00:09:09,870 --> 00:09:07,300
looking at and so we really can track it

199
00:09:12,420 --> 00:09:09,880
but you need high precision telescopes

200
00:09:15,569 --> 00:09:12,430
to track it G where would we have a high

201
00:09:17,490 --> 00:09:15,579
precision telescope yes Hubble has

202
00:09:20,910 --> 00:09:17,500
helped the other thing that we noticed

203
00:09:22,560 --> 00:09:20,920
about it is also that it had brightness

204
00:09:24,480 --> 00:09:22,570
variations periodic brightness

205
00:09:28,019 --> 00:09:24,490
variations indicating that it was

206
00:09:30,150 --> 00:09:28,029
rotating and very likely was very

207
00:09:32,460 --> 00:09:30,160
elongated wasn't like a round object

208
00:09:33,810 --> 00:09:32,470
okay if a round object rotates you

209
00:09:36,630 --> 00:09:33,820
don't get these strong brightness

210
00:09:38,130 --> 00:09:36,640
variations but a elongated object

211
00:09:41,100 --> 00:09:38,140
rotates you get these strong brightness

212
00:09:42,600 --> 00:09:41,110
variations so what we knew about it last

213
00:09:43,950 --> 00:09:42,610

time I talked about it is that its orbit

214
00:09:46,680 --> 00:09:43,960
is consistent with an interstellar

215
00:09:48,570 --> 00:09:46,690
origin it rotates about every seven

216
00:09:51,600 --> 00:09:48,580
point three hours and there are these

217
00:09:55,410 --> 00:09:51,610
large brightness variations what we

218
00:09:57,900 --> 00:09:55,420
didn't know back then was it sighs you

219
00:10:00,060 --> 00:09:57,910
know about half a kilometer the axis

220
00:10:04,020 --> 00:10:00,070
ratio was at three to one or was it ten

221
00:10:06,090 --> 00:10:04,030
to one the color and the amount of

222
00:10:09,060 --> 00:10:06,100
reflectivity which is called the albedo

223
00:10:10,830 --> 00:10:09,070
the measurements appeared to disagree we

224
00:10:13,400 --> 00:10:10,840
didn't know it was composed of is it

225
00:10:17,280 --> 00:10:13,410
more asteroid like is it more comet-like

226
00:10:18,930 --> 00:10:17,290
and this is only the first one of this

227
00:10:20,880 --> 00:10:18,940
group what are they what are

228
00:10:23,190 --> 00:10:20,890
interstellar objects generally like and

229
00:10:24,000 --> 00:10:23,200
I finished with this slide to be

230
00:10:27,300 --> 00:10:24,010
continued

231
00:10:29,040 --> 00:10:27,310
tonight we continue the story tonight

232
00:10:32,000 --> 00:10:29,050
I'm going to show you an artist

233
00:10:36,630 --> 00:10:32,010
rendition of what oh mama look like on

234
00:10:39,600 --> 00:10:36,640
January 2nd 2018 so this is the artist

235
00:10:43,440 --> 00:10:39,610
rendition of omoi here on the left on

236
00:10:46,530 --> 00:10:43,450
January second 2018 and how do I know

237
00:10:49,080 --> 00:10:46,540
it's January 2nd 2018 because you see

238
00:10:51,870 --> 00:10:49,090

those positions of those planets yeah I

239
00:10:54,900 --> 00:10:51,880
calculated them okay I made sure that

240
00:10:57,810 --> 00:10:54,910
we're aware more was we got the planets

241
00:10:59,040 --> 00:10:57,820
right in the back I also calculated the

242
00:11:02,250 --> 00:10:59,050
position of the stars in the background

243
00:11:04,830 --> 00:11:02,260
okay so this is the star Spica in the

244
00:11:06,510 --> 00:11:04,840
constellation Virgo okay so not only are

245
00:11:09,060 --> 00:11:06,520
the planets in the right place the stars

246
00:11:11,040 --> 00:11:09,070
are in mostly right place I can't say

247
00:11:12,210 --> 00:11:11,050
it's absolutely the right place okay due

248
00:11:14,490 --> 00:11:12,220
to various things we did with the

249
00:11:17,550 --> 00:11:14,500
artistic aspect of it but you know all

250
00:11:20,100 --> 00:11:17,560
right so this is relatively scientific

251
00:11:22,980 --> 00:11:20,110
in being at art we try to try to combine

252
00:11:25,110 --> 00:11:22,990
science and art here okay and then you

253
00:11:27,570 --> 00:11:25,120
can see that there's all sorts of fuzz

254
00:11:32,340 --> 00:11:27,580
around it okay in these Jay jets coming

255
00:11:35,280 --> 00:11:32,350
out of it and that is the real story so

256
00:11:38,550 --> 00:11:35,290
in watching OMA more over the past

257
00:11:41,130 --> 00:11:38,560
several months Kay and basically the the

258
00:11:44,580 --> 00:11:41,140
observations ended in Jinbo January they

259
00:11:46,500 --> 00:11:44,590
found that its orbit deviated

260
00:11:49,410 --> 00:11:46,510
what would be expected just due to

261
00:11:53,100 --> 00:11:49,420
gravity now gravity is a solved problem

262
00:11:56,280 --> 00:11:53,110
we know how to solve gravity so if an

263
00:11:59,340 --> 00:11:56,290

object moves off of a path that gravity

264
00:12:02,130 --> 00:11:59,350
would predict some other forces involved

265
00:12:03,870 --> 00:12:02,140
okay so there's just a slight

266
00:12:06,000 --> 00:12:03,880
acceleration but we can measure these

267
00:12:08,640 --> 00:12:06,010
slight accelerations and it could be

268
00:12:10,530 --> 00:12:08,650
caused by jets of outgassing all right

269
00:12:15,210 --> 00:12:10,540
and that would be the ices near the

270
00:12:18,060 --> 00:12:15,220
surface spewing out as it passes by the

271
00:12:20,040 --> 00:12:18,070
Sun and heats up okay and so that's why

272
00:12:22,260 --> 00:12:20,050
you can see there are jets here in this

273
00:12:25,230 --> 00:12:22,270
artist's illustration pointing towards

274
00:12:27,840 --> 00:12:25,240
the Sun that would add a small force

275
00:12:30,120 --> 00:12:27,850
that would cause a deviation in the

276
00:12:33,270 --> 00:12:30,130
orbit this is similar to what we see for

277
00:12:36,390 --> 00:12:33,280
comets in our solar system however the

278
00:12:39,510 --> 00:12:36,400
important point to note is that no

279
00:12:41,220 --> 00:12:39,520
outgassing was observed which causes a

280
00:12:43,950 --> 00:12:41,230
little bit of a problem so you need some

281
00:12:47,670 --> 00:12:43,960
outgassing to create the orbit deviation

282
00:12:49,440 --> 00:12:47,680
but not so much outgassing that it would

283
00:12:52,170 --> 00:12:49,450
actually be observed by the telescopes

284
00:12:54,660 --> 00:12:52,180
that looked at it there's still lots of

285
00:12:56,490 --> 00:12:54,670
uncertainty here we still don't have

286
00:12:58,650 --> 00:12:56,500
great estimates we still only have

287
00:13:00,960 --> 00:12:58,660
estimates of the size the shape and the

288
00:13:03,060 --> 00:13:00,970

composition but if this outgassing is

289
00:13:06,600 --> 00:13:03,070
true then it's probably more comet-like

290
00:13:08,220 --> 00:13:06,610
than it is asteroid like and

291
00:13:09,900 --> 00:13:08,230
unfortunately we're not going to get any

292
00:13:12,120 --> 00:13:09,910
more observations because now it's out

293
00:13:14,760 --> 00:13:12,130
past the orbit of Jupiter and heading

294
00:13:20,370 --> 00:13:14,770
out of the solar system never to be seen

295
00:13:23,370 --> 00:13:20,380
again so where do we go from here on

296
00:13:26,910 --> 00:13:23,380
this there should be other interstellar

297
00:13:30,180 --> 00:13:26,920
interlopers in our future if there's one

298
00:13:32,760 --> 00:13:30,190
there's got to be more right and now we

299
00:13:34,680 --> 00:13:32,770
know that there is a population we will

300
00:13:36,530 --> 00:13:34,690
continue to look for them I sort of

301
00:13:39,900 --> 00:13:36,540
think of it like the Kuiper belt objects

302
00:13:42,270 --> 00:13:39,910
when we saw the first recognizable

303
00:13:43,800 --> 00:13:42,280
Kuiper belt objects in 1993 we started

304
00:13:45,930 --> 00:13:43,810
searching and searching for more and

305
00:13:47,790 --> 00:13:45,940
more and we developed a whole family

306
00:13:49,860 --> 00:13:47,800
hopefully over the next year's and

307
00:13:51,930 --> 00:13:49,870
decades will develop a whole family of

308
00:13:54,060 --> 00:13:51,940
these interstellar objects and we'll be

309
00:13:56,700 --> 00:13:54,070
able to understand the characteristics

310
00:13:58,100 --> 00:13:56,710
of a population one is just an

311
00:14:00,019 --> 00:13:58,110
interesting object

312
00:14:02,449 --> 00:14:00,029
until you have a dozen or so then you

313
00:14:04,160 --> 00:14:02,459

can't really make group statements so we

314
00:14:04,819 --> 00:14:04,170
look forward to more interstellar

315
00:14:06,650 --> 00:14:04,829
visitors

316
00:14:08,449 --> 00:14:06,660
I wish they'd hang around a little bit

317
00:14:09,530 --> 00:14:08,459
longer but the nature of their orbits

318
00:14:11,630 --> 00:14:09,540
means that they're gonna come through

319
00:14:14,530 --> 00:14:11,640
BAM we get about six months of observing

320
00:14:18,590 --> 00:14:14,540
and then they're gone forever all right

321
00:14:22,579 --> 00:14:18,600
finally our third story a ten million

322
00:14:25,850 --> 00:14:22,589
year old baby this just hit the news

323
00:14:27,680 --> 00:14:25,860
wires today okay and I could not stop

324
00:14:29,990 --> 00:14:27,690
myself from adding it to the public

325
00:14:35,000 --> 00:14:30,000
lectures the presentation all right so

326
00:14:35,960 --> 00:14:35,010
this somewhere in here is the star PDS

327
00:14:38,030 --> 00:14:35,970
70

328
00:14:40,519 --> 00:14:38,040
I'd love to point out the exact star but

329
00:14:41,750 --> 00:14:40,529
they didn't tell us in when they when

330
00:14:43,579 --> 00:14:41,760
they put out this image they said oh

331
00:14:45,860 --> 00:14:43,589
it's in the center well this is the

332
00:14:48,920 --> 00:14:45,870
center I don't know exactly which one it

333
00:14:51,829 --> 00:14:48,930
is all right and so the star PDS 70 is

334
00:14:54,470 --> 00:14:51,839
special it's you know well first of all

335
00:14:56,660 --> 00:14:54,480
it's an ordinary case five star but it's

336
00:14:59,690 --> 00:14:56,670
only ten million years old it's a young

337
00:15:00,889 --> 00:14:59,700
star it's a recently formed star okay

338
00:15:10,790 --> 00:15:00,899

all right

339
00:15:13,220 --> 00:15:10,800
blocking out a little bit of the light

340
00:15:14,990 --> 00:15:13,230
from the Sun with this coal tting spot

341
00:15:17,030 --> 00:15:15,000
you'll notice there'll be a black circle

342
00:15:19,040 --> 00:15:17,040
at the center of all these images that's

343
00:15:20,389 --> 00:15:19,050
not because there's nothing there it's

344
00:15:22,400 --> 00:15:20,399
because we're actually blocking it out

345
00:15:25,120 --> 00:15:22,410
that black circle is blocking the light

346
00:15:28,009 --> 00:15:25,130
from the star okay so here's the star

347
00:15:29,060 --> 00:15:28,019
here's a potential companion that they

348
00:15:31,310 --> 00:15:29,070
identified okay

349
00:15:32,720 --> 00:15:31,320
and when they analyzed this and did all

350
00:15:36,050 --> 00:15:32,730
sorts of computer process you can pulled

351
00:15:38,480 --> 00:15:36,060
it out they found that first of all that

352
00:15:41,660 --> 00:15:38,490
this star was a brown dwarf that could

353
00:15:44,720 --> 00:15:41,670
be a companion all right and then they

354
00:15:47,090 --> 00:15:44,730
found a disk of material orbiting around

355
00:15:49,519 --> 00:15:47,100
the star all right so you're seeing an

356
00:15:51,079 --> 00:15:49,529
disc of material edge on right so you're

357
00:15:54,310 --> 00:15:51,089
seeing material orbiting around the star

358
00:15:56,900 --> 00:15:54,320
plus a jet of material spewing out

359
00:15:58,490 --> 00:15:56,910
perpendicular to the disk and we see

360
00:16:00,920 --> 00:15:58,500
this in other places for example in

361
00:16:03,170 --> 00:16:00,930
Orion when we see newborn stars okay we

362
00:16:07,069 --> 00:16:03,180
have discs and we have jets all right

363
00:16:09,350 --> 00:16:07,079

and so this was interesting and there

364
00:16:11,630 --> 00:16:09,360
were strong hints that a giant planet

365
00:16:14,510 --> 00:16:11,640
could have formed in the interior

366
00:16:16,730 --> 00:16:14,520
and the inner parts of the disc they

367
00:16:19,760 --> 00:16:16,740
went back and studied this again over

368
00:16:22,640 --> 00:16:19,770
time and in 2012 they released this

369
00:16:25,310 --> 00:16:22,650
image again this black spot is just the

370
00:16:27,260 --> 00:16:25,320
occulting circle to get rid of this

371
00:16:30,230 --> 00:16:27,270
flight of the star but you can see how

372
00:16:33,170 --> 00:16:30,240
there's a bright ring here and inside

373
00:16:36,680 --> 00:16:33,180
the ring is an empty region okay there's

374
00:16:38,900 --> 00:16:36,690
a gap that's about 140 astronomical

375
00:16:41,390 --> 00:16:38,910
units across and if you don't remember

376
00:16:44,300 --> 00:16:41,400
an astronomical unit is one the distance

377
00:16:47,060 --> 00:16:44,310
from Earth to the Sun Neptune is about

378
00:16:48,920 --> 00:16:47,070
30 astronomical units and radius so this

379
00:16:52,070 --> 00:16:48,930
is a hundred and forty astronomical

380
00:16:54,590 --> 00:16:52,080
units okay and so there is a gap in

381
00:16:57,890 --> 00:16:54,600
there and that really says hey if

382
00:17:00,020 --> 00:16:57,900
there's a giant planet in there or more

383
00:17:02,930 --> 00:17:00,030
one or more giant planets that can clear

384
00:17:06,980 --> 00:17:02,940
out that gap well that sets the stage

385
00:17:08,960 --> 00:17:06,990
for what was just announced in 2018 they

386
00:17:11,270 --> 00:17:08,970
got a picture from the Very Large

387
00:17:13,939 --> 00:17:11,280
Telescope yes that is its name

388
00:17:15,020 --> 00:17:13,949

the Very Large Telescope we astronomers

389
00:17:17,600 --> 00:17:15,030
are pretty straightforward

390
00:17:23,180 --> 00:17:17,610
from the European Southern Observatory

391
00:17:28,760 --> 00:17:23,190
the VLT got that image you can see the

392
00:17:31,570 --> 00:17:28,770
gap and you can see that ladies and

393
00:17:39,220 --> 00:17:31,580
gentlemen this is the first confirmed

394
00:17:45,430 --> 00:17:40,650
[Music]

395
00:17:47,170 --> 00:17:45,440
this planet is called PDS 70 B the

396
00:17:49,540 --> 00:17:47,180
lowercase B indicating that it's a

397
00:17:52,840 --> 00:17:49,550
planet it's about 20 astronomical units

398
00:17:56,110 --> 00:17:52,850
from its star it is a few Jupiter masses

399
00:17:58,030 --> 00:17:56,120
so only 2 or 3 or 4 Jupiter masses all

400
00:18:01,720 --> 00:17:58,040
right so it's Jupiter size it's a gas

401
00:18:05,170 --> 00:18:01,730
giant planet it's very hot okay

402
00:18:07,870 --> 00:18:05,180
1,800 degrees Fahrenheit all right for

403
00:18:09,580 --> 00:18:07,880
example the the cloud tops of Jupiter or

404
00:18:12,400 --> 00:18:09,590
minus a hundred degrees Fahrenheit as

405
00:18:15,850 --> 00:18:12,410
such all right this is still in

406
00:18:18,400 --> 00:18:15,860
formation okay at 10 million years old

407
00:18:21,310 --> 00:18:18,410
this is the 10 million year old baby I

408
00:18:23,770 --> 00:18:21,320
was talking about in the title ok and

409
00:18:25,870 --> 00:18:23,780
when they do further analysis on it and

410
00:18:29,110 --> 00:18:25,880
they really study it they can tell that

411
00:18:30,640 --> 00:18:29,120
its atmosphere is cloudy I can't tell

412
00:18:32,950 --> 00:18:30,650
you how because I didn't have enough

413
00:18:35,230 --> 00:18:32,960

time to read all the papers today too I

414
00:18:38,080 --> 00:18:35,240
think but as one of the results that

415
00:18:41,140 --> 00:18:38,090
they came out from it so we have had

416
00:18:43,570 --> 00:18:41,150
pictures of planets and such but this is

417
00:18:47,410 --> 00:18:43,580
a newborn planet it takes approximately

418
00:18:50,950 --> 00:18:47,420
10 million years for a gas giant to form

419
00:18:54,070 --> 00:18:50,960
so this is really just a newborn gas

420
00:18:57,010 --> 00:18:54,080
giant and it's a really cool result that

421
00:18:59,200 --> 00:18:57,020
just got announced today all right so I

422
00:19:01,180 --> 00:18:59,210
like to bring you the the really cool

423
00:19:03,060 --> 00:19:01,190
results as they come even though this

424
00:19:06,060 --> 00:19:03,070
isn't a Hubble or a Space Telescope

425
00:19:10,620 --> 00:19:06,070
story it was just too important to skip

426
00:19:15,280 --> 00:19:10,630
and that's our news from the universe

427
00:19:18,420 --> 00:19:15,290
our featured speaker tonight is David

428
00:19:23,110 --> 00:19:18,430
Netto from the Johns Hopkins University

429
00:19:26,800 --> 00:19:23,120
he did his PhD work at the Ohio State

430
00:19:28,870 --> 00:19:26,810
University and then did a postdoc down

431
00:19:31,570 --> 00:19:28,880
in Australia although you he says he

432
00:19:34,630 --> 00:19:31,580
originally hails from Canada came to the

433
00:19:36,940 --> 00:19:34,640
u.s. to do the the PhD went to Australia

434
00:19:38,440 --> 00:19:36,950
to do a postdoc and fortunately came

435
00:19:40,720 --> 00:19:38,450
back to the u.s. to the Johns Hopkins

436
00:19:43,810 --> 00:19:40,730
University and he holds the Davis post

437
00:19:46,420 --> 00:19:43,820
starbuck post doctoral fellowship across

438
00:19:50,290 --> 00:19:46,430

the way he'll tell you about his

439
00:19:52,720 --> 00:19:50,300
research but he says that in his in his

440
00:19:55,510 --> 00:19:52,730
spare time when he's not doing research

441
00:19:57,010 --> 00:19:55,520
he works with the summer interns that

442
00:19:58,270 --> 00:19:57,020
the high school and college students

443
00:20:01,030 --> 00:19:58,280
that come in and work with us over the

444
00:20:05,220 --> 00:20:01,040
summer and he's also can be found down

445
00:20:21,340 --> 00:20:05,230
at the SPCA walking the dogs

446
00:20:23,050 --> 00:20:21,350
ladies gentlemen David natal thank you

447
00:20:26,080 --> 00:20:23,060
for the introduction Frank can everyone

448
00:20:27,940 --> 00:20:26,090
hear me all right good all right so I'll

449
00:20:30,340 --> 00:20:27,950
be speaking about the Milky Way's bulge

450
00:20:33,550 --> 00:20:30,350
and I'll explain what a ball just

451
00:20:35,140 --> 00:20:33,560
shortly but you can see one in the image

452
00:20:37,270 --> 00:20:35,150
that was given out earlier that's the

453
00:20:40,540 --> 00:20:37,280
sombrero galaxy a relatively famous

454
00:20:43,480 --> 00:20:40,550
galaxy and that is a spectacular image

455
00:20:46,720 --> 00:20:43,490
of a galaxy which is a combination of a

456
00:20:51,850 --> 00:20:46,730
disc and a bulge somewhat similar to the

457
00:20:54,280 --> 00:20:51,860
Milky Way but not quite this is an image

458
00:20:58,090 --> 00:20:54,290
that'll look very familiar to people who

459
00:20:59,740 --> 00:20:58,100
have gone camping and maybe not familiar

460
00:21:02,350 --> 00:20:59,750
to people have never been outside the

461
00:21:05,890 --> 00:21:02,360
city that is what the Milky Way will

462
00:21:07,750 --> 00:21:05,900
look like from the grounds if you don't

463
00:21:15,370 --> 00:21:07,760

have light pollution and if you have

464
00:21:16,840 --> 00:21:15,380
decent night vision oh okay and I heard

465
00:21:18,460 --> 00:21:16,850
an interesting anecdote a few years ago

466
00:21:20,620 --> 00:21:18,470
I don't know if it's true but it sounds

467
00:21:22,300 --> 00:21:20,630
like it could be true apparently many

468
00:21:25,180 --> 00:21:22,310
years ago there was a huge power outage

469
00:21:27,550 --> 00:21:25,190
in Southern California and then people

470
00:21:29,440 --> 00:21:27,560
saw this and they had no idea what was

471
00:21:34,020 --> 00:21:29,450
so they got scared and they called

472
00:21:38,710 --> 00:21:34,030
police there you go

473
00:21:41,620 --> 00:21:38,720
so here's two images of the Milky Way

474
00:21:42,690 --> 00:21:41,630
panoramic Li in optical and

475
00:21:45,670 --> 00:21:42,700
near-infrared

476
00:21:49,360 --> 00:21:45,680
photography I'll explain what so optical

477
00:21:51,550 --> 00:21:49,370
is the type of light that we can see we

478
00:21:55,060 --> 00:21:51,560
can see Li you know it goes from blue

479
00:21:58,990 --> 00:21:55,070
lights - and then you got green light

480
00:22:00,490 --> 00:21:59,000
orange or orange light and red lights

481
00:22:03,039 --> 00:22:00,500
with a bit more detail actually I

482
00:22:06,039 --> 00:22:03,049
skipped purple lights and this is near

483
00:22:08,620 --> 00:22:06,049
infrared lights and can somebody point

484
00:22:11,080 --> 00:22:08,630
out so you can all see that it's kind of

485
00:22:12,760 --> 00:22:11,090
the same but there's some differences

486
00:22:15,520 --> 00:22:12,770
could somebody point out a difference

487
00:22:17,620 --> 00:22:15,530
between the top image and the bottom

488
00:22:22,390 --> 00:22:17,630

image other than the kind of light

489
00:22:25,899 --> 00:22:22,400
they're in yes yeah so there's all these

490
00:22:28,120 --> 00:22:25,909
dust lanes in the top image it looks

491
00:22:30,010 --> 00:22:28,130
like it's black but it's not black

492
00:22:32,860 --> 00:22:30,020
there's a ton of stars there just a lot

493
00:22:36,010 --> 00:22:32,870
of the light is blocked out by

494
00:22:38,980 --> 00:22:36,020
intervening dust particles and dust it

495
00:22:42,220 --> 00:22:38,990
kind of affects all lights but it

496
00:22:44,649 --> 00:22:42,230
affects bluer lights a lot more than

497
00:22:46,899 --> 00:22:44,659
rhetoric or optical light a lot more

498
00:22:48,880 --> 00:22:46,909
than infrared light I learned something

499
00:22:51,340 --> 00:22:48,890
cool when I lived in Australia which is

500
00:22:53,320 --> 00:22:51,350
kind of after it was explained to me it

501
00:22:55,299 --> 00:22:53,330
was obvious so in the southern

502
00:22:57,159 --> 00:22:55,309
hemisphere this do see more of the Milky

503
00:22:59,830 --> 00:22:57,169
Way due to how things are oriented and

504
00:23:03,310 --> 00:22:59,840
for the Australian Aborigines their

505
00:23:06,750 --> 00:23:03,320
constellations weren't just you know

506
00:23:09,159 --> 00:23:06,760
connections of stars the dust lanes

507
00:23:11,020 --> 00:23:09,169
themselves could also be constellations

508
00:23:12,730 --> 00:23:11,030
it would make animals out of that and as

509
00:23:14,200 --> 00:23:12,740
it moved through season it would

510
00:23:21,730 --> 00:23:14,210
correspond to different parts of the

511
00:23:24,039 --> 00:23:21,740
fertility cycle so here's the Milky Way

512
00:23:27,039 --> 00:23:24,049
bulge or rather actions a whole galaxy

513
00:23:30,460 --> 00:23:27,049

including the Bulge as part of an

514
00:23:32,560 --> 00:23:30,470
artist's rendition and some of you may

515
00:23:34,720 --> 00:23:32,570
feel I'm being cheap right now I'm

516
00:23:37,240 --> 00:23:34,730
showing an artist's rendition of our own

517
00:23:39,370 --> 00:23:37,250
galaxy because someone tell me why I

518
00:23:47,740 --> 00:23:39,380
wouldn't be showing a photo of our

519
00:23:50,980 --> 00:23:47,750
galaxy yes in the back thank you that's

520
00:23:53,590 --> 00:23:50,990
exactly right yeah so the previous image

521
00:23:55,240 --> 00:23:53,600
is we're kind of like in the galaxy to

522
00:23:57,700 --> 00:23:55,250
see that right but really we're only

523
00:24:00,039 --> 00:23:57,710
seeing I don't know we're like 70 or 80

524
00:24:01,840 --> 00:24:00,049
percent outwards so in those image we're

525
00:24:04,419 --> 00:24:01,850
kind of seeing the inner 70% of the

526
00:24:06,190 --> 00:24:04,429
galaxy but here it's with somebody yeah

527
00:24:08,139 --> 00:24:06,200
if you've traveled like ten thousand

528
00:24:10,180 --> 00:24:08,149
light-years outwards and it's worse than

529
00:24:11,590 --> 00:24:10,190
that because if you did go out by ten or

530
00:24:13,210 --> 00:24:11,600
50,000 light years

531
00:24:16,600 --> 00:24:13,220
good luck sending this

532
00:24:17,260 --> 00:24:16,610
back you'd be like Oh how did I end up

533
00:24:22,510 --> 00:24:17,270
here

534
00:24:24,310 --> 00:24:22,520
or do I go you'd be screwed and so in

535
00:24:26,500 --> 00:24:24,320
this image of the galaxy the part that's

536
00:24:28,510 --> 00:24:26,510
rel so it's very idealized image the

537
00:24:32,500 --> 00:24:28,520
real galaxy is probably not super

538
00:24:34,299 --> 00:24:32,510

symmetric we kind of all galaxies many

539
00:24:37,000 --> 00:24:34,309
galaxies are symmetric but not perfectly

540
00:24:41,110 --> 00:24:37,010
so but Bryce Raman here the spiral arms

541
00:24:43,930 --> 00:24:41,120
are in blue and the Bulge or bar is in

542
00:24:46,690 --> 00:24:43,940
yellow the reason it's a different color

543
00:24:49,000 --> 00:24:46,700
is that there are fewer young stars in

544
00:24:51,940 --> 00:24:49,010
the Bulge and I'll explain I'll discuss

545
00:24:54,370 --> 00:24:51,950
that at the end so now we're going to

546
00:24:55,960 --> 00:24:54,380
see a video of a forming galaxies

547
00:24:57,220 --> 00:24:55,970
there's so many videos of galaxies

548
00:25:01,270 --> 00:24:57,230
forming out there I didn't know which

549
00:25:02,799 --> 00:25:01,280
ones to take but I took these two well

550
00:25:05,080 --> 00:25:02,809
okay look there's this one and another

551
00:25:08,620 --> 00:25:05,090
one afterwards we're gonna watch this go

552
00:25:10,690 --> 00:25:08,630
it shows Z or Z sorry on the top left

553
00:25:13,810 --> 00:25:10,700
that's the cosmological redshift that

554
00:25:16,120 --> 00:25:13,820
corresponds to time Zetas 15 means about

555
00:25:18,880 --> 00:25:16,130
13 and a half Giga years ago billion

556
00:25:19,990 --> 00:25:18,890
years ago sorry Zetas one means seven

557
00:25:23,440 --> 00:25:20,000
point eight billion years ago and the

558
00:25:25,690 --> 00:25:23,450
way galaxies form over there they're

559
00:25:27,580 --> 00:25:25,700
believed to have formed from tiny proto

560
00:25:29,470 --> 00:25:27,590
galaxies maybe a thousand or ten

561
00:25:32,140 --> 00:25:29,480
thousand times smaller and as the

562
00:25:34,480 --> 00:25:32,150
universe age they all come together and

563
00:25:38,049 --> 00:25:34,490

eventually we have a disk like we have

564
00:25:40,270 --> 00:25:38,059
now this picture is definitely accurate

565
00:25:43,029 --> 00:25:40,280
but the details might be off it's not

566
00:25:45,100 --> 00:25:43,039
it's a matter of controversy and so we

567
00:25:47,860 --> 00:25:45,110
see by this point most of the galaxies

568
00:25:49,630 --> 00:25:47,870
assembled there's kind of fewer big

569
00:25:54,039 --> 00:25:49,640
pieces coming in now there's still a lot

570
00:25:56,020 --> 00:25:54,049
of small pieces like for own galaxy but

571
00:26:00,279 --> 00:25:56,030
you know and the big things are there

572
00:26:01,899 --> 00:26:00,289
and does that thing have slowed down so

573
00:26:04,149 --> 00:26:01,909
it kind of looks like maybe the computer

574
00:26:07,000 --> 00:26:04,159
got slower cuz it's too complicated but

575
00:26:09,909 --> 00:26:07,010
that's not it it's just the ways that is

576
00:26:10,779 --> 00:26:09,919
defines as you go from Z to 15th is out

577
00:26:13,570 --> 00:26:10,789
of 5

578
00:26:15,220 --> 00:26:13,580
you only travel 1 billion years but as

579
00:26:17,230 --> 00:26:15,230
you go from 5 to 1

580
00:26:20,289 --> 00:26:17,240
you try let you go like 8 billion years

581
00:26:22,299 --> 00:26:20,299
it's kind of it's the mapping between

582
00:26:26,590 --> 00:26:22,309
the history of expansion of the universe

583
00:26:29,590 --> 00:26:26,600
and the actual age of things and now

584
00:26:31,720 --> 00:26:29,600
four is about when the Sun formed so

585
00:26:33,190 --> 00:26:31,730
this galaxy here would have a baby son

586
00:26:35,560 --> 00:26:33,200
if that was like the Milky Way we see

587
00:26:37,240 --> 00:26:35,570
that so reasonable spiral it's not

588
00:26:40,289 --> 00:26:37,250

completely symmetric but it's pretty

589
00:26:42,340 --> 00:26:40,299
close right like if this was a flower

590
00:26:44,590 --> 00:26:42,350
okay I mean it doesn't look like a

591
00:26:47,980 --> 00:26:44,600
flower but pretend it does it'd be kind

592
00:26:50,049 --> 00:26:47,990
of a pretty flower and unlike our galaxy

593
00:26:52,779 --> 00:26:50,059
this one has a pretty big merger going

594
00:26:55,390 --> 00:26:52,789
on at the end our galaxy now only has a

595
00:26:57,100 --> 00:26:55,400
has small mergers going on right now

596
00:26:59,740 --> 00:26:57,110
that's still ouch

597
00:27:02,590 --> 00:26:59,750
that's our galaxy into two billion years

598
00:27:04,779 --> 00:27:02,600
when it emerges from Andromeda and now

599
00:27:07,630 --> 00:27:04,789
here's a second galaxy and it already

600
00:27:09,549 --> 00:27:07,640
started it looks the same at first

601
00:27:15,940 --> 00:27:09,559
because they all wait you know I

602
00:27:22,000 --> 00:27:15,950
actually know sorry okay this is

603
00:27:25,630 --> 00:27:22,010
actually what I meant to look at okay

604
00:27:28,750 --> 00:27:25,640
this is just the this galaxy the point

605
00:27:31,029 --> 00:27:28,760
of it is that it's thought to be more

606
00:27:32,820 --> 00:27:31,039
similar to what the Milky Way might have

607
00:27:35,020 --> 00:27:32,830
gone through of course these are random

608
00:27:39,159 --> 00:27:35,030
realizations and go through the trillion

609
00:27:41,230 --> 00:27:39,169
times and never find a match but you'll

610
00:27:52,590 --> 00:27:41,240
get a qualitative match you know which

611
00:28:03,370 --> 00:27:57,430
so in this image the we see the light of

612
00:28:06,760 --> 00:28:03,380
gas and stars stars form from gas what

613
00:28:09,820 --> 00:28:06,770

we're not seeing is the lights from dust

614
00:28:11,860 --> 00:28:09,830
it's it's just turned off in this video

615
00:28:13,480 --> 00:28:11,870
the dust is still active and having

616
00:28:15,279 --> 00:28:13,490
physical effects but it's turned off

617
00:28:19,720 --> 00:28:15,289
because the video is meaning to

618
00:28:21,399 --> 00:28:19,730
emphasize the gas and the stars and what

619
00:28:24,039 --> 00:28:21,409
they bragged about when they made this

620
00:28:27,340 --> 00:28:24,049
is that they're able to make a pretty

621
00:28:29,380 --> 00:28:27,350
thin disc the people simulate these

622
00:28:31,390 --> 00:28:29,390
galaxies have been able to make disks of

623
00:28:34,029 --> 00:28:31,400
galaxies like the Milky Way hasn't shown

624
00:28:37,590 --> 00:28:34,039
you earlier for a long time but to make

625
00:28:39,700 --> 00:28:37,600
thin disks you know crêpes rather than

626
00:28:43,899 --> 00:28:39,710
pancakes from blue moon

627
00:28:46,330 --> 00:28:43,909
is a bit hard and galaxies are small are

628
00:28:49,240 --> 00:28:46,340
some more similar to crepes than to

629
00:28:52,240 --> 00:28:49,250
pancakes from Blue Moon all okay maybe

630
00:28:54,310 --> 00:28:52,250
not in this image but yeah this has a

631
00:28:56,500 --> 00:28:54,320
pretty thin bulge

632
00:29:03,130 --> 00:28:56,510
I ain't thin disc and you can see that

633
00:29:05,680 --> 00:29:03,140
there's a bulge already and so to go

634
00:29:08,260 --> 00:29:05,690
through why ball just matter really the

635
00:29:09,820 --> 00:29:08,270
whole galaxy matters you might come to

636
00:29:12,279 --> 00:29:09,830
another talking year from now they'll be

637
00:29:14,740 --> 00:29:12,289
talking about the disc or the outskirts

638
00:29:18,010 --> 00:29:14,750

or the star clusters every part of the

639
00:29:23,049 --> 00:29:18,020
galaxy matters the reason that the Bulge

640
00:29:25,720 --> 00:29:23,059
now and that the Balch matters is that

641
00:29:28,750 --> 00:29:25,730
it's many of the oldest stars in the

642
00:29:30,880 --> 00:29:28,760
galaxy that's why it's yellow and so by

643
00:29:33,850 --> 00:29:30,890
understanding that we can have a pretty

644
00:29:37,149 --> 00:29:33,860
good idea of how a disproportionate

645
00:29:38,529 --> 00:29:37,159
number of the first stars forms even

646
00:29:41,799 --> 00:29:38,539
though it's only a third of the total

647
00:29:44,889 --> 00:29:41,809
stars it might be like one half to two

648
00:29:47,380 --> 00:29:44,899
thirds of the oldest stars and I make a

649
00:29:49,570 --> 00:29:47,390
lot of analogies with history the field

650
00:29:52,360 --> 00:29:49,580
is now called galactic archaeology maybe

651
00:29:55,870 --> 00:29:52,370
for marketing reasons but imagine in

652
00:29:58,870 --> 00:29:55,880
history like you knew about you know the

653
00:30:01,330 --> 00:29:58,880
American Civil War and the Spanish

654
00:30:03,220 --> 00:30:01,340
Inquisition and that interesting stuff

655
00:30:05,289 --> 00:30:03,230
but you didn't know but the Sumerians

656
00:30:07,029 --> 00:30:05,299
and the Greeks your knowledge would be

657
00:30:08,799 --> 00:30:07,039
very incomplete you need to know that

658
00:30:13,180 --> 00:30:08,809
stuff is interesting as well and it

659
00:30:15,850 --> 00:30:13,190
helps complete the story all right

660
00:30:17,860 --> 00:30:15,860
so part one it's the shortest part it's

661
00:30:23,260 --> 00:30:17,870
the chemical characterization of ball

662
00:30:25,019 --> 00:30:23,270
stars it's it's short because located

663
00:30:28,750 --> 00:30:25,029

three parts in here there's chemistry

664
00:30:31,240 --> 00:30:28,760
there's structure and there's ages and

665
00:30:33,460 --> 00:30:31,250
chemistry might be the simplest in that

666
00:30:36,399 --> 00:30:33,470
it's reasonably solved I don't have as

667
00:30:39,669 --> 00:30:36,409
much controversy to share for you it

668
00:30:41,110 --> 00:30:39,679
wasn't solved maybe 30 years ago but

669
00:30:42,789 --> 00:30:41,120
it's solved now because we have these

670
00:30:45,370 --> 00:30:42,799
great new instruments we could look at

671
00:30:50,409 --> 00:30:45,380
hundreds of stars at a time this was

672
00:30:53,500 --> 00:30:50,419
taken by PhD thesis in Australia who

673
00:30:57,340 --> 00:30:53,510
knows what Fe might be

674
00:31:00,400 --> 00:30:57,350
that's right so the distribution and the

675
00:31:02,680 --> 00:31:00,410
metallicity of stars is usually it could

676
00:31:05,530 --> 00:31:02,690
be any metal you know why not copper or

677
00:31:07,299 --> 00:31:05,540
why not zinc iron is used because it

678
00:31:09,460 --> 00:31:07,309
happens to have a lot of atomic

679
00:31:12,100 --> 00:31:09,470
transitions and so you get a ton of

680
00:31:15,909 --> 00:31:12,110
lines when you look at the atmosphere of

681
00:31:18,520 --> 00:31:15,919
a star absorption lines that are due to

682
00:31:21,220 --> 00:31:18,530
iron and in fact if you go back a

683
00:31:23,070 --> 00:31:21,230
hundred years a lot of astronomers back

684
00:31:25,960 --> 00:31:23,080
then so they didn't have quantum physics

685
00:31:27,820 --> 00:31:25,970
understood but they knew that they

686
00:31:29,830 --> 00:31:27,830
didn't really know what's going on in

687
00:31:32,110 --> 00:31:29,840
the solar atmosphere they thought that

688
00:31:34,840 --> 00:31:32,120

the Sun was made of iron because iron

689
00:31:37,930 --> 00:31:34,850
makes a ton of absorption lines but

690
00:31:39,549 --> 00:31:37,940
that's not it it's just it just happens

691
00:31:42,760 --> 00:31:39,559
that at the typical temperature of a

692
00:31:44,650 --> 00:31:42,770
star a iron has a lot of transitions and

693
00:31:46,930 --> 00:31:44,660
so we use iron to measure things all

694
00:31:51,330 --> 00:31:46,940
right so here it's a logarithmic ratio

695
00:31:53,950 --> 00:31:51,340
of iron to hydrogen minus 1 means

696
00:31:58,240 --> 00:31:53,960
one-tenth the iron to hydrogen ratio of

697
00:32:00,070 --> 00:31:58,250
the Sun and plus 0.4 means about four

698
00:32:02,409 --> 00:32:00,080
times the iron to hydrogen ratio of the

699
00:32:05,200 --> 00:32:02,419
start of the Sun and it turns out that

700
00:32:09,610 --> 00:32:05,210
almost all bulb stars are in that range

701
00:32:12,340 --> 00:32:09,620
and a typical value is zero I always

702
00:32:14,919 --> 00:32:12,350
think that this is a big coincidence but

703
00:32:18,490 --> 00:32:14,929
the iron the metallicity of the Sun is

704
00:32:20,200 --> 00:32:18,500
very typical of the metallicity of most

705
00:32:21,820 --> 00:32:20,210
of the stars in the Balch and indeed

706
00:32:23,950 --> 00:32:21,830
elsewhere in the galaxy it's a little

707
00:32:26,620 --> 00:32:23,960
higher but I don't know I think it's

708
00:32:29,620 --> 00:32:26,630
cool that the Sun is such an all right

709
00:32:31,390 --> 00:32:29,630
an average star in metallicity where

710
00:32:33,970 --> 00:32:31,400
metallicity and chemistry is a thing

711
00:32:39,039 --> 00:32:33,980
that marries the most between different

712
00:32:41,740 --> 00:32:39,049
stars and we can also study other

713
00:32:43,990 --> 00:32:41,750

elements I could go on and on with other

714
00:32:45,700 --> 00:32:44,000
elements but it'd be like too much

715
00:32:49,120 --> 00:32:45,710
information and to be honest the other

716
00:32:53,799 --> 00:32:49,130
elements aren't measured as well so it's

717
00:32:57,250 --> 00:32:53,809
not as informative but here we show OSI

718
00:33:00,430 --> 00:32:57,260
and SIA and see CA calcium so oxygen

719
00:33:02,740 --> 00:33:00,440
silicon and calcium and it's the ratio

720
00:33:05,890 --> 00:33:02,750
relative to iron and what's been

721
00:33:06,940 --> 00:33:05,900
confirmed over most decades of research

722
00:33:09,669 --> 00:33:06,950
the past 20 or 3

723
00:33:13,990 --> 00:33:09,679
years is that the ratios are higher

724
00:33:17,470 --> 00:33:14,000
involved stars than in the Sun so this

725
00:33:20,350 --> 00:33:17,480
is one place in which one area in which

726
00:33:23,019 --> 00:33:20,360
both stars are different they just have

727
00:33:24,759 --> 00:33:23,029
more relative abundances of these

728
00:33:27,610 --> 00:33:24,769
elements and that's kind of cool imagine

729
00:33:30,490 --> 00:33:27,620
you form an earth there right and earth

730
00:33:32,980 --> 00:33:30,500
is I think iron is the second most

731
00:33:34,930 --> 00:33:32,990
abundant element after oxygen and the

732
00:33:35,889 --> 00:33:34,940
earth and so imagine you truncated that

733
00:33:38,799 --> 00:33:35,899
in half it might have a different

734
00:33:40,930 --> 00:33:38,809
evolution of life going on and the

735
00:33:43,600 --> 00:33:40,940
reason for this is thought to be that

736
00:33:45,610 --> 00:33:43,610
the balls formed quickly that's why it

737
00:33:49,990 --> 00:33:45,620
was yellow in the previous images the

738
00:33:51,960 --> 00:33:50,000

stars are older and therefore it says

739
00:33:54,370 --> 00:33:51,970
more of those kinds of supernovae

740
00:33:55,980 --> 00:33:54,380
alright I'll skip this law structure of

741
00:34:00,750 --> 00:33:55,990
the Bulge

742
00:34:06,779 --> 00:34:04,060
alright so this is the Hubble tuning

743
00:34:10,270 --> 00:34:06,789
fork diagram and it kind of shows that

744
00:34:12,569 --> 00:34:10,280
galaxies come in a huge variety of

745
00:34:14,889 --> 00:34:12,579
shapes and sizes it was first under

746
00:34:17,800 --> 00:34:14,899
written down by Edwin Hubble

747
00:34:19,599 --> 00:34:17,810
approximately 100 years ago and he had

748
00:34:22,419 --> 00:34:19,609
some story about it about why this

749
00:34:23,859 --> 00:34:22,429
happens it doesn't hold up that's fine

750
00:34:25,240 --> 00:34:23,869
he didn't guess the reason but what's

751
00:34:28,510 --> 00:34:25,250
interesting is that we still don't know

752
00:34:31,210 --> 00:34:28,520
the reason well we know a little bit but

753
00:34:34,270 --> 00:34:31,220
not really fully why galaxies come in

754
00:34:38,050 --> 00:34:34,280
these shapes and when astronomers

755
00:34:40,659 --> 00:34:38,060
realized that there were galaxies there

756
00:34:43,260 --> 00:34:40,669
they didn't realize what kind of galaxy

757
00:34:47,649 --> 00:34:43,270
the Milky Way was is it one like this

758
00:34:50,710 --> 00:34:47,659
like this like this like this of course

759
00:34:53,079 --> 00:34:50,720
you guys might guess because I showed

760
00:34:56,319 --> 00:34:53,089
you an image earlier of an artist's

761
00:34:59,079 --> 00:34:56,329
rendition does anyone want to point to

762
00:35:01,510 --> 00:34:59,089
one of these or I don't know if it's big

763
00:35:03,460 --> 00:35:01,520

enough for everybody see and you say

764
00:35:09,849 --> 00:35:03,470
which one is most similar to the Milky

765
00:35:13,569 --> 00:35:09,859
Way yes who said that yeah down there

766
00:35:16,450 --> 00:35:13,579
probably this one maybe this one so the

767
00:35:20,000 --> 00:35:16,460
bar as I'll explain soon as reasonably

768
00:35:23,690 --> 00:35:20,010
well understood however the spiral arms

769
00:35:26,420 --> 00:35:23,700
are not that well understood and maybe I

770
00:35:28,700 --> 00:35:26,430
will show you great images of the bar

771
00:35:30,140 --> 00:35:28,710
shortly of what it could look like it's

772
00:35:32,210 --> 00:35:30,150
one of the achievement not really my

773
00:35:33,710 --> 00:35:32,220
main five minutes one of the

774
00:35:36,410 --> 00:35:33,720
achievements of astronomy in the past

775
00:35:37,390 --> 00:35:36,420
ten years but there's spiral arms not

776
00:35:41,270 --> 00:35:37,400
yet solved

777
00:35:43,970 --> 00:35:41,280
alright so the Milky Way is not an

778
00:35:48,380 --> 00:35:43,980
unbarred galaxy like the Whirlpool

779
00:35:50,480 --> 00:35:48,390
Galaxy this is an image of a typical

780
00:35:52,820 --> 00:35:50,490
unbarred galaxy it might have a very

781
00:35:55,670 --> 00:35:52,830
very weak bar in here that's possible

782
00:35:57,260 --> 00:35:55,680
but it'll be very weak so whatever if

783
00:35:59,120 --> 00:35:57,270
somebody tell me something else about

784
00:36:05,570 --> 00:35:59,130
the Whirlpool Galaxy that's different

785
00:36:07,670 --> 00:36:05,580
from the Milky Way yes as a companion

786
00:36:09,410 --> 00:36:07,680
right here the Milky Way does have

787
00:36:14,060 --> 00:36:09,420
companions but nothing that's like a

788
00:36:18,250 --> 00:36:14,070

quarter of the size like that the Milky

789
00:36:21,770 --> 00:36:18,260
Way is a barred spiral galaxy like NGC

790
00:36:24,380 --> 00:36:21,780
1559 maybe not quite exactly like this

791
00:36:26,030 --> 00:36:24,390
this is a very strong bar we see there's

792
00:36:29,060 --> 00:36:26,040
a lot of dust lanes just like in our

793
00:36:30,410 --> 00:36:29,070
galaxy and if I could ask another

794
00:36:34,640 --> 00:36:30,420
question for you guys though the

795
00:36:36,200 --> 00:36:34,650
question is on the screen why is it that

796
00:36:39,770 --> 00:36:36,210
this galaxy the one that showed you

797
00:36:43,250 --> 00:36:39,780
before circles but this one here appears

798
00:36:45,830 --> 00:36:43,260
to be longer in one axis and the other

799
00:36:47,390 --> 00:36:45,840
axis it's like twice the length does

800
00:36:54,650 --> 00:36:47,400
anyone have a good guess as to why that

801
00:36:57,350 --> 00:36:54,660
might be yes that's right

802
00:36:59,450 --> 00:36:57,360
of course it could actually be that it

803
00:37:01,580 --> 00:36:59,460
is slightly asymmetric that does happen

804
00:37:04,100 --> 00:37:01,590
there could be a companion just off

805
00:37:06,080 --> 00:37:04,110
that's torquing it but the most likely

806
00:37:10,040 --> 00:37:06,090
explanation you take something that's

807
00:37:14,210 --> 00:37:10,050
flat you tilt it and then it will appear

808
00:37:16,850 --> 00:37:14,220
longer in one axis then the other the

809
00:37:19,100 --> 00:37:16,860
Milky Way is the only galaxy that we can

810
00:37:21,350 --> 00:37:19,110
study in three dimensions all other

811
00:37:25,880 --> 00:37:21,360
galaxies appears two-dimensional

812
00:37:28,070 --> 00:37:25,890
projections and another image this one

813
00:37:32,330 --> 00:37:28,080

is more plausible the Milky Way is a

814
00:37:33,880 --> 00:37:32,340
barred spiral galaxy like NGC 43 94 this

815
00:37:35,650 --> 00:37:33,890
one's 54 million light years

816
00:37:38,230 --> 00:37:35,660
away in the constellation Coma Berenices

817
00:37:41,170 --> 00:37:38,240
no one's gonna remember that that's okay

818
00:37:44,560 --> 00:37:41,180
what's cool about this one this is such

819
00:37:47,710 --> 00:37:44,570
a strong bar this is like really strong

820
00:37:50,290 --> 00:37:47,720
and it's actually kind of similar to the

821
00:37:51,940 --> 00:37:50,300
Milky Way's bar yeah we're gonna see in

822
00:37:58,630 --> 00:37:51,950
a few screens somebody said something

823
00:38:01,690 --> 00:37:58,640
yes oh sorry okay so let's go back here

824
00:38:03,190 --> 00:38:01,700
so bulge is like the central part if you

825
00:38:05,500 --> 00:38:03,200
think of a disk of the galaxy as a

826
00:38:07,030 --> 00:38:05,510
pancake in the middle of the pancake you

827
00:38:16,900 --> 00:38:07,040
can have like a pile of whipped cream or

828
00:38:19,930 --> 00:38:16,910
butter or I don't know spinach so that

829
00:38:22,450 --> 00:38:19,940
can take on different shapes apparent

830
00:38:23,950 --> 00:38:22,460
shapes depending on the dynamics and the

831
00:38:26,950 --> 00:38:23,960
gravity and the interactions of

832
00:38:28,900 --> 00:38:26,960
neighboring galaxies and sometimes it's

833
00:38:33,300 --> 00:38:28,910
just a big blob in the middle like in

834
00:38:36,630 --> 00:38:33,310
these or in fact like right here and

835
00:38:41,740 --> 00:38:36,640
sometimes you end up with a barred shape

836
00:38:43,180 --> 00:38:41,750
like this in different contexts and it

837
00:38:45,670 --> 00:38:43,190
really depends on the history of the

838
00:38:49,240 --> 00:38:45,680

interaction so I'll get to that soon but

839
00:38:53,110 --> 00:38:49,250
thank you for asking that all right

840
00:38:55,240 --> 00:38:53,120
where we were on this one and okay so we

841
00:38:57,970 --> 00:38:55,250
didn't we didn't always know if the

842
00:39:03,550 --> 00:38:57,980
Milky Way's Bulge was a Bart shaped like

843
00:39:07,930 --> 00:39:03,560
a bar like this right or if it was

844
00:39:10,540 --> 00:39:07,940
shaped as a spheroid like this it's hard

845
00:39:12,700 --> 00:39:10,550
to guess and you go back thirty years

846
00:39:15,430 --> 00:39:12,710
and everything was less precise and it

847
00:39:20,050 --> 00:39:15,440
was less data the first really good

848
00:39:21,730 --> 00:39:20,060
evidence came from Stan akin all 1994

849
00:39:24,310 --> 00:39:21,740
Chris Stanek then he was a graduate

850
00:39:26,920 --> 00:39:24,320
student at Princeton and imagine that

851
00:39:29,410 --> 00:39:26,930
we're in this artist rendition if you

852
00:39:32,020 --> 00:39:29,420
look at the stars here and then you look

853
00:39:34,540 --> 00:39:32,030
at the stars here the ones that are here

854
00:39:37,330 --> 00:39:34,550
because they're closer are going to be

855
00:39:40,390 --> 00:39:37,340
brighter let's say they're like thirty

856
00:39:42,100 --> 00:39:40,400
percent after twenty percent closer then

857
00:39:46,300 --> 00:39:42,110
there'll be about forty percent brighter

858
00:39:47,000 --> 00:39:46,310
and that's what he found when he looked

859
00:39:59,480 --> 00:39:47,010
at

860
00:40:04,130 --> 00:39:59,490
stars are slightly brighter over here

861
00:40:06,050 --> 00:40:04,140
than over here and from that he infer he

862
00:40:08,960 --> 00:40:06,060
called it evidence for the Galactic Bar

863
00:40:11,420 --> 00:40:08,970

this was done of Polish astronomers here

864
00:40:13,400 --> 00:40:11,430
I show a photo of him it's an

865
00:40:15,080 --> 00:40:13,410
interesting anecdote about the referee

866
00:40:16,880 --> 00:40:15,090
process in science this was somewhat

867
00:40:19,070 --> 00:40:16,890
controversial people thought the Milky

868
00:40:22,220 --> 00:40:19,080
Way had more of a balls like this a

869
00:40:24,590 --> 00:40:22,230
spheroid and I think the first referee

870
00:40:27,470 --> 00:40:24,600
either challenged it or rejected the

871
00:40:29,570 --> 00:40:27,480
paper he said you cannot submit a paper

872
00:40:35,290 --> 00:40:29,580
on the evidence for the Galactic Bar

873
00:40:38,300 --> 00:40:35,300
because there is no Galactic bar so ok

874
00:40:39,740 --> 00:40:38,310
the process of peer review which we hear

875
00:40:42,800 --> 00:40:39,750
about in the media in the newspaper

876
00:40:46,040 --> 00:40:42,810
sometimes is making science sacred it's

877
00:40:48,830 --> 00:40:46,050
really good it does help things but it's

878
00:40:51,950 --> 00:40:48,840
not perfect something that helps in

879
00:40:55,040 --> 00:40:51,960
general will have instances where it

880
00:40:57,980 --> 00:40:55,050
either helps something bad or blocks

881
00:41:00,020 --> 00:40:57,990
something good though in this case they

882
00:41:02,840 --> 00:41:00,030
were able to get to another referee and

883
00:41:04,430 --> 00:41:02,850
that's fine you do get second chances

884
00:41:07,820 --> 00:41:04,440
because it's realized that this can

885
00:41:11,210 --> 00:41:07,830
happen but you know that was kind of a

886
00:41:13,040 --> 00:41:11,220
course image that static God right he

887
00:41:14,750 --> 00:41:13,050
said evidence for the Galactic Bar

888
00:41:17,270 --> 00:41:14,760

that's great but if we want to know what

889
00:41:19,220 --> 00:41:17,280
the Milky Way looks like right we need a

890
00:41:21,200 --> 00:41:19,230
lot more than evidence right I mean both

891
00:41:24,500 --> 00:41:21,210
of these have evidence they're different

892
00:41:27,470 --> 00:41:24,510
which one's the accurate representation

893
00:41:29,510 --> 00:41:27,480
we'd like to know and one thing that's

894
00:41:32,840 --> 00:41:29,520
helped is the improvements in CCD

895
00:41:35,120 --> 00:41:32,850
technology I remember when digital

896
00:41:37,190 --> 00:41:35,130
cameras first went on sale or maybe when

897
00:41:40,760 --> 00:41:37,200
ii went on sale at prime that's at first

898
00:41:42,620 --> 00:41:40,770
you had like 3 or 4 megapixels and that

899
00:41:47,630 --> 00:41:42,630
was good and it was like five hundred

900
00:41:49,370 --> 00:41:47,640
dollars no now you could get i don't

901
00:41:51,920 --> 00:41:49,380
even know what it's up to now maybe like

902
00:41:55,280 --> 00:41:51,930
20 megapixels for $200 or something it's

903
00:41:57,970 --> 00:41:55,290
just improved very rapidly and the same

904
00:41:59,480 --> 00:41:57,980
thing is true of astronomy observatories

905
00:42:07,040 --> 00:41:59,490
the

906
00:42:09,800 --> 00:42:07,050
Stanek used was five megapixels it was

907
00:42:13,160 --> 00:42:09,810
from me the Warsaw observatory located

908
00:42:14,420 --> 00:42:13,170
in Chile in South America a few hours

909
00:42:16,910 --> 00:42:14,430
north of Santiago

910
00:42:18,170 --> 00:42:16,920
now we regularly use cameras and

911
00:42:22,520 --> 00:42:18,180
astronomy that are a few hundred

912
00:42:26,810 --> 00:42:22,530
megapixels this is a CCD charge-coupled

913
00:42:30,140 --> 00:42:26,820

device a single one of these has more

914
00:42:31,760 --> 00:42:30,150
pixels on it actually this is the CCD

915
00:42:33,350 --> 00:42:31,770
charge-coupled device you see there's

916
00:42:34,790 --> 00:42:33,360
many of them together it's hollow many

917
00:42:37,010 --> 00:42:34,800
of them together because it's easier to

918
00:42:40,250 --> 00:42:37,020
do it that way than to make one big one

919
00:42:43,100 --> 00:42:40,260
and a single one of these has more

920
00:42:44,840 --> 00:42:43,110
pixels on it than the camera that was

921
00:42:46,640 --> 00:42:44,850
used to confirm the existence to the bar

922
00:42:49,040 --> 00:42:46,650
in the 1990s it's really improved

923
00:42:51,530 --> 00:42:49,050
rapidly and here we have an image of the

924
00:42:53,600 --> 00:42:51,540
sky here it's great and then there's

925
00:42:57,590 --> 00:42:53,610
another coincidence that as much as

926
00:43:01,040 --> 00:42:57,600
cameras have gotten bigger right at

927
00:43:03,130 --> 00:43:01,050
about the same speed hard drives have

928
00:43:06,080 --> 00:43:03,140
gone in bigger as well right I remember

929
00:43:07,990 --> 00:43:06,090
playing computer games and their 90s if

930
00:43:10,400 --> 00:43:08,000
you wanted to play one game

931
00:43:14,120 --> 00:43:10,410
you'd have to delete the other game

932
00:43:16,700 --> 00:43:14,130
first hard drives are really small and I

933
00:43:23,090 --> 00:43:16,710
think the teenagers here have any of you

934
00:43:25,700 --> 00:43:23,100
ever done that Wow okay well I had to do

935
00:43:26,560 --> 00:43:25,710
that all the time and you know climbing

936
00:43:29,660 --> 00:43:26,570
back here

937
00:43:32,720 --> 00:43:29,670
imagine CCDs had grown much much faster

938
00:43:34,099 --> 00:43:32,730

than hard drives that would totally suck

939
00:43:36,170 --> 00:43:34,109
for astronomy because we would take

940
00:43:38,270 --> 00:43:36,180
these great pictures and we wouldn't be

941
00:43:41,270 --> 00:43:38,280
able to store it ok so there's like 100

942
00:43:44,450 --> 00:43:41,280
times more data now and people have used

943
00:43:48,760 --> 00:43:44,460
it properly and this is from Christopher

944
00:43:54,349 --> 00:43:48,770
Wegg who did a postdoc in Germany and

945
00:43:56,240 --> 00:43:54,359
but grew up in the UK and it's a deep

946
00:43:58,670 --> 00:43:56,250
rejected model so same methodology of

947
00:44:01,210 --> 00:43:58,680
static slightly more sophisticated but

948
00:44:04,160 --> 00:44:01,220
just hundreds of times more data and

949
00:44:05,840 --> 00:44:04,170
this is a deep rejected model this is

950
00:44:09,200 --> 00:44:05,850
what the Milky Way's bar would look like

951
00:44:11,780 --> 00:44:09,210
face on this is what it look like slide

952
00:44:12,890 --> 00:44:11,790
on and this is kind of what it looks

953
00:44:18,230 --> 00:44:12,900
like

954
00:44:21,019 --> 00:44:18,240
from the Sun what happens is here okay

955
00:44:23,150 --> 00:44:21,029
so if the Sun is here we see this and

956
00:44:25,970 --> 00:44:23,160
then like this side here is taller than

957
00:44:28,339 --> 00:44:25,980
that side because it's closer but this

958
00:44:30,170 --> 00:44:28,349
here the second image is what you would

959
00:44:31,849 --> 00:44:30,180
see if you were living right here if the

960
00:44:33,529 --> 00:44:31,859
Sun was there it see both sides

961
00:44:36,140 --> 00:44:33,539
symmetrically and it kind of has like an

962
00:44:39,680 --> 00:44:36,150
X shape or a peanut shape it's a really

963
00:44:42,890 --> 00:44:39,690

remarkable image in 20 years we've gone

964
00:44:45,559 --> 00:44:42,900
from rejecting papers that said that the

965
00:44:49,130 --> 00:44:45,569
galaxy might have a bar to having a

966
00:44:51,289 --> 00:44:49,140
really precisely projection of what the

967
00:44:53,870 --> 00:44:51,299
bar looks like I think that's a great

968
00:44:55,999 --> 00:44:53,880
achievement and then you might be say

969
00:44:57,799 --> 00:44:56,009
okay that's from a model there's a lot

970
00:44:59,420 --> 00:44:57,809
of analysis going on

971
00:45:01,099 --> 00:44:59,430
I don't trust it's too complicated

972
00:45:04,370 --> 00:45:01,109
computer models will give you whatever

973
00:45:06,170 --> 00:45:04,380
you want okay well sometimes true in

974
00:45:09,440 --> 00:45:06,180
this case I don't agree because I know

975
00:45:13,660 --> 00:45:09,450
what went into the model but here is an

976
00:45:16,039 --> 00:45:13,670
image not taken in the near-infrared

977
00:45:20,059 --> 00:45:16,049
data like this but from mid-infrared

978
00:45:22,759 --> 00:45:20,069
data like that so maybe 5,000 nanometers

979
00:45:24,559 --> 00:45:22,769
or light that's about eight times longer

980
00:45:27,559 --> 00:45:24,569
than the reddest lights that we can see

981
00:45:30,769 --> 00:45:27,569
and at those wavelengths thus there's

982
00:45:34,940 --> 00:45:30,779
almost nothing and young stars don't

983
00:45:38,630 --> 00:45:34,950
contribute much so we only see sorry we

984
00:45:41,599 --> 00:45:38,640
only see old red stars and if you look

985
00:45:45,519 --> 00:45:41,609
at in those image the Milky Way has an X

986
00:45:47,960 --> 00:45:45,529
shape in its bar when if you slide on

987
00:45:49,160 --> 00:45:47,970
which is very very prominent I don't

988
00:45:50,390 --> 00:45:49,170

know if you guys could see it because

989
00:45:52,299 --> 00:45:50,400
there's a lot of light in this room can

990
00:45:54,559 --> 00:45:52,309
you guys see that there's an X in here

991
00:45:59,120 --> 00:45:54,569
okay great

992
00:46:02,749 --> 00:45:59,130
oh okay actually there's this better

993
00:46:05,059 --> 00:46:02,759
image here and you see like the disc

994
00:46:07,700 --> 00:46:05,069
right I said it was thin earlier look at

995
00:46:10,519 --> 00:46:07,710
how thin that is relative to its length

996
00:46:18,380 --> 00:46:10,529
right it's like 50 times longer than its

997
00:46:20,239 --> 00:46:18,390
tall that is a type of a class of orbits

998
00:46:21,920 --> 00:46:20,249
happening so the X you might think it's

999
00:46:24,049 --> 00:46:21,930
one thing it's actually two things I'm

1000
00:46:26,390 --> 00:46:24,059
gonna try and hold my hand really steady

1001
00:46:29,720 --> 00:46:26,400
over here to get this right you've got

1002
00:46:31,549 --> 00:46:29,730
some orbits that are like this right and

1003
00:46:34,460 --> 00:46:31,559
then you've got some other orbits that

1004
00:46:35,900 --> 00:46:34,470
are like this and they're even there's

1005
00:46:37,640 --> 00:46:35,910
an even number of them because the

1006
00:46:39,769 --> 00:46:37,650
galaxy is symmetric between the north

1007
00:46:45,529 --> 00:46:39,779
and south and when you view them

1008
00:46:48,799 --> 00:46:45,539
together you end up with an X in

1009
00:46:51,589 --> 00:46:48,809
combination and now that's an

1010
00:46:52,010 --> 00:46:51,599
explanation but why do we care I'll

1011
00:46:54,700 --> 00:46:52,020
answer

1012
00:47:02,829 --> 00:46:54,710
oh sorry do you want to ask something

1013
00:47:16,069 --> 00:47:13,190

that is I think so that's a very good

1014
00:47:18,079 --> 00:47:16,079
question actually I think it kind of

1015
00:47:21,769 --> 00:47:18,089
looks like a funnel but like a weak one

1016
00:47:26,299 --> 00:47:21,779
in the middle of it and then as you move

1017
00:47:29,329 --> 00:47:26,309
to the side there isn't going on here

1018
00:47:31,490 --> 00:47:29,339
it's okay sorry I'm not sure actually

1019
00:47:40,039 --> 00:47:31,500
but that's that's actually a very good

1020
00:47:41,750 --> 00:47:40,049
question yes they come in a variety

1021
00:47:44,180 --> 00:47:41,760
there actually so some of them are

1022
00:47:46,789 --> 00:47:44,190
circular or elliptical Ammar completely

1023
00:47:49,309 --> 00:47:46,799
chaotic I I don't have pictures of balls

1024
00:47:50,960 --> 00:47:49,319
orbits in here why are give an

1025
00:47:53,870 --> 00:47:50,970
explanation of why orbits are

1026
00:47:56,750 --> 00:47:53,880
complicated in the solar system orbits

1027
00:47:59,660 --> 00:47:56,760
are circle circle sorry they're circles

1028
00:48:01,609 --> 00:47:59,670
or ellipses and the reason that

1029
00:48:03,829 --> 00:48:01,619
simplicity happens is that no matter

1030
00:48:08,059 --> 00:48:03,839
where you are in the solar system all of

1031
00:48:10,190 --> 00:48:08,069
the mass is within you because 99.9% of

1032
00:48:12,289 --> 00:48:10,200
the mass is due to the Sun but in a

1033
00:48:14,859 --> 00:48:12,299
galaxy let's say you start off on an

1034
00:48:17,329 --> 00:48:14,869
eccentric orbit as you move outwards

1035
00:48:19,010 --> 00:48:17,339
then there's more mass within you

1036
00:48:21,799 --> 00:48:19,020
there's no point mass at the center it's

1037
00:48:23,420 --> 00:48:21,809
a distribution of mass and that causes

1038
00:48:29,240 --> 00:48:23,430

the orbits to take on really weird

1039
00:48:31,640 --> 00:48:29,250
shapes really good question - so I

1040
00:48:33,589 --> 00:48:31,650
notice why do we care that there's an X

1041
00:48:37,460 --> 00:48:33,599
I show three different things here this

1042
00:48:39,500 --> 00:48:37,470
is NGC 4710 another similar galaxy with

1043
00:48:41,600 --> 00:48:39,510
a very strong X

1044
00:48:43,460 --> 00:48:41,610
this is the D projection shown below and

1045
00:48:46,130 --> 00:48:43,470
this is an n body simulation with like

1046
00:48:50,050 --> 00:48:46,140
500,000 particles that evolve and we see

1047
00:48:52,780 --> 00:48:50,060
that an X emerges in the bar over time

1048
00:48:56,060 --> 00:48:52,790
so bars are kind of generic in

1049
00:48:58,460 --> 00:48:56,070
simulations of galaxy formation pretty

1050
00:49:02,300 --> 00:48:58,470
much anything can form a bar but

1051
00:49:05,660 --> 00:49:02,310
typically to have a very strong X not

1052
00:49:10,130 --> 00:49:05,670
always but usually you need to have a

1053
00:49:12,290 --> 00:49:10,140
very quiet galaxy if you have a merger

1054
00:49:15,860 --> 00:49:12,300
it'll jumble up the orbits and you'll

1055
00:49:18,350 --> 00:49:15,870
get a spheroid usually and so for the X

1056
00:49:20,930 --> 00:49:18,360
in the Milky Way to be so strong that

1057
00:49:22,790 --> 00:49:20,940
means that there probably hasn't been a

1058
00:49:26,930 --> 00:49:22,800
major merger in a long time do you have

1059
00:49:30,020 --> 00:49:26,940
your hand up okay all right so that's

1060
00:49:32,630 --> 00:49:30,030
the global picture of the bar it solved

1061
00:49:35,210 --> 00:49:32,640
that I think that's really cool what's

1062
00:49:37,430 --> 00:49:35,220
not solved well the detailed picture is

1063
00:49:40,190 --> 00:49:37,440

not solved if you look at all the stars

1064
00:49:42,290 --> 00:49:40,200
together there's an X but if you break

1065
00:49:46,370 --> 00:49:42,300
up the Stars into different ethnicities

1066
00:49:49,520 --> 00:49:46,380
let's say they're really so at the

1067
00:49:51,590 --> 00:49:49,530
metal-rich stars that yeah it's pretty

1068
00:49:54,170 --> 00:49:51,600
prominent this is an analysis done by

1069
00:49:56,120 --> 00:49:54,180
Matt apartheid he was a graduate student

1070
00:49:58,340 --> 00:49:56,130
in Germany where the brilliant thesis

1071
00:50:00,140 --> 00:49:58,350
but for more metal-poor stars the ones

1072
00:50:01,850 --> 00:50:00,150
that are more metal form in a Sun it's

1073
00:50:05,180 --> 00:50:01,860
much weaker it's still there but it's

1074
00:50:09,200 --> 00:50:05,190
far weaker and you might wonder why that

1075
00:50:10,250 --> 00:50:09,210
is and the answer is don't know that's

1076
00:50:15,440 --> 00:50:10,260
the next step

1077
00:50:17,380 --> 00:50:15,450
in bolts research ok part 3 the ages of

1078
00:50:20,090 --> 00:50:17,390
all stars

1079
00:50:23,060 --> 00:50:20,100
so galactic archaeology and the

1080
00:50:25,160 --> 00:50:23,070
challenge of age dating I used that term

1081
00:50:27,500 --> 00:50:25,170
before so historical archaeology has

1082
00:50:30,440 --> 00:50:27,510
been revolutionized by carbon dating

1083
00:50:32,240 --> 00:50:30,450
methods no such luck for galactic

1084
00:50:34,910 --> 00:50:32,250
archaeology we're not successful at

1085
00:50:36,470 --> 00:50:34,920
least so far when we estimate the ages

1086
00:50:39,260 --> 00:50:36,480
of stars to try and figure out which

1087
00:50:42,350 --> 00:50:39,270
group of stars came first for usually

1088
00:50:45,680 --> 00:50:42,360

off by like 10 or 15% unfortunately and

1089
00:50:48,980 --> 00:50:45,690
that and often more actually I think 10%

1090
00:50:51,440 --> 00:50:48,990
is an optimistic estimate of the error

1091
00:50:53,230 --> 00:50:51,450
in estimating the ages of stars because

1092
00:50:55,900 --> 00:50:53,240
there's no equivalent to carbon dating

1093
00:50:57,520 --> 00:50:55,910
that could give you a 1% age and you

1094
00:50:59,859 --> 00:50:57,530
might imagine that we'd have more

1095
00:51:02,770 --> 00:50:59,869
uncertainty in our books on the history

1096
00:51:05,200 --> 00:51:02,780
of civilization if we didn't know who

1097
00:51:07,060 --> 00:51:05,210
came first we might be able to

1098
00:51:10,900 --> 00:51:07,070
reconstruct it from improvements in

1099
00:51:15,010 --> 00:51:10,910
pottery or written history when we have

1100
00:51:17,020 --> 00:51:15,020
it but sometimes it wouldn't be all

1101
00:51:20,710 --> 00:51:17,030
right so the first evidence that the

1102
00:51:24,790 --> 00:51:20,720
Stars and the balls were older came from

1103
00:51:26,440 --> 00:51:24,800
Nassau and Blanco they looked at red

1104
00:51:28,300 --> 00:51:26,450
variables towards the center of the

1105
00:51:31,620 --> 00:51:28,310
Milky Way and they found that those

1106
00:51:34,600 --> 00:51:31,630
variables had shorter periods of

1107
00:51:37,359 --> 00:51:34,610
oscillation so typically they or they

1108
00:51:40,120 --> 00:51:37,369
they so these are variables they get

1109
00:51:42,010 --> 00:51:40,130
bigger bigger bigger smaller smaller

1110
00:51:44,140 --> 00:51:42,020
smaller bigger bigger bigger smaller

1111
00:51:45,430 --> 00:51:44,150
smaller smaller big differences in

1112
00:51:47,830 --> 00:51:45,440
variations it could be two or three

1113
00:51:50,530 --> 00:51:47,840

times brighter at the end the periods

1114
00:51:52,060 --> 00:51:50,540
were like a couple hundred days and in

1115
00:51:54,160 --> 00:51:52,070
the solar neighborhood we get such

1116
00:51:57,520 --> 00:51:54,170
within like a thousand light years at a

1117
00:51:59,590 --> 00:51:57,530
Sun we get such variables but we also

1118
00:52:03,970 --> 00:51:59,600
get variables that take thousands of

1119
00:52:06,400 --> 00:52:03,980
days to oscillate and so they observed

1120
00:52:09,550 --> 00:52:06,410
that difference and they didn't and they

1121
00:52:13,109 --> 00:52:09,560
actually did not know that this was due

1122
00:52:15,010 --> 00:52:13,119
to an age effect but it's the first

1123
00:52:17,349 --> 00:52:15,020
within the literature it's when the

1124
00:52:19,300 --> 00:52:17,359
first statements that's explicitly

1125
00:52:20,980 --> 00:52:19,310
written down which now with what we know

1126
00:52:23,349 --> 00:52:20,990
now about astronomy and how in variable

1127
00:52:26,260 --> 00:52:23,359
stars can be interpreted as new to an

1128
00:52:28,480 --> 00:52:26,270
age difference a distribution and a

1129
00:52:31,720 --> 00:52:28,490
difference in the distribution of Ages

1130
00:52:36,570 --> 00:52:31,730
in the galaxy okay I'm gonna skip this

1131
00:52:39,070 --> 00:52:36,580
and this actually so how do we know that

1132
00:52:42,099 --> 00:52:39,080
stars in the center of the galaxy are

1133
00:52:44,890 --> 00:52:42,109
older there's a few arguments probably

1134
00:52:46,210 --> 00:52:44,900
the the strongest argument I think is

1135
00:52:48,910 --> 00:52:46,220
this one which has been through many

1136
00:52:52,540 --> 00:52:48,920
iterations but it was done really really

1137
00:52:55,240 --> 00:52:52,550
well by my noella luckily she is an

1138
00:52:57,880 --> 00:52:55,250

Italian astronomer who now works in

1139
00:53:02,050 --> 00:52:57,890
Chile in South America and she's

1140
00:53:03,490 --> 00:53:02,060
probably contributed either the most or

1141
00:53:06,310 --> 00:53:03,500
among the most that people have

1142
00:53:07,330 --> 00:53:06,320
contributed to this field in the past 20

1143
00:53:08,530 --> 00:53:07,340
years

1144
00:53:12,760 --> 00:53:08,540
and so now we're going to look at

1145
00:53:14,890 --> 00:53:12,770
distributions of stars this is stars in

1146
00:53:18,520 --> 00:53:14,900
the solar neighborhood so you got

1147
00:53:21,670 --> 00:53:18,530
brightness here and color here we have

1148
00:53:26,710 --> 00:53:21,680
faint red stars we have bright red stars

1149
00:53:30,190 --> 00:53:26,720
and we have bright blue stars right now

1150
00:53:33,100 --> 00:53:30,200
in the balls faint red stars bright red

1151
00:53:36,820 --> 00:53:33,110
stars and four bright blue stars there's

1152
00:53:41,010 --> 00:53:36,830
nothing can anybody tell me why there

1153
00:53:44,350 --> 00:53:41,020
are no bright blue stars there yes

1154
00:53:47,440 --> 00:53:44,360
that's right so bright blue stars those

1155
00:53:51,130 --> 00:53:47,450
are a really massive stars they don't

1156
00:53:55,000 --> 00:53:51,140
live a long life right so they die

1157
00:53:57,100 --> 00:53:55,010
within like hundreds of millions of

1158
00:53:59,710 --> 00:53:57,110
years and there's just very few of them

1159
00:54:04,470 --> 00:53:59,720
in the Bulge just might be a sprinkling

1160
00:54:08,380 --> 00:54:04,480
of them but it's a tiny amount and so

1161
00:54:09,970 --> 00:54:08,390
right there's a shortage of younger

1162
00:54:11,260 --> 00:54:09,980
stars I'll skip those cool actually this

1163
00:54:14,080 --> 00:54:11,270

is just meant to show that there was a

1164
00:54:16,720 --> 00:54:14,090
consensus from various experts I'll just

1165
00:54:20,170 --> 00:54:16,730
quote mine wallows locally there since I

1166
00:54:22,720 --> 00:54:20,180
showed her work the Balch age which was

1167
00:54:24,370 --> 00:54:22,730
found to be as large of that as the

1168
00:54:27,010 --> 00:54:24,380
Galactic globular clusters were at least

1169
00:54:30,310 --> 00:54:27,020
10 billion years old so twice as old as

1170
00:54:32,860 --> 00:54:30,320
the Sun no train no trace sorry

1171
00:54:36,580 --> 00:54:32,870
not not no train it's found for any

1172
00:54:40,270 --> 00:54:36,590
younger stellar population here's a more

1173
00:54:43,450 --> 00:54:40,280
recent analysis it's a histogram done by

1174
00:54:45,640 --> 00:54:43,460
astronomers based in Sweden they use the

1175
00:54:49,720 --> 00:54:45,650
same method to look at stars near the

1176
00:54:52,690 --> 00:54:49,730
Sun here and in the Bulge here and four

1177
00:54:54,700 --> 00:54:52,700
stars near the Sun they find all ages

1178
00:54:56,770 --> 00:54:54,710
their stars of all ages which has been

1179
00:54:59,260 --> 00:54:56,780
known for a very long time but the most

1180
00:55:01,540 --> 00:54:59,270
common age is four and a half billion

1181
00:55:03,190 --> 00:55:01,550
years do you guys can think you guys

1182
00:55:05,430 --> 00:55:03,200
think of another star that's about

1183
00:55:08,680 --> 00:55:05,440
four-and-a-half billion years old

1184
00:55:10,690 --> 00:55:08,690
yeah so that's another coincidence here

1185
00:55:13,690 --> 00:55:10,700
the Sun is very typical in metallicity

1186
00:55:16,210 --> 00:55:13,700
as I mentioned earlier and it's also

1187
00:55:19,630 --> 00:55:16,220
very typical in age of the stars near it

1188
00:55:20,980 --> 00:55:19,640

it's kind of weird and for the Bulge

1189
00:55:22,930 --> 00:55:20,990
they also see

1190
00:55:25,660 --> 00:55:22,940
stars of all ages the sample is smaller

1191
00:55:30,010 --> 00:55:25,670
because it's hard harder to measure

1192
00:55:32,710 --> 00:55:30,020
those stars but there isn't as big a

1193
00:55:58,600 --> 00:55:32,720
peak at 4 Giga years it's kind of like

1194
00:56:02,950 --> 00:55:58,610
flat from 4 to 12 yes sorry can you see

1195
00:56:06,750 --> 00:56:02,960
that again oh they wouldn't have time to

1196
00:56:09,100 --> 00:56:06,760
move out for a star in a typical orbit

1197
00:56:11,710 --> 00:56:09,110
it would take several hundred million

1198
00:56:13,450 --> 00:56:11,720
years well for a Sun for example it

1199
00:56:16,090 --> 00:56:13,460
takes 200 million years to go around the

1200
00:56:17,800 --> 00:56:16,100
galaxy and that's a small and then it

1201
00:56:19,330 --> 00:56:17,810
ends up at the same spot right if you

1202
00:56:21,910 --> 00:56:19,340
want a big change you'll need a lot more

1203
00:56:24,310 --> 00:56:21,920
time than that so relative to the

1204
00:56:31,510 --> 00:56:24,320
lifetime of a blue star that's actually

1205
00:56:37,000 --> 00:56:31,520
pretty big now okay I get it

1206
00:56:39,609 --> 00:56:37,010
thank you so originally there was a lot

1207
00:56:42,040 --> 00:56:39,619
of gas there and the center of the

1208
00:56:44,740 --> 00:56:42,050
galaxy I think that's what you said had

1209
00:56:46,330 --> 00:56:44,750
a higher density of gas and it does

1210
00:56:49,930 --> 00:56:46,340
happen that when you have a higher

1211
00:56:52,540 --> 00:56:49,940
density of gas physically it gets

1212
00:56:55,210 --> 00:56:52,550
converted to stars much more efficiently

1213
00:56:58,150 --> 00:56:55,220

the more gas you have if you have like

1214
00:57:00,490 --> 00:56:58,160
three times as much gas you might form 9

1215
00:57:02,920 --> 00:57:00,500
times as many stars in a certain amount

1216
00:57:04,980 --> 00:57:02,930
of time so you do run out of gas more

1217
00:57:08,140 --> 00:57:04,990
rapidly once you run out of gas you

1218
00:57:10,150 --> 00:57:08,150
can't form stars anymore there's other

1219
00:57:16,780 --> 00:57:10,160
ways to stop forming stars but that's

1220
00:57:19,450 --> 00:57:16,790
the simplest one and all right so

1221
00:57:21,970 --> 00:57:19,460
perhaps the ages are even older I want

1222
00:57:24,160 --> 00:57:21,980
it to stop there but there was a wrinkle

1223
00:57:26,830 --> 00:57:24,170
published today and so I decided to add

1224
00:57:33,009 --> 00:57:26,840
it because it does inform our science we

1225
00:57:37,149 --> 00:57:35,259
and it's kind of flats between 4 and 12

1226
00:57:39,789 --> 00:57:37,159
Giga years right so there's already a

1227
00:57:42,159 --> 00:57:39,799
story and that it's different than what

1228
00:57:45,489 --> 00:57:42,169
we have near the Sun but how different

1229
00:57:47,019 --> 00:57:45,499
and it might be even more different than

1230
00:57:50,259 --> 00:57:47,029
they think and I happen to agree

1231
00:57:52,120 --> 00:57:50,269
personally there was a new analysis that

1232
00:57:53,739 --> 00:57:52,130
came out I think it was yesterday or the

1233
00:57:55,989 --> 00:57:53,749
day before not not yesterday I have

1234
00:57:58,299 --> 00:57:55,999
Friday or Thursday by an Italian

1235
00:57:59,889 --> 00:57:58,309
astronomer alveolar and Zini Italians

1236
00:58:01,659 --> 00:57:59,899
have contributed a lot to astronomy and

1237
00:58:06,039 --> 00:58:01,669
particularly this to this astronomy of

1238
00:58:09,159 --> 00:58:06,049

the galaxy and he says stars that are

1239
00:58:12,279 --> 00:58:09,169
less than 5 billion years old exist in

1240
00:58:15,669 --> 00:58:12,289
at most a trace amounts or not at all no

1241
00:58:18,549 --> 00:58:15,679
more than 3% of the stars and this

1242
00:58:21,699 --> 00:58:18,559
contradicts this image who's right who's

1243
00:58:24,639 --> 00:58:21,709
wrong so I think that they're wrong and

1244
00:58:27,159 --> 00:58:24,649
he's right but I cannot prove it right

1245
00:58:29,729 --> 00:58:27,169
now it's an ongoing controversy and

1246
00:58:34,569 --> 00:58:29,739
people have been going back and forth on

1247
00:58:36,099 --> 00:58:34,579
this controversy for a few years so

1248
00:58:39,339 --> 00:58:36,109
conclusions asked to the

1249
00:58:43,689 --> 00:58:39,349
characterization of the Bulge right I

1250
00:58:46,749 --> 00:58:43,699
should have brought more water sorry the

1251
00:58:49,359 --> 00:58:46,759
ball stars have a broad range in metals

1252
00:58:51,549 --> 00:58:49,369
abundance you know or you have stars

1253
00:58:54,099 --> 00:58:51,559
with very few metals stars and are like

1254
00:58:56,620 --> 00:58:54,109
the Sun and stars that have four or five

1255
00:58:59,979 --> 00:58:56,630
times more metals in the Sun it's a big

1256
00:59:01,749 --> 00:58:59,989
range and the typical value is about the

1257
00:59:04,809 --> 00:59:01,759
same iron to hydrogen ratio as a Sun

1258
00:59:06,909 --> 00:59:04,819
which is a cool coincidence but they

1259
00:59:10,689 --> 00:59:06,919
have somewhat more oxygen silicon

1260
00:59:14,379 --> 00:59:10,699
calcium relative to iron then the Sun

1261
00:59:16,989 --> 00:59:14,389
has almost all the stars in the Bulge

1262
00:59:19,419 --> 00:59:16,999
are distributed as an exceptionally

1263
00:59:21,579 --> 00:59:19,429

strong bar and my exceptionally strong I

1264
00:59:24,689 --> 00:59:21,589
mean relative to other spiral galaxies

1265
00:59:27,519 --> 00:59:24,699
in the sky half of spirals have bars

1266
00:59:29,620 --> 00:59:27,529
approximately but already it's stronger

1267
00:59:31,719 --> 00:59:29,630
than half of them but even among the

1268
00:59:34,120 --> 00:59:31,729
half that have bars very few of them

1269
00:59:36,249 --> 00:59:34,130
have a bar which is as strong as the

1270
00:59:38,649 --> 00:59:36,259
Milky Way's bar it's not clear why that

1271
00:59:40,659 --> 00:59:38,659
is on the one hand I've been telling you

1272
00:59:42,309 --> 00:59:40,669
that the Sun is typical within the Milky

1273
00:59:45,549 --> 00:59:42,319
Way but on the other hand the Milky Way

1274
00:59:46,599 --> 00:59:45,559
is a typical among galaxies should we

1275
00:59:49,660 --> 00:59:46,609
interpret that

1276
00:59:51,579 --> 00:59:49,670
or should we not I'm not sure and this

1277
00:59:53,589 --> 00:59:51,589
effect is strongest among the most

1278
00:59:54,999 --> 00:59:53,599
metal-rich stars it does suggest that

1279
01:00:00,999 --> 00:59:55,009
there hasn't been a merger here in a

1280
01:00:04,289 --> 01:00:01,009
long time a merger of galaxies and the

1281
01:00:10,210 --> 01:00:04,299
stars in the Bulge are typically older

1282
01:00:34,329 --> 01:00:10,220
than most of the stars near the Sun all

1283
01:00:36,729 --> 01:00:34,339
right that's all thank you yes okay so

1284
01:00:38,170 --> 01:00:36,739
the question is what is in the center of

1285
01:00:40,960 --> 01:00:38,180
the galaxy that causes everything to

1286
01:00:43,559 --> 01:00:40,970
spin around it yeah I'm just repeating

1287
01:00:47,920 --> 01:00:43,569
questions for the online audience there

1288
01:00:51,370 --> 01:00:47,930

so okay why do galaxies spin and have

1289
01:00:52,479 --> 01:00:51,380
angular momentum so if you spin

1290
01:00:55,779 --> 01:00:52,489
something on earth

1291
01:00:59,170 --> 01:00:55,789
it'll stop spinning do the drag but if

1292
01:01:04,239 --> 01:00:59,180
you spin something in space it will keep

1293
01:01:06,789 --> 01:01:04,249
spinning forever so if you're asking why

1294
01:01:09,849 --> 01:01:06,799
does the galaxy have angular momentum

1295
01:01:11,620 --> 01:01:09,859
it's kind of a random thing some

1296
01:01:14,259 --> 01:01:11,630
galaxies have very little angular

1297
01:01:17,470 --> 01:01:14,269
momentum some have a lot in one

1298
01:01:21,009 --> 01:01:17,480
direction and some have a lot in the

1299
01:01:23,950 --> 01:01:21,019
other direction and so it just happens

1300
01:01:25,450 --> 01:01:23,960
that we live in one that has a lot in

1301
01:01:29,440 --> 01:01:25,460
its current direction but if you take

1302
01:01:33,160 --> 01:01:29,450
the sum of spin of all the galaxies it

1303
01:01:36,009 --> 01:01:33,170
has to add up to zero kurz Goodell who's

1304
01:01:37,599 --> 01:01:36,019
a mathematician who contribute a lot to

1305
01:01:39,880 --> 01:01:37,609
our understanding of logic actually

1306
01:01:43,680 --> 01:01:39,890
showed in the mid twentieth century that

1307
01:01:46,720 --> 01:01:43,690
if the universe as a whole was spinning

1308
01:01:48,880 --> 01:01:46,730
then not only would time-travel be

1309
01:01:51,430 --> 01:01:48,890
possible but it would be necessary and

1310
01:01:54,910 --> 01:01:51,440
happening all the time and we'd have

1311
01:01:56,349 --> 01:01:54,920
causal loops going on maybe that's true

1312
01:01:58,150 --> 01:01:56,359
and we don't realize it for pi the

1313
01:01:59,779 --> 01:01:58,160

universe as a whole is not spinning oh

1314
01:02:15,199 --> 01:01:59,789
yeah

1315
01:02:17,569 --> 01:02:15,209
okay so many questions so there is this

1316
01:02:19,609 --> 01:02:17,579
gentleman there was a there's a black

1317
01:02:21,829 --> 01:02:19,619
hole in the center of these galaxies how

1318
01:02:23,329 --> 01:02:21,839
does that affect the Bulge I'm sorry I

1319
01:02:24,529 --> 01:02:23,339
didn't repeat the last question thank

1320
01:02:31,729 --> 01:02:24,539
you

1321
01:02:34,309 --> 01:02:31,739
major topic of research in astronomy

1322
01:02:36,919 --> 01:02:34,319
it's probably 10% of the papers that are

1323
01:02:39,889 --> 01:02:36,929
published debating that point so I

1324
01:02:42,049 --> 01:02:39,899
cannot give you an answer I can give you

1325
01:02:45,079 --> 01:02:42,059
some of the answers that people have

1326
01:02:48,439 --> 01:02:45,089
suggested so the Milky Way does have a

1327
01:02:51,129 --> 01:02:48,449
black hole in its center it's about four

1328
01:02:53,929 --> 01:02:51,139
million times more massive than the Sun

1329
01:02:56,599 --> 01:02:53,939
it's pretty big and it does turn out

1330
01:02:59,269 --> 01:02:56,609
that four galaxies the properties of

1331
01:03:02,049 --> 01:02:59,279
black hole are tightly correlated with

1332
01:03:04,759 --> 01:03:02,059
the properties of the galaxy as a whole

1333
01:03:07,879 --> 01:03:04,769
some people say that's a coincidence and

1334
01:03:10,669 --> 01:03:07,889
some people say that's a causal link

1335
01:03:12,979 --> 01:03:10,679
it's not clear who's right and who's

1336
01:03:15,889 --> 01:03:12,989
wrong what could be the case for example

1337
01:03:17,959 --> 01:03:15,899
is that maybe you go back to the movie

1338
01:03:20,509 --> 01:03:17,969

at the start of the prudhoe galaxies

1339
01:03:22,939 --> 01:03:20,519
merging maybe all proto galaxies

1340
01:03:25,309 --> 01:03:22,949
themselves have black holes and so when

1341
01:03:28,909 --> 01:03:25,319
they merge their black holes Cora last

1342
01:03:31,069 --> 01:03:28,919
is center and that's and so and then

1343
01:03:33,319 --> 01:03:31,079
eventually the bigger galaxies which

1344
01:03:35,209 --> 01:03:33,329
were formed from more mergers also have

1345
01:03:38,749 --> 01:03:35,219
big or black holes at their center but

1346
01:03:40,639 --> 01:03:38,759
there's huge scatter there but there

1347
01:03:43,129 --> 01:03:40,649
will be much better measurements of that

1348
01:03:44,899 --> 01:03:43,139
this year the way that's measured there

1349
01:03:46,849 --> 01:03:44,909
happens to be we're very lucky there's a

1350
01:03:50,120 --> 01:03:46,859
star that passes very close to the black

1351
01:03:53,479 --> 01:03:50,130
hole it's on an elliptical orbit and so

1352
01:03:55,309 --> 01:03:53,489
it passes closest sometime this year and

1353
01:03:55,789 --> 01:03:55,319
they're taking a lot of images of it

1354
01:03:57,589 --> 01:03:55,799
right now

1355
01:03:59,479 --> 01:03:57,599
and we'll have much more detail on the

1356
01:04:01,370 --> 01:03:59,489
black hole that will probably be one of

1357
01:04:02,599 --> 01:04:01,380
the next year's public talks it

1358
01:04:10,160 --> 01:04:02,609
certainly hope so yeah that's an

1359
01:04:15,430 --> 01:04:11,809
see how do they relate to each of it

1360
01:04:18,380 --> 01:04:15,440
this is the black hole inside the bar

1361
01:04:20,089 --> 01:04:18,390
yes how does the black hole at the

1362
01:04:21,440 --> 01:04:20,099
center of the galaxy and the bar the

1363
01:04:25,190 --> 01:04:21,450

center of the galaxy relate to each

1364
01:04:26,870 --> 01:04:25,200
other so geometrically the black hole is

1365
01:04:29,660 --> 01:04:26,880
approximately the size of the solar

1366
01:04:32,660 --> 01:04:29,670
system and it's four million times more

1367
01:04:38,059 --> 01:04:32,670
mass in the Sun it defines the center of

1368
01:04:41,420 --> 01:04:38,069
the galaxy the bar itself is not the

1369
01:04:43,519 --> 01:04:41,430
size or source system it's maybe so half

1370
01:04:47,539 --> 01:04:43,529
the length the bar as in from the middle

1371
01:04:50,539 --> 01:04:47,549
to the end is about thirteen thousand

1372
01:04:54,799 --> 01:04:50,549
light-years so it's far bigger and the

1373
01:04:57,589 --> 01:04:54,809
bar as a whole is about twenty billion

1374
01:05:01,430 --> 01:04:57,599
solar masses so it's a totally different

1375
01:05:03,589 --> 01:05:01,440
scale but the the supermassive black

1376
01:05:05,359 --> 01:05:03,599
hole should be at the center that said

1377
01:05:07,870 --> 01:05:05,369
you can always define the center of a

1378
01:05:10,549 --> 01:05:07,880
circle or the center of a square a

1379
01:05:13,370 --> 01:05:10,559
galaxy doesn't have a very precise shape

1380
01:05:16,940 --> 01:05:13,380
so this the meaning of the center isn't

1381
01:05:31,999 --> 01:05:16,950
perfect whew yes way back in the corner

1382
01:05:33,710 --> 01:05:32,009
there I say the question was you said

1383
01:05:35,359 --> 01:05:33,720
that a black hole of a supermassive

1384
01:05:36,019 --> 01:05:35,369
black hole is about the size of a solar

1385
01:05:38,210 --> 01:05:36,029
system

1386
01:05:40,249 --> 01:05:38,220
he thinks that black holes don't take up

1387
01:05:41,809 --> 01:05:40,259
any space can you clarify that

1388
01:05:45,440 --> 01:05:41,819

all right that's a very good question

1389
01:05:50,059 --> 01:05:45,450
thank you and so it depends how you

1390
01:05:54,410 --> 01:05:50,069
define it so black holes in pop culture

1391
01:05:56,599 --> 01:05:54,420
and also in a lot of physics are just a

1392
01:06:00,440 --> 01:05:56,609
single arity at the center which is

1393
01:06:03,380 --> 01:06:00,450
exactly it's a point of no space and the

1394
01:06:05,990 --> 01:06:03,390
point of infinite density another way to

1395
01:06:09,230 --> 01:06:06,000
define a black hole is in terms of an

1396
01:06:10,970 --> 01:06:09,240
event horizon and that's where if you

1397
01:06:13,249 --> 01:06:10,980
get close enough to the black hole

1398
01:06:13,579 --> 01:06:13,259
nobody is ever going to hear from you

1399
01:06:16,279 --> 01:06:13,589
again

1400
01:06:19,430 --> 01:06:16,289
and you're done it's the point of no

1401
01:06:21,410 --> 01:06:19,440
turning back and so that defines a

1402
01:06:23,150 --> 01:06:21,420
radius which for the black hole the

1403
01:06:23,740 --> 01:06:23,160
center of the galaxy is about the size

1404
01:06:27,100 --> 01:06:23,750
of the source

1405
01:06:29,140 --> 01:06:27,110
if the Sun was a black hole that radius

1406
01:06:30,880 --> 01:06:29,150
would be three kilometers I think or is

1407
01:06:33,940 --> 01:06:30,890
it one and a half kilometers I think

1408
01:06:34,900 --> 01:06:33,950
three kilometers okay the other question

1409
01:06:38,470 --> 01:06:34,910
in the back there

1410
01:06:44,260 --> 01:06:38,480
yes you so you said that starts in the

1411
01:06:46,900 --> 01:06:44,270
bolger RM in average older than those we

1412
01:06:49,900 --> 01:06:46,910
have at next door yes does that mean

1413
01:06:52,540 --> 01:06:49,910

that when in the far future when those

1414
01:06:54,580 --> 01:06:52,550
stars in the boobs will have died there

1415
01:07:03,190 --> 01:06:54,590
will be a mostly empty space in the

1416
01:07:05,350 --> 01:07:03,200
middle it'll look like empty space but

1417
01:07:09,070 --> 01:07:05,360
when stars die they leave behind

1418
01:07:12,040 --> 01:07:09,080
remnants typically called white dwarfs a

1419
01:07:15,100 --> 01:07:12,050
white dwarf might be like typically half

1420
01:07:18,520 --> 01:07:15,110
the mass of the original star but it's

1421
01:07:20,890 --> 01:07:18,530
the old core of the star and it's about

1422
01:07:24,040 --> 01:07:20,900
the size of the earth and it's very

1423
01:07:26,230 --> 01:07:24,050
faint so you'll have a bunch of dark

1424
01:07:27,670 --> 01:07:26,240
remnants and aside from the white dwarfs

1425
01:07:30,070 --> 01:07:27,680
there will be like millions or billions

1426
01:07:31,600 --> 01:07:30,080
of black holes that are much smaller

1427
01:07:33,100 --> 01:07:31,610
than a supermassive black hole at the

1428
01:07:36,370 --> 01:07:33,110
center of galaxies but still pretty big

1429
01:07:37,540 --> 01:07:36,380
so it'll look like empty space that's a

1430
01:07:39,670 --> 01:07:37,550
great question actually I'll go back to

1431
01:07:42,370 --> 01:07:39,680
the beginning oh where is it where's

1432
01:07:44,950 --> 01:07:42,380
that photo artist's rendition instead of

1433
01:07:47,170 --> 01:07:44,960
this being yellow it'll look black but

1434
01:07:55,240 --> 01:07:47,180
there will be a ton of objects down I

1435
01:08:04,090 --> 01:07:55,250
have about the same amount of mass what

1436
01:08:08,980 --> 01:08:06,640
I'm not sure if there is a precise

1437
01:08:10,900 --> 01:08:08,990
definition of the edge and I know for

1438
01:08:13,570 --> 01:08:10,910

example at a conference that I went to a

1439
01:08:16,030 --> 01:08:13,580
couple years ago they debated what is

1440
01:08:18,610 --> 01:08:16,040
the mass of the galaxy and that depends

1441
01:08:20,440 --> 01:08:18,620
how far out you go because it just keeps

1442
01:08:22,510 --> 01:08:20,450
adding more mass as you go further out

1443
01:08:24,190 --> 01:08:22,520
and eventually you're like an

1444
01:08:25,780 --> 01:08:24,200
intergalactic space and you have one

1445
01:08:27,820 --> 01:08:25,790
point that might be closer to another

1446
01:08:30,340 --> 01:08:27,830
galaxy and then you move in some other

1447
01:08:34,030 --> 01:08:30,350
direction and it's not clear there's no

1448
01:08:36,670 --> 01:08:34,040
border so in Star Trek

1449
01:08:39,820 --> 01:08:36,680
for example there's like borders and

1450
01:08:42,760 --> 01:08:39,830
interstellar space and they police them

1451
01:08:47,170 --> 01:08:42,770
or even in did anyone watch Battlestar

1452
01:08:49,630 --> 01:08:47,180
Galactica it was a Cylon armistice line

1453
01:08:52,360 --> 01:08:49,640
and that was brought back so it's like a

1454
01:08:54,610 --> 01:08:52,370
line in space but I'm not sure how that

1455
01:08:58,570 --> 01:08:54,620
would work and that'd be like a huge

1456
01:09:00,310 --> 01:08:58,580
area to patrol this audience learned a

1457
01:09:02,410 --> 01:09:00,320
few months ago the size of the

1458
01:09:04,690 --> 01:09:02,420
Federation space and Star Trek is only

1459
01:09:07,450 --> 01:09:04,700
like 200 light-years across I thought it

1460
01:09:10,450 --> 01:09:07,460
was a whole awful hundred light-years

1461
01:09:13,060 --> 01:09:10,460
it's really crazy and I would also add

1462
01:09:14,680 --> 01:09:13,070
that the edge of the galaxy is defined

1463
01:09:16,990 --> 01:09:14,690

differently by different astronomers

1464
01:09:20,080 --> 01:09:17,000
visible light astronomers might do one

1465
01:09:21,820 --> 01:09:20,090
thing h1 astronomers radio astronomers

1466
01:09:23,890 --> 01:09:21,830
would do another thing in terms of the

1467
01:09:25,660 --> 01:09:23,900
edge yeah he's right there's just a lot

1468
01:09:29,890 --> 01:09:25,670
of different variations we have a

1469
01:09:32,950 --> 01:09:29,900
question from online let's see what the

1470
01:09:37,210 --> 01:09:32,960
ramifications are two bulges colliding

1471
01:09:40,840 --> 01:09:37,220
reclining galaxies that's a great

1472
01:09:44,140 --> 01:09:40,850
question and its relevance but one of

1473
01:09:46,840 --> 01:09:44,150
the reasons it's relevant is that it may

1474
01:09:49,330 --> 01:09:46,850
happen in a few billion years here when

1475
01:09:52,320 --> 01:09:49,340
the Milky Way and Andromeda are very

1476
01:09:54,940 --> 01:09:52,330
likely to merge so it does depend on the

1477
01:09:57,700 --> 01:09:54,950
configuration that they have and whether

1478
01:09:59,200 --> 01:09:57,710
it's like head-on or just like skidding

1479
01:10:01,330 --> 01:09:59,210
each other because it could be any

1480
01:10:04,320 --> 01:10:01,340
configuration but typically they will

1481
01:10:07,240 --> 01:10:04,330
end up forming a bigger bulge and

1482
01:10:09,430 --> 01:10:07,250
statistically what happens is that stars

1483
01:10:11,890 --> 01:10:09,440
that were in the center of their

1484
01:10:14,470 --> 01:10:11,900
respective bulges will also be in the

1485
01:10:15,880 --> 01:10:14,480
center of the combined bulge and stars

1486
01:10:16,430 --> 01:10:15,890
that were in the outskirts of the

1487
01:10:19,130 --> 01:10:16,440
respect

1488
01:10:20,720 --> 01:10:19,140

we'll also be in the outskirts of their

1489
01:10:23,959 --> 01:10:20,730
combined ball just need how that works

1490
01:10:30,410 --> 01:10:23,969
out all right other questions from here

1491
01:10:32,060 --> 01:10:30,420
is there any evidence is there any

1492
01:10:37,120 --> 01:10:32,070
evidence that our galaxy is already

1493
01:10:39,740 --> 01:10:37,130
collided with another galaxy yes so I

1494
01:10:42,080 --> 01:10:39,750
showed you the movies to start so you

1495
01:10:44,630 --> 01:10:42,090
could argue that's evidence because

1496
01:10:45,890 --> 01:10:44,640
within cosmological simulations that

1497
01:10:47,720 --> 01:10:45,900
start with our understanding of the

1498
01:10:50,120 --> 01:10:47,730
universe galaxies are formed from

1499
01:10:51,650 --> 01:10:50,130
mergers of proto galaxies but maybe you

1500
01:10:55,160 --> 01:10:51,660
want more evidence to that and so the

1501
01:10:58,550 --> 01:10:55,170
best evidence we have is that we do see

1502
01:11:00,439 --> 01:10:58,560
a few small streams around the Milky Way

1503
01:11:02,540 --> 01:11:00,449
which are they're not shown in this

1504
01:11:08,570 --> 01:11:02,550
image I don't know if they're shown in

1505
01:11:14,090 --> 01:11:08,580
any of the other images see I'll try and

1506
01:11:21,979 --> 01:11:14,100
see if there's one somewhere okay and

1507
01:11:23,540 --> 01:11:21,989
HAP may be actually okay so it happens

1508
01:11:25,700 --> 01:11:23,550
that there's no streams anywhere but

1509
01:11:28,189 --> 01:11:25,710
around the Milky Way we actually do see

1510
01:11:30,680 --> 01:11:28,199
a few weak streams which are due to

1511
01:11:32,780 --> 01:11:30,690
active accretion of smaller galaxies but

1512
01:11:36,979 --> 01:11:32,790
these are very minor mergers happening

1513
01:11:38,689 --> 01:11:36,989

it's like a 100 to 1 ratio and whereas

1514
01:11:40,490 --> 01:11:38,699
in simulations we expect that at some

1515
01:11:43,250 --> 01:11:40,500
point there should be two to one ratio

1516
01:11:44,990 --> 01:11:43,260
mergers 3 to 1 ratio mergers and so on

1517
01:11:48,080 --> 01:11:45,000
the mergers that we're seeing in the

1518
01:11:52,580 --> 01:11:48,090
Milky Way now are in the very very minor

1519
01:11:56,209 --> 01:11:52,590
merger regime as it's called ok and we

1520
01:11:58,670 --> 01:11:56,219
have one last question from online how

1521
01:12:00,590 --> 01:11:58,680
old is the oldest star in the Milky Way

1522
01:12:05,330 --> 01:12:00,600
and how does that compare to the age of

1523
01:12:08,150 --> 01:12:05,340
the universe so that is a very good

1524
01:12:11,420 --> 01:12:08,160
question as well and the answer is that

1525
01:12:13,550 --> 01:12:11,430
we can't know that that well because

1526
01:12:16,490 --> 01:12:13,560
ages of stars are only measured to about

1527
01:12:18,680 --> 01:12:16,500
10% precision or so and because of that

1528
01:12:21,920 --> 01:12:18,690
we actually have stars for which the

1529
01:12:24,620 --> 01:12:21,930
best estimate of the age is older than

1530
01:12:27,140 --> 01:12:24,630
the age of the universe but that's fine

1531
01:12:28,920 --> 01:12:27,150
because we know that's what the

1532
01:12:31,290 --> 01:12:28,930
measurement error is

1533
01:12:34,470 --> 01:12:31,300
and so we're okay with that but

1534
01:12:35,970 --> 01:12:34,480
eventually as ages improve we should not

1535
01:12:37,830 --> 01:12:35,980
have any stars older in the age of

1536
01:12:40,200 --> 01:12:37,840
universe and one thing that we'd like to

1537
01:12:42,240 --> 01:12:40,210
find out and for which Baltimore

1538
01:12:44,490 --> 01:12:42,250

astronomers will take a leading role is

1539
01:12:46,380 --> 01:12:44,500
when did the first stars in the universe

1540
01:12:48,270 --> 01:12:46,390
form was it a hundred million years

1541
01:12:50,760 --> 01:12:48,280
after the Big Bang two hundred million

1542
01:12:55,860 --> 01:12:50,770
years after the Big Bang that is an open

1543
01:12:57,810 --> 01:12:55,870
topic which may be the James Webb Space

1544
01:13:00,150 --> 01:12:57,820
Telescope mentioned by Frank earlier

1545
01:13:02,160 --> 01:13:00,160
will help us solve within a year or two

1546
01:13:05,610 --> 01:13:02,170
it's one of the points of the James Webb

1547
01:13:17,460 --> 01:13:05,620
Space Telescope okay and in the back

1548
01:13:18,860 --> 01:13:17,470
corner so if Andromeda look we're gonna

1549
01:13:21,030 --> 01:13:18,870
combine does that mean that the

1550
01:13:21,720 --> 01:13:21,040
Andromeda has a blue shift relative to

1551
01:13:24,210 --> 01:13:21,730
the Milky Way

1552
01:13:26,760 --> 01:13:24,220
yeah it does it's one of the few blue

1553
01:13:39,660 --> 01:13:26,770
shifted galaxies we have one more

1554
01:13:43,890 --> 01:13:39,670
question here typically they will end up

1555
01:13:46,080 --> 01:13:43,900
sinking faster too because they're more

1556
01:13:47,880 --> 01:13:46,090
massive they will end up sinking faster

1557
01:13:51,990 --> 01:13:47,890
and then you'll also have a merger of

1558
01:13:53,970 --> 01:13:52,000
your black holes eventually and that'll

1559
01:13:57,390 --> 01:13:53,980
make big gravitational waves the most

1560
01:13:59,640 --> 01:13:57,400
energetic events in the universe within

1561
01:14:01,470 --> 01:13:59,650
pop-culture knowledge it might be

1562
01:14:03,090 --> 01:14:01,480
believed to be supernova but it's

1563
01:14:05,430 --> 01:14:03,100

actually the mergers of supermassive

1564
01:14:08,460 --> 01:14:05,440
black holes where the energy comes down

1565
01:14:10,710 --> 01:14:08,470
in gravitational waves and eventually

1566
01:14:13,050 --> 01:14:10,720
they merge but I might be like some

1567
01:14:14,640 --> 01:14:13,060
billion years after the galaxies

1568
01:14:16,950 --> 01:14:14,650
themselves approached because it'll take

1569
01:14:19,140 --> 01:14:16,960
time for the smaller black hole to make

1570
01:14:21,750 --> 01:14:19,150
it to the center of gravity and

1571
01:14:24,300 --> 01:14:21,760
encounter the bigger black hole all

1572
01:14:26,460 --> 01:14:24,310
right we're gonna end it there ireenie

1573
01:14:28,170 --> 01:14:26,470
are you here anybody from the Maryland

1574
01:14:30,930 --> 01:14:28,180
Space Grant Observatory here to take

1575
01:14:32,700 --> 01:14:30,940
people across the street I guess not so

1576
01:14:33,780 --> 01:14:32,710
there will be no observing across the

1577
01:14:34,590 --> 01:14:33,790
street with the Maryland Space Grant

1578
01:14:36,270 --> 01:14:34,600
observatory

1579
01:14:38,940 --> 01:14:36,280
please check their website for their

1580
01:14:41,220 --> 01:14:38,950
Friday night open houses next month

1581
01:14:43,560 --> 01:14:41,230
August 7th ashes to

1582
01:14:45,900 --> 01:14:43,570
ashes dust to dust the fate of stars

1583
01:14:48,360 --> 01:14:45,910
like the Sun you want to know how the

1584
01:14:50,580 --> 01:14:48,370
story ends for our Sun you got to come

1585
01:14:50,970 --> 01:14:50,590
next month let's give another great big