
HUBBLE
hangouts
Unusual Structure In A Galaxy Collision
Thursday, August 7 2014, 3pm EDT, 7pm UTC

1
00:00:06,860 --> 00:00:04,969
hello everybody and welcome to our

2
00:00:08,510 --> 00:00:06,870
latest Hubble hang out my name is Tony

3
00:00:10,250 --> 00:00:08,520
Darnell I work at the Space Telescope

4
00:00:12,080 --> 00:00:10,260
Science Institute and today we have a

5
00:00:14,360 --> 00:00:12,090
really interesting hangout plan for you

6
00:00:16,579 --> 00:00:14,370
we are going to be talking about galaxy

7
00:00:18,710 --> 00:00:16,589
collisions in particular one galaxy

8
00:00:23,450 --> 00:00:18,720
collision that is had some strange

9
00:00:25,370 --> 00:00:23,460
unusual bizarre things in it and we've

10
00:00:27,109 --> 00:00:25,380
got the astronomers here to help us

11
00:00:29,029 --> 00:00:27,119
decipher what they're looking at and

12
00:00:30,710 --> 00:00:29,039
what they are we'll talk about galaxy

13
00:00:33,380 --> 00:00:30,720

collisions and what you know where they

14
00:00:36,110 --> 00:00:33,390
occur and and in particular what this

15
00:00:40,310 --> 00:00:36,120
strange feature that they found might

16
00:00:41,420 --> 00:00:40,320
actually be and so we will be starting

17
00:00:42,860 --> 00:00:41,430
that discussion in just a minute but

18
00:00:45,200 --> 00:00:42,870
before I start with introductions i want

19
00:00:49,160 --> 00:00:45,210
to say we're hoping you guys will leave

20
00:00:50,630 --> 00:00:49,170
us comments and questions on the Q&A app

21
00:00:52,819 --> 00:00:50,640
which we're also which we're watching

22
00:00:54,650 --> 00:00:52,829
the hubble hang out hashtag on twitter

23
00:00:57,470 --> 00:00:54,660
we're also doing come we're looking at

24
00:00:59,060 --> 00:00:57,480
comments on YouTube and G+ so we hope

25
00:01:00,560 --> 00:00:59,070
you'll interact with us and let us know

26
00:01:02,360 --> 00:01:00,570
what you think give us some questions

27
00:01:04,999 --> 00:01:02,370
and we'll get to those hopefully

28
00:01:07,609 --> 00:01:05,009
throughout the hang out with me to help

29
00:01:09,499 --> 00:01:07,619
with this hang out here are my two good

30
00:01:10,730 --> 00:01:09,509
friends and colleagues dr. carol

31
00:01:13,640 --> 00:01:10,740
christian she's the Hubble Space

32
00:01:17,030 --> 00:01:13,650
Telescope outreach astronomer and and

33
00:01:19,130 --> 00:01:17,040
also with me is scott lewis from know

34
00:01:20,389 --> 00:01:19,140
the cosmos calm and he's just getting

35
00:01:22,730 --> 00:01:20,399
started doing all kinds of cool things

36
00:01:24,830 --> 00:01:22,740
with the Natural History Museum in Los

37
00:01:31,810 --> 00:01:24,840
Angeles so welcome Scott welcome Carol

38
00:01:35,630 --> 00:01:31,820

hey I'm going awesome a rock ready this

39
00:01:38,420 --> 00:01:35,640
okay so today galaxy collisions with me

40
00:01:40,459 --> 00:01:38,430
to the web got three astronomers who've

41
00:01:42,499 --> 00:01:40,469
been using the Hubble Space Telescope to

42
00:01:45,350 --> 00:01:42,509
look at these things I have first of all

43
00:01:47,810 --> 00:01:45,360
dr. grant trembly he was but at the time

44
00:01:49,490 --> 00:01:47,820
the press release came out was working

45
00:01:51,649 --> 00:01:49,500
at the european southern observatory now

46
00:01:54,999 --> 00:01:51,659
he is the nasa Einstein fellow at Yale

47
00:01:57,620 --> 00:01:55,009
University welcome dr. Tremblay hi guys

48
00:01:59,240 --> 00:01:57,630
also is Jane rig I'm just doing this

49
00:02:01,520 --> 00:01:59,250
from left to right as they appear on my

50
00:02:05,260 --> 00:02:01,530
screen dr. Jane rib Rigby she's an

51
00:02:09,499 --> 00:02:05,270
astronomer at NASA Goddard hi Jane hello

52
00:02:11,270 --> 00:02:09,509
and finally we have Karen sharone she's

53
00:02:13,010 --> 00:02:11,280
a professor from the University of

54
00:02:16,610 --> 00:02:13,020
Michigan hi

55
00:02:18,260 --> 00:02:16,620
guys okay galaxy collisions you guys

56
00:02:21,260 --> 00:02:18,270
have been using the Hubble Space

57
00:02:22,910 --> 00:02:21,270
Telescope to study these things is this

58
00:02:25,310 --> 00:02:22,920
what you've always been doing all three

59
00:02:27,290 --> 00:02:25,320
this your primary area of research your

60
00:02:29,180 --> 00:02:27,300
grand I'll start with you well well

61
00:02:31,070 --> 00:02:29,190
first of all I work on clusters of

62
00:02:33,110 --> 00:02:31,080
galaxies in general namely star

63
00:02:35,480 --> 00:02:33,120

formation and black hole feedback so

64
00:02:38,960 --> 00:02:35,490
energy feedback from black holes ah but

65
00:02:41,990 --> 00:02:38,970
on this particular study I was very

66
00:02:43,880 --> 00:02:42,000
lucky to be sort of a guest uh in Jane

67
00:02:45,950 --> 00:02:43,890
and Karen's house because this is their

68
00:02:47,120 --> 00:02:45,960
data this is their amazing program all

69
00:02:50,600 --> 00:02:47,130
right they can tell you a little bit

70
00:02:52,430 --> 00:02:50,610
about it okay so wait a minute now you

71
00:02:53,690 --> 00:02:52,440
said feedback say that again feedback

72
00:02:56,480 --> 00:02:53,700
from black holes what kind of feedback

73
00:02:59,060 --> 00:02:56,490
yeah so I work on on brightest cluster

74
00:03:01,100 --> 00:02:59,070
galaxies in the center of rich clusters

75
00:03:02,480 --> 00:03:01,110
of galaxies so clusters of galaxies are

76
00:03:04,130 --> 00:03:02,490
giant groups of galaxies which we'll

77
00:03:05,960 --> 00:03:04,140
talk about today and I work on the

78
00:03:08,270 --> 00:03:05,970
galaxies in the very center of them and

79
00:03:09,950 --> 00:03:08,280
many of these galaxies have what are

80
00:03:11,660 --> 00:03:09,960
called active galactic nuclei so

81
00:03:14,500 --> 00:03:11,670
accreting supermassive black holes

82
00:03:16,910 --> 00:03:14,510
billion solar mass black holes ah and

83
00:03:18,440 --> 00:03:16,920
when you dump a lot of matter into a

84
00:03:21,590 --> 00:03:18,450
black hole it liberates tons of energy

85
00:03:24,620 --> 00:03:21,600
and I work on what effect that energy

86
00:03:26,000 --> 00:03:24,630
has other its ambient environment good

87
00:03:27,110 --> 00:03:26,010
because I wanted to clarify that because

88
00:03:28,730 --> 00:03:27,120

it's a little counterintuitive people

89
00:03:29,930 --> 00:03:28,740
think of black holes is just grabbing

90
00:03:32,840 --> 00:03:29,940
and sucking everything in but they

91
00:03:34,460 --> 00:03:32,850
actually throw things back out again too

92
00:03:36,110 --> 00:03:34,470
so that sounds like an interesting hang

93
00:03:38,780 --> 00:03:36,120
out in and of itself so that's great

94
00:03:41,540 --> 00:03:38,790
okay how about you Jane in a Jane and

95
00:03:43,070 --> 00:03:41,550
Karen let's start with you Karen are you

96
00:03:44,690 --> 00:03:43,080
this is this your main area of research

97
00:03:46,610 --> 00:03:44,700
have you always been involved in

98
00:03:48,650 --> 00:03:46,620
galactic or galaxy clusters and

99
00:03:50,690 --> 00:03:48,660
collisions well I've been involved in

100
00:03:53,230 --> 00:03:50,700
that galaxy clusters for as long as I

101
00:03:55,190 --> 00:03:53,240
have been in astronomy but uh not

102
00:03:58,220 --> 00:03:55,200
necessarily what we're talking about

103
00:03:59,830 --> 00:03:58,230
today so my main interest is in a

104
00:04:02,470 --> 00:03:59,840
phenomenon called gravitational lensing

105
00:04:05,360 --> 00:04:02,480
which is the bending of light around

106
00:04:07,400 --> 00:04:05,370
very massive object right we're going

107
00:04:09,110 --> 00:04:07,410
some of that in a little bit so right we

108
00:04:12,620 --> 00:04:09,120
got some area so we got some graphic for

109
00:04:15,140 --> 00:04:12,630
that too right so like granted we have

110
00:04:17,630 --> 00:04:15,150
this amazing project with the Hubble

111
00:04:20,030 --> 00:04:17,640
Space Telescope looking at galaxy

112
00:04:22,430 --> 00:04:20,040
clusters which are very very massive so

113
00:04:24,409 --> 00:04:22,440

that they bend the light of galaxies

114
00:04:26,410 --> 00:04:24,419
behind them and this is our main

115
00:04:29,220 --> 00:04:26,420
progress program with

116
00:04:31,720 --> 00:04:29,230
main signs with this great program

117
00:04:33,970 --> 00:04:31,730
however sometimes when you take a lot of

118
00:04:35,350 --> 00:04:33,980
pictures with a Space Telescope you find

119
00:04:38,290 --> 00:04:35,360
some things that you do not necessarily

120
00:04:39,520 --> 00:04:38,300
expect and this object that we're

121
00:04:43,990 --> 00:04:39,530
talking about today is one of those

122
00:04:45,460 --> 00:04:44,000
things right okay Jane how about so give

123
00:04:47,350 --> 00:04:45,470
us a little background on what you have

124
00:04:50,920 --> 00:04:47,360
your research interest in background

125
00:04:52,630 --> 00:04:50,930
sure so I'm interested in galaxies of

126
00:04:55,300 --> 00:04:52,640
all kinds whether they're forming stars

127
00:04:56,440 --> 00:04:55,310
are not especially those that have black

128
00:04:58,690 --> 00:04:56,450
holes in their centers that are

129
00:05:01,090 --> 00:04:58,700
currently feeding and fueling like grant

130
00:05:02,920 --> 00:05:01,100
was talking about and recently I've

131
00:05:05,170 --> 00:05:02,930
gotten very interested in studying

132
00:05:07,750 --> 00:05:05,180
galaxies using gravitational lensing

133
00:05:09,310 --> 00:05:07,760
which we'll talk about and so Karen and

134
00:05:10,990 --> 00:05:09,320
I and our colleague Mike ladders and

135
00:05:14,620 --> 00:05:11,000
some other astronomers have this big

136
00:05:16,840 --> 00:05:14,630
program to study of galaxy clusters that

137
00:05:19,240 --> 00:05:16,850
are really good gravitational lenses and

138
00:05:22,990 --> 00:05:19,250

kind of by act that's why we took this

139
00:05:26,050 --> 00:05:23,000
data so it's one of 37 clusters that we

140
00:05:27,730 --> 00:05:26,060
wanted to that we wanted to study the

141
00:05:30,220 --> 00:05:27,740
background galaxies they're getting lens

142
00:05:32,950 --> 00:05:30,230
and this was a case this paper that

143
00:05:35,950 --> 00:05:32,960
grant invited you to our house I like

144
00:05:38,380 --> 00:05:35,960
that that came from was we were looking

145
00:05:41,590 --> 00:05:38,390
at this cluster and saying wait a minute

146
00:05:43,870 --> 00:05:41,600
what's not right what is that what's

147
00:05:50,050 --> 00:05:43,880
going on in the sermon really did do

148
00:05:51,640 --> 00:05:50,060
this mmm pours right ok so I had to put

149
00:05:54,910 --> 00:05:51,650
up a picture of the cluster we're

150
00:05:57,190 --> 00:05:54,920
talking about so you guys looked at this

151
00:06:01,000 --> 00:05:57,200
cluster known as sdss which i think

152
00:06:04,960 --> 00:06:01,010
stands for Sloan Digital Sky Survey j15

153
00:06:09,370 --> 00:06:04,970
31 + 34 14 I just love these names so

154
00:06:12,160 --> 00:06:09,380
here is a picture of the galaxy cluster

155
00:06:17,320 --> 00:06:12,170
itself I how many galaxies are in this

156
00:06:19,600 --> 00:06:17,330
thing do we know we have to counter a

157
00:06:28,300 --> 00:06:19,610
lot more than just wondered if anybody

158
00:06:29,860 --> 00:06:28,310
know who is quote so first of all when

159
00:06:31,990 --> 00:06:29,870
you look at this picture you can notice

160
00:06:34,450 --> 00:06:32,000
that some of the galaxies look sort of

161
00:06:36,640 --> 00:06:34,460
the same they look like they're yellow

162
00:06:38,740 --> 00:06:36,650
orange and they sort of have about the

163
00:06:40,270 --> 00:06:38,750

same color and those are all cluster

164
00:06:42,720 --> 00:06:40,280
galaxies other

165
00:06:45,129 --> 00:06:42,730
Alexei's that can be smaller or larger

166
00:06:46,960 --> 00:06:45,139
have different color and they would

167
00:06:49,150 --> 00:06:46,970
typically be either in front of the

168
00:06:51,040 --> 00:06:49,160
cluster or behind the cluster so when

169
00:06:54,520 --> 00:06:51,050
you come galaxies please only count that

170
00:06:56,379 --> 00:06:54,530
yellow orange ones okay all right so

171
00:06:58,210 --> 00:06:56,389
what there's the first thing that

172
00:06:59,260 --> 00:06:58,220
strikes me when I look at this is

173
00:07:02,230 --> 00:06:59,270
obviously like you said there's these

174
00:07:06,070 --> 00:07:02,240
these orange ones these big roundish

175
00:07:07,810 --> 00:07:06,080
sort of oblong shaped galaxies in here

176
00:07:09,250 --> 00:07:07,820
is and then there's all these other

177
00:07:11,920 --> 00:07:09,260
squiggles all the way around these

178
00:07:13,630 --> 00:07:11,930
bluish kind of squiggles can you

179
00:07:15,130 --> 00:07:13,640
describe to us what's going on here what

180
00:07:18,100 --> 00:07:15,140
are we what are we looking at as far as

181
00:07:21,070 --> 00:07:18,110
the the colors and the shapes right so

182
00:07:23,050 --> 00:07:21,080
the orange galaxies those oval shaped

183
00:07:26,290 --> 00:07:23,060
galaxies those are members of the

184
00:07:29,260 --> 00:07:26,300
cluster which has hundreds and probably

185
00:07:31,780 --> 00:07:29,270
a few couple hundred galaxies in it some

186
00:07:33,640 --> 00:07:31,790
are larger some are smaller um besides

187
00:07:36,040 --> 00:07:33,650
those galaxies there is a whole bunch of

188
00:07:39,570 --> 00:07:36,050

dark matter which we can't see kind of

189
00:07:41,740 --> 00:07:39,580
by definition one and all that mass

190
00:07:44,800 --> 00:07:41,750
makes this cluster a very good

191
00:07:46,930 --> 00:07:44,810
gravitational lens and those uh all

192
00:07:49,870 --> 00:07:46,940
those round shape things that you see

193
00:07:51,760 --> 00:07:49,880
there okay and it looked like arcs and

194
00:07:53,890 --> 00:07:51,770
this is what we call them those are our

195
00:07:56,800 --> 00:07:53,900
background sources that are being bent

196
00:07:59,650 --> 00:07:56,810
and distorted by the mass of this

197
00:08:01,930 --> 00:07:59,660
cluster or more correctly the light from

198
00:08:06,100 --> 00:08:01,940
those galaxies is distorted and we see

199
00:08:09,010 --> 00:08:06,110
them as I those are key shapes so the

200
00:08:11,320 --> 00:08:09,020
orangish blobs and those are actually in

201
00:08:14,860 --> 00:08:11,330
the foreground those are between us and

202
00:08:17,770 --> 00:08:14,870
the bluish stretched out shapes right

203
00:08:19,719 --> 00:08:17,780
yes exactly okay so does the color mean

204
00:08:21,580 --> 00:08:19,729
anything I mean I know that these these

205
00:08:23,140 --> 00:08:21,590
orange ones are orange and they're

206
00:08:24,430 --> 00:08:23,150
they're kind of blobby looking but the

207
00:08:28,779 --> 00:08:24,440
other thing everything else seems kind

208
00:08:32,050 --> 00:08:28,789
of blue does that signify anything yes

209
00:08:35,170 --> 00:08:32,060
it does okay tell us what am I waiting

210
00:08:36,219 --> 00:08:35,180
for Jane to us yeah well i guess i

211
00:08:37,870 --> 00:08:36,229
should have direct that directly at

212
00:08:40,240 --> 00:08:37,880
someone how about you answer that one

213
00:08:42,010 --> 00:08:40,250

sure so the color tells you a lot of

214
00:08:44,770 --> 00:08:42,020
just looking at that image you can see

215
00:08:47,670 --> 00:08:44,780
that the yellow orange e blobby galaxies

216
00:08:50,500 --> 00:08:47,680
aren't forming stars they're done

217
00:08:52,960 --> 00:08:50,510
clusters of galaxies are these extreme

218
00:08:54,070 --> 00:08:52,970
environments that seems to accelerate

219
00:08:56,380 --> 00:08:54,080
the evolution

220
00:08:58,660 --> 00:08:56,390
of galaxies okay so when we look at a

221
00:09:00,250 --> 00:08:58,670
cluster of galaxies they look yellow or

222
00:09:02,950 --> 00:09:00,260
red like that because they're done

223
00:09:04,990 --> 00:09:02,960
they're not forming any stars they are

224
00:09:07,450 --> 00:09:05,000
they have their stars have already been

225
00:09:10,180 --> 00:09:07,460
formed and that's it no new star

226
00:09:14,290 --> 00:09:10,190
formation all right so we thought or so

227
00:09:16,660 --> 00:09:14,300
we thought right portion that's a review

228
00:09:18,460 --> 00:09:16,670
today okay so and then those background

229
00:09:19,990 --> 00:09:18,470
galaxies are forming buckets of stars

230
00:09:23,110 --> 00:09:20,000
and that's why they're blue because hot

231
00:09:25,060 --> 00:09:23,120
new stars are blue okay so let's talk

232
00:09:26,500 --> 00:09:25,070
let's go before we get too much into the

233
00:09:27,630 --> 00:09:26,510
details of this cluster let's go ahead

234
00:09:30,460 --> 00:09:27,640
and talk a little bit about

235
00:09:32,830 --> 00:09:30,470
gravitational lensing we have a diagram

236
00:09:34,270 --> 00:09:32,840
here and grant I was wondering if you

237
00:09:36,490 --> 00:09:34,280
might be able tell us a little bit about

238
00:09:38,200 --> 00:09:36,500

what gravitational lensing is and maybe

239
00:09:42,820 --> 00:09:38,210
what we're looking at here sure things

240
00:09:46,210 --> 00:09:42,830
sort so I if you imagine a galaxy

241
00:09:47,950 --> 00:09:46,220
cluster as a contact lens um it works in

242
00:09:49,930 --> 00:09:47,960
a lot of the same way in that if you

243
00:09:52,000 --> 00:09:49,940
imagine space and time as a big rubber

244
00:09:54,460 --> 00:09:52,010
sheet and put a big bowling ball on it

245
00:09:57,100 --> 00:09:54,470
and then roll marbles past that rolling

246
00:10:00,040 --> 00:09:57,110
ball that bowling ball the trajectory or

247
00:10:02,110 --> 00:10:00,050
the path of the marbles will change if a

248
00:10:04,330 --> 00:10:02,120
very similar thing happens in that the

249
00:10:06,730 --> 00:10:04,340
enormous mass of this galaxy cluster

250
00:10:09,100 --> 00:10:06,740
warp space and time around it so light

251
00:10:11,950 --> 00:10:09,110
from distant background galaxies passing

252
00:10:15,280 --> 00:10:11,960
near this cluster um its trajectory gets

253
00:10:18,220 --> 00:10:15,290
gets bent just into these arcs that you

254
00:10:20,710 --> 00:10:18,230
see so I mean caring and caring in Jane

255
00:10:22,630 --> 00:10:20,720
work on this more directly and they can

256
00:10:24,220 --> 00:10:22,640
also tell you some stuff about it okay

257
00:10:26,920 --> 00:10:24,230
we have one more graphic that's a little

258
00:10:28,650 --> 00:10:26,930
more lesser ative of the stretching out

259
00:10:30,640 --> 00:10:28,660
effect this just shows that there's a

260
00:10:32,800 --> 00:10:30,650
something in the middle that's doing the

261
00:10:35,620 --> 00:10:32,810
bending here's another look we have a

262
00:10:39,010 --> 00:10:35,630
distant background galaxy that is whose

263
00:10:40,750 --> 00:10:39,020

light is being distorted by the group of

264
00:10:43,540 --> 00:10:40,760
galaxies in front of it and you can see

265
00:10:44,710 --> 00:10:43,550
that these arcs are being made here Jane

266
00:10:46,900 --> 00:10:44,720
you want to comment on that a little bit

267
00:10:50,620 --> 00:10:46,910
more I'm turning this one over to Karen

268
00:10:52,950 --> 00:10:50,630
oh it's all good very hard to give you

269
00:10:56,830 --> 00:10:52,960
fun hangul i love this already you know

270
00:11:00,930 --> 00:10:56,840
yeah yeah so right so everything you

271
00:11:03,820 --> 00:11:00,940
said is correct and sometimes this um

272
00:11:06,160 --> 00:11:03,830
not that gas is not are not only being

273
00:11:07,430 --> 00:11:06,170
stretched but I might the lights can

274
00:11:09,560 --> 00:11:07,440
like a funhouse mirror

275
00:11:11,660 --> 00:11:09,570
r-type effect they're being stretching

276
00:11:13,970 --> 00:11:11,670
you sometimes would see multiple images

277
00:11:16,250 --> 00:11:13,980
of the same thing so the light would

278
00:11:17,840 --> 00:11:16,260
start from a galaxy go around the

279
00:11:20,690 --> 00:11:17,850
cluster and get to you from one

280
00:11:21,950 --> 00:11:20,700
direction but also some other ray of

281
00:11:23,630 --> 00:11:21,960
light that was supposed to go in a

282
00:11:25,400 --> 00:11:23,640
completely different direction we've

283
00:11:27,110 --> 00:11:25,410
been around the cluster and get to you

284
00:11:29,990 --> 00:11:27,120
as well this is what you're seeing here

285
00:11:32,390 --> 00:11:30,000
and this uh in this graphic you see

286
00:11:33,800 --> 00:11:32,400
light from the galaxy going around the

287
00:11:36,290 --> 00:11:33,810
cluster in two different directions and

288
00:11:41,900 --> 00:11:36,300

gets to the Hubble Space Telescope image

289
00:11:44,300 --> 00:11:41,910
and I my job in this cooperation is to

290
00:11:46,790 --> 00:11:44,310
try to figure out what the optics of

291
00:11:49,670 --> 00:11:46,800
this gravitational telescope is so we're

292
00:11:53,540 --> 00:11:49,680
using the cluster which is far away in

293
00:11:56,330 --> 00:11:53,550
space to magnify light from the

294
00:11:57,950 --> 00:11:56,340
background universe so it's acting sort

295
00:12:00,350 --> 00:11:57,960
of like a cosmic telescope or a

296
00:12:02,630 --> 00:12:00,360
magnifying glass which we don't know the

297
00:12:04,220 --> 00:12:02,640
optics for and my job is to solve this

298
00:12:07,520 --> 00:12:04,230
problem and figure out what the optics

299
00:12:10,550 --> 00:12:07,530
are and then we can once we figure out

300
00:12:12,320 --> 00:12:10,560
the opticore the mass of the cluster

301
00:12:14,660 --> 00:12:12,330
that is responsible for the

302
00:12:16,430 --> 00:12:14,670
gravitational lensing then we can use it

303
00:12:22,940 --> 00:12:16,440
to start studying the background sources

304
00:12:27,710 --> 00:12:22,950
and now back to Jane okay hey you James

305
00:12:29,240 --> 00:12:27,720
factory hey guys so I guess what blows

306
00:12:31,040 --> 00:12:29,250
me away about what you just said though

307
00:12:33,320 --> 00:12:31,050
is you said it in a kind of nonchalant

308
00:12:35,930 --> 00:12:33,330
way my job is to figure out the optics

309
00:12:37,130 --> 00:12:35,940
in this and once I figured that out i we

310
00:12:38,930 --> 00:12:37,140
you know we can kind of tell which

311
00:12:41,750 --> 00:12:38,940
galaxies are which and things how do you

312
00:12:44,630 --> 00:12:41,760
do that how do you sort this all out

313
00:12:46,190 --> 00:12:44,640

you've got these smudges in an image

314
00:12:47,930 --> 00:12:46,200
some of them are all over the way

315
00:12:49,910 --> 00:12:47,940
sometimes you have two images of the

316
00:12:51,920 --> 00:12:49,920
same galaxy in different parts you've

317
00:12:54,230 --> 00:12:51,930
got this big old galaxy cluster in the

318
00:12:55,640 --> 00:12:54,240
middle doing all of the distorting how

319
00:12:57,140 --> 00:12:55,650
do you sort it out what do you what do

320
00:12:59,150 --> 00:12:57,150
you swear do you even start all you have

321
00:13:03,160 --> 00:12:59,160
is an image just well I started by

322
00:13:06,440 --> 00:13:03,170
staring at the image really really hard

323
00:13:08,950 --> 00:13:06,450
part of my job I love looking at those

324
00:13:12,500 --> 00:13:08,960
beautiful pictures of space I think what

325
00:13:16,100 --> 00:13:12,510
imagine you know how like you have that

326
00:13:19,250 --> 00:13:16,110
that you know those what back when we

327
00:13:19,700 --> 00:13:19,260
had newspapers um there were those who

328
00:13:22,550 --> 00:13:19,710
care

329
00:13:26,840 --> 00:13:22,560
hers is sorry I can't y'all pray that I

330
00:13:28,340 --> 00:13:26,850
newspapers I'm on Saturdays and it would

331
00:13:30,440 --> 00:13:28,350
be like those two pictures that you have

332
00:13:33,620 --> 00:13:30,450
to match this thing looks like this

333
00:13:37,010 --> 00:13:33,630
thing is sort of like a puzzle so I look

334
00:13:39,200 --> 00:13:37,020
at the pictures and try to find things

335
00:13:40,850 --> 00:13:39,210
that look sort of the same so they may

336
00:13:43,190 --> 00:13:40,860
look the same because they have their

337
00:13:46,460 --> 00:13:43,200
very distinctive color maybe they look

338
00:13:47,840 --> 00:13:46,470

pink or green sometimes they look the

339
00:13:50,840 --> 00:13:47,850
same because they have very similar

340
00:13:53,120 --> 00:13:50,850
morphology so they're kind of like now

341
00:13:55,010 --> 00:13:53,130
have a look like a spiral galaxy that's

342
00:13:58,010 --> 00:13:55,020
you started in one way or just starting

343
00:13:59,870 --> 00:13:58,020
another way and when I can find two or

344
00:14:01,820 --> 00:13:59,880
three or five of those it looks at stick

345
00:14:05,090 --> 00:14:01,830
look like they're the same I can say

346
00:14:08,420 --> 00:14:05,100
these are a few objects are images of

347
00:14:11,090 --> 00:14:08,430
the same thing in the background and I

348
00:14:14,240 --> 00:14:11,100
can use this information to try to

349
00:14:17,720 --> 00:14:14,250
figure out what sort of mass

350
00:14:21,530 --> 00:14:17,730
distribution could cause this distortion

351
00:14:23,120 --> 00:14:21,540
in space-time wow so you're kind of

352
00:14:25,610 --> 00:14:23,130
doing though one of these things is not

353
00:14:27,800 --> 00:14:25,620
like the other game for a while and then

354
00:14:29,630 --> 00:14:27,810
you figure you you match up some stuff

355
00:14:31,670 --> 00:14:29,640
from different parts of the image from

356
00:14:34,250 --> 00:14:31,680
that you try to figure out the gret the

357
00:14:36,200 --> 00:14:34,260
mass distribution now that's just a you

358
00:14:37,730 --> 00:14:36,210
know a way of saying where all the mass

359
00:14:39,470 --> 00:14:37,740
is in the cluster and how it might be

360
00:14:42,230 --> 00:14:39,480
bending the light and then you do right

361
00:14:44,330 --> 00:14:42,240
so we we have a pretty good idea of how

362
00:14:46,100 --> 00:14:44,340
the map mass bends the light and this

363
00:14:49,970 --> 00:14:46,110

comes from Einstein's relativity theory

364
00:14:52,420 --> 00:14:49,980
and uh we have a set of equation so we

365
00:14:55,760 --> 00:14:52,430
can use we know how physics fork and

366
00:14:57,950 --> 00:14:55,770
when I plug those it sounds kind of

367
00:15:00,950 --> 00:14:57,960
simple but there's a lot of physics

368
00:15:04,100 --> 00:15:00,960
behind it I can put those constraints in

369
00:15:05,420 --> 00:15:04,110
the equations and try a whole bunch of

370
00:15:06,980 --> 00:15:05,430
different models or different math

371
00:15:09,320 --> 00:15:06,990
distributions and find just the right

372
00:15:12,710 --> 00:15:09,330
one that gives me the correct answer

373
00:15:14,990 --> 00:15:12,720
okay so let's go on to the so that's a

374
00:15:17,000 --> 00:15:15,000
little brief idea of what gravitational

375
00:15:18,560 --> 00:15:17,010
lensing is if you got any more questions

376
00:15:20,240 --> 00:15:18,570
please you know feel free to drop us

377
00:15:21,650 --> 00:15:20,250
some some notes in the comment box or

378
00:15:22,850 --> 00:15:21,660
whatever and we'll try to get to them to

379
00:15:25,730 --> 00:15:22,860
clarify things but I'm going to get on

380
00:15:27,620 --> 00:15:25,740
to the observation grant said that this

381
00:15:30,080 --> 00:15:27,630
was you guys this thing you and you guys

382
00:15:31,280 --> 00:15:30,090
were somebody you guys took the data is

383
00:15:33,560 --> 00:15:31,290
that Chrysler who wants to tell me about

384
00:15:35,660 --> 00:15:33,570
the story behind why you did this

385
00:15:38,450 --> 00:15:35,670
and who who decided to point Hubble at

386
00:15:42,290 --> 00:15:38,460
this thing and look at the data and then

387
00:15:44,180 --> 00:15:42,300
you found this very surprising thing

388
00:15:46,730 --> 00:15:44,190

that wasn't there before I'm gonna say

389
00:15:50,060 --> 00:15:46,740
thing a few more times about you girl

390
00:15:53,240 --> 00:15:50,070
how about you Jane sure listen this

391
00:15:55,010 --> 00:15:53,250
cluster is one of 37 clusters that we

392
00:15:59,090 --> 00:15:55,020
propose to observe with the Hubble Space

393
00:16:02,330 --> 00:15:59,100
Telescope and there are about 70 bright

394
00:16:05,330 --> 00:16:02,340
big blue arcs like the one in this

395
00:16:08,510 --> 00:16:05,340
cluster that are the targets for this

396
00:16:10,280 --> 00:16:08,520
proposal so the way Hubble works is that

397
00:16:13,610 --> 00:16:10,290
if you have a really good idea you write

398
00:16:17,060 --> 00:16:13,620
a proposal and if it beats nine out of

399
00:16:20,240 --> 00:16:17,070
ten other proposals we win on that see

400
00:16:22,370 --> 00:16:20,250
last week passed right over it and it

401
00:16:24,260 --> 00:16:22,380
sadly right it's ninety percent

402
00:16:25,670 --> 00:16:24,270
rejection rate there's very few things

403
00:16:28,190 --> 00:16:25,680
that we do in our lives where we have a

404
00:16:30,170 --> 00:16:28,200
ten percent chance of succeeding but

405
00:16:32,240 --> 00:16:30,180
writing couple proposals is one of them

406
00:16:35,260 --> 00:16:32,250
so that was last week so we wrote this

407
00:16:37,990 --> 00:16:35,270
proposal because we wanted to both

408
00:16:40,430 --> 00:16:38,000
understand where the masses and clusters

409
00:16:42,830 --> 00:16:40,440
and stead understand clusters of

410
00:16:44,810 --> 00:16:42,840
galaxies better and it's a wood this is

411
00:16:46,670 --> 00:16:44,820
a way to probe dark matter I mean

412
00:16:47,810 --> 00:16:46,680
Karen's saying it's so cavalierly but

413
00:16:49,790 --> 00:16:47,820

what she does is figure out where all

414
00:16:52,280 --> 00:16:49,800
the dark matter is right I mean it's one

415
00:16:54,410 --> 00:16:52,290
of the few ways you can actually see not

416
00:16:57,380 --> 00:16:54,420
what dark matter is but how but but

417
00:16:58,970 --> 00:16:57,390
where is it how does it behave but we

418
00:17:01,940 --> 00:16:58,980
also wanted to study these background

419
00:17:05,120 --> 00:17:01,950
galaxies and that's my particular

420
00:17:08,569 --> 00:17:05,130
interest is that I want to study how

421
00:17:11,689 --> 00:17:08,579
galaxies evolve and galaxies universe is

422
00:17:14,840 --> 00:17:11,699
annoying in the galaxies are faint far

423
00:17:17,390 --> 00:17:14,850
away with any registration it just says

424
00:17:19,910 --> 00:17:17,400
the university's really annoying the it

425
00:17:21,920 --> 00:17:19,920
is annoying right that the telescopes we

426
00:17:24,530 --> 00:17:21,930
have that we've been able to build

427
00:17:26,480 --> 00:17:24,540
galaxies that are far away look faint

428
00:17:27,740 --> 00:17:26,490
fuzzy and tiny and just can't study them

429
00:17:30,830 --> 00:17:27,750
the way you really want to so

430
00:17:34,070 --> 00:17:30,840
inconvenient well you know I in my other

431
00:17:35,900 --> 00:17:34,080
job I am working to build the James Webb

432
00:17:38,150 --> 00:17:35,910
Space Telescope so we are working to

433
00:17:40,760 --> 00:17:38,160
build bigger and better telescopes but

434
00:17:43,160 --> 00:17:40,770
being impatient I don't want to wait so

435
00:17:45,860 --> 00:17:43,170
using these natural telescopes is a way

436
00:17:47,490 --> 00:17:45,870
to for small parts of the sky that are

437
00:17:49,020 --> 00:17:47,500
lucky that there's a galaxy cluster

438
00:17:50,750 --> 00:17:49,030

the way you can study the background

439
00:17:53,580 --> 00:17:50,760
universe and you get these

440
00:17:55,530 --> 00:17:53,590
magnifications so it's like you're so it

441
00:17:57,420 --> 00:17:55,540
really is a natural telescope in front

442
00:17:59,010 --> 00:17:57,430
of in front of your Hubble Space

443
00:18:00,450 --> 00:17:59,020
Telescope yeah we've talked about that a

444
00:18:02,820 --> 00:18:00,460
lot with frontier fields they're doing

445
00:18:04,920 --> 00:18:02,830
the same yeah right so that's the so

446
00:18:07,080 --> 00:18:04,930
that was the that was our hook that was

447
00:18:11,070 --> 00:18:07,090
the argument we have 37 fields on the

448
00:18:13,440 --> 00:18:11,080
sky that of that our team has found

449
00:18:15,180 --> 00:18:13,450
they're really good lenses and so we

450
00:18:17,850 --> 00:18:15,190
want to take images with Hubble and

451
00:18:21,360 --> 00:18:17,860
study background galaxies to study the

452
00:18:24,330 --> 00:18:21,370
universe at high high spatial resolution

453
00:18:26,040 --> 00:18:24,340
basically to do illegal things to be

454
00:18:28,200 --> 00:18:26,050
able to see sharper images the Hubble

455
00:18:30,360 --> 00:18:28,210
can normally see and to see fainter

456
00:18:32,100 --> 00:18:30,370
objects that Hubble can normally see so

457
00:18:35,220 --> 00:18:32,110
that's the program that was the project

458
00:18:39,210 --> 00:18:35,230
and this is one of 37 clusters that we

459
00:18:41,400 --> 00:18:39,220
got that we got data for so it was a 107

460
00:18:44,280 --> 00:18:41,410
orbit program which is a big but not

461
00:18:47,940 --> 00:18:44,290
huge project for Hubble we submitted it

462
00:18:51,630 --> 00:18:47,950
three times um so you know to get

463
00:18:54,120 --> 00:18:51,640

together come yeah and then time it was

464
00:18:55,470 --> 00:18:54,130
accepted and we got the observations and

465
00:18:57,600 --> 00:18:55,480
the observations just finished a couple

466
00:18:59,700 --> 00:18:57,610
months ago so all 37 clusters have now

467
00:19:00,930 --> 00:18:59,710
been observed yeah Carol I just want to

468
00:19:02,550 --> 00:19:00,940
ask you real quick sometimes when you're

469
00:19:04,620 --> 00:19:02,560
doing a Hubble proposal isn't always

470
00:19:05,730 --> 00:19:04,630
about the science itself is it I me

471
00:19:07,500 --> 00:19:05,740
sometimes it's about the timing

472
00:19:09,960 --> 00:19:07,510
sometimes a science is good but there's

473
00:19:12,360 --> 00:19:09,970
so many proposals that you know you can

474
00:19:14,190 --> 00:19:12,370
always work it in that's true and so the

475
00:19:16,950 --> 00:19:14,200
panels have to take a look at that and

476
00:19:18,840 --> 00:19:16,960
try to do it because I mean in the early

477
00:19:20,850 --> 00:19:18,850
days there were probably some proposals

478
00:19:23,700 --> 00:19:20,860
that weren't great now all the proposals

479
00:19:25,980 --> 00:19:23,710
are great we know that going in so it's

480
00:19:29,280 --> 00:19:25,990
trying to balance you know the different

481
00:19:31,050 --> 00:19:29,290
fields exoplanets the cluster lenses

482
00:19:33,900 --> 00:19:31,060
stellar populations all that kind of

483
00:19:36,570 --> 00:19:33,910
stuff against each other and lots of

484
00:19:38,750 --> 00:19:36,580
times people put in a proposal and they

485
00:19:41,100 --> 00:19:38,760
might not get time that they they get

486
00:19:42,810 --> 00:19:41,110
magnificent scores it's just we only

487
00:19:45,660 --> 00:19:42,820
have so many orbits as we talked about

488
00:19:48,390 --> 00:19:45,670

last time we look like 3,000 Orbis I was

489
00:19:50,490 --> 00:19:48,400
going to comment that you know yet what

490
00:19:52,350 --> 00:19:50,500
you're hearing is that you're getting a

491
00:19:55,560 --> 00:19:52,360
lot out of these observations you're

492
00:19:58,470 --> 00:19:55,570
getting you're getting understanding the

493
00:20:01,289 --> 00:19:58,480
orange galaxies that you see what is

494
00:20:03,450 --> 00:20:01,299
that cluster what kind of

495
00:20:05,310 --> 00:20:03,460
galaxies make up that cluster then

496
00:20:07,379 --> 00:20:05,320
you're finding out Oh something about

497
00:20:10,049 --> 00:20:07,389
those background galaxies because their

498
00:20:11,820 --> 00:20:10,059
lens and then when you build the lens

499
00:20:13,289 --> 00:20:11,830
you say well there's a lot of mass in

500
00:20:15,029 --> 00:20:13,299
those orange galaxies that start with

501
00:20:16,950 --> 00:20:15,039
that but then you have to add the dark

502
00:20:19,229 --> 00:20:16,960
matter because that's what really makes

503
00:20:21,720 --> 00:20:19,239
up this lens phenomenon so you're

504
00:20:24,299 --> 00:20:21,730
learning you know all those things and

505
00:20:26,310 --> 00:20:24,309
then lo and behold they saw this chain

506
00:20:29,009 --> 00:20:26,320
and they went oh there's something else

507
00:20:31,350 --> 00:20:29,019
we're learning about well just from the

508
00:20:32,909 --> 00:20:31,360
best known image so it's a it's a lot of

509
00:20:34,619 --> 00:20:32,919
information and that's why you need this

510
00:20:38,820 --> 00:20:34,629
marvelous team to work together because

511
00:20:40,259 --> 00:20:38,830
each person it has expertise and in some

512
00:20:41,999 --> 00:20:40,269
other thing and they're interested in in

513
00:20:43,769 --> 00:20:42,009

a different aspect of it and that's what

514
00:20:47,159 --> 00:20:43,779
makes these fields very rich because a

515
00:20:49,560 --> 00:20:47,169
lot of science comes out of it what the

516
00:20:52,080 --> 00:20:49,570
picture that you showed before well or

517
00:20:55,139 --> 00:20:52,090
okay go ahead you got Kelly can you put

518
00:20:58,799 --> 00:20:55,149
that first one after we had um that the

519
00:21:00,810 --> 00:20:58,809
galaxy cluster itself a lot of our mr.

520
00:21:02,070 --> 00:21:00,820
which will cause everyone in short

521
00:21:05,820 --> 00:21:02,080
because we don't want to say the entire

522
00:21:08,820 --> 00:21:05,830
phone number thing so what what drew us

523
00:21:12,840 --> 00:21:08,830
into this cluster as you can see is like

524
00:21:15,899 --> 00:21:12,850
the ring of stretchy arcs around the

525
00:21:18,029 --> 00:21:15,909
center which from the ground kind of

526
00:21:19,080 --> 00:21:18,039
just looked like a ring so from the

527
00:21:22,049 --> 00:21:19,090
ground meaning from ground-based

528
00:21:24,450 --> 00:21:22,059
telescopes we had nice images from that

529
00:21:29,039 --> 00:21:24,460
Gemini and Subaru and other telescopes

530
00:21:32,279 --> 00:21:29,049
and so this is a great lens this is a

531
00:21:34,259 --> 00:21:32,289
fantastic cluster lens because it's so

532
00:21:36,749 --> 00:21:34,269
around the the stuff that the features

533
00:21:39,299 --> 00:21:36,759
around it or so complete is that why or

534
00:21:40,950 --> 00:21:39,309
yeah it's very easy it's very certain

535
00:21:43,710 --> 00:21:40,960
that this is a gravitational lens and

536
00:21:45,330 --> 00:21:43,720
it's magnified and we can study those

537
00:21:47,669 --> 00:21:45,340
out background sources and you can see a

538
00:21:50,399 --> 00:21:47,679

lot of little mission klum's like little

539
00:21:54,090 --> 00:21:50,409
knots of blue knots on the ring itself

540
00:21:57,210 --> 00:21:54,100
so this is fantastic for our science so

541
00:21:58,799 --> 00:21:57,220
we and we also saw some little some blue

542
00:22:01,320 --> 00:21:58,809
stuff at the center which we thought was

543
00:22:03,060 --> 00:22:01,330
maybe also some part of the lensing but

544
00:22:04,830 --> 00:22:03,070
we couldn't really resolve it we can see

545
00:22:08,039 --> 00:22:04,840
it well from ground-based observations

546
00:22:09,930 --> 00:22:08,049
because they're so blurry and then we

547
00:22:12,899 --> 00:22:09,940
pointed the Hubble Space Telescope on

548
00:22:14,950 --> 00:22:12,909
edit and we said you know what this is a

549
00:22:16,779 --> 00:22:14,960
fantastic cleanse just like

550
00:22:19,180 --> 00:22:16,789
thought it would be but wait a minute

551
00:22:21,909 --> 00:22:19,190
what's that over there that's a center

552
00:22:23,620 --> 00:22:21,919
what is this yeah okay let's pick that

553
00:22:25,779 --> 00:22:23,630
up let's go ahead and put that up we

554
00:22:28,419 --> 00:22:25,789
have a pother here we go here's a here's

555
00:22:30,460 --> 00:22:28,429
a slight blow up but we have an even

556
00:22:31,720 --> 00:22:30,470
closer one coming up so yeah you're

557
00:22:35,320 --> 00:22:31,730
talking about this stuff in the center

558
00:22:38,110 --> 00:22:35,330
there we go exactly so that stuff in the

559
00:22:40,149 --> 00:22:38,120
center what is this this cannot be lent

560
00:22:43,090 --> 00:22:40,159
I'm looking at this I'm saying this is

561
00:22:44,830 --> 00:22:43,100
not lensing this is not a background

562
00:22:46,750 --> 00:22:44,840
galaxy that's being when's by the

563
00:22:48,370 --> 00:22:46,760

cluster it's way too bright to be a

564
00:22:55,120 --> 00:22:48,380
background galaxies being lens by the

565
00:22:59,680 --> 00:22:55,130
cluster space unicorns right and such a

566
00:23:00,970 --> 00:22:59,690
thing should not exist in a cluster when

567
00:23:02,470 --> 00:23:00,980
I looked at this image for the first

568
00:23:04,090 --> 00:23:02,480
time not being an extra I don't work on

569
00:23:06,789 --> 00:23:04,100
gravitational lensing like Karen and

570
00:23:08,409 --> 00:23:06,799
Jane do I saw this and said well this is

571
00:23:09,669 --> 00:23:08,419
unlike any star formation and field

572
00:23:11,350 --> 00:23:09,679
ellipticals that are in cluster

573
00:23:13,090 --> 00:23:11,360
ellipticals that I've ever seen so this

574
00:23:15,789 --> 00:23:13,100
has to be a gravitational lens this

575
00:23:17,740 --> 00:23:15,799
would be some really crazy gravitational

576
00:23:21,100 --> 00:23:17,750
lens and that's really exciting but uh

577
00:23:23,590 --> 00:23:21,110
that was my first hypothesis and so we

578
00:23:24,940 --> 00:23:23,600
ended up independently ruling that out

579
00:23:27,279 --> 00:23:24,950
in two different ways both with

580
00:23:30,130 --> 00:23:27,289
ground-based spectroscopy and with

581
00:23:31,840 --> 00:23:30,140
Karen's paper which goes through full

582
00:23:34,029 --> 00:23:31,850
detail explaining how this could not

583
00:23:36,340 --> 00:23:34,039
possibly be a gravitationally lensed

584
00:23:39,370 --> 00:23:36,350
image and so what you're left with is

585
00:23:40,930 --> 00:23:39,380
this amazing result that this is

586
00:23:42,820 --> 00:23:40,940
actually star formation taking place

587
00:23:45,340 --> 00:23:42,830
within these two colliding giant

588
00:23:47,049 --> 00:23:45,350

elliptical galaxies so Karen can you

589
00:23:50,500 --> 00:23:47,059
give us some idea why you're so sure

590
00:23:53,820 --> 00:23:50,510
it's not Lindsay oh so in a

591
00:23:56,590 --> 00:23:53,830
gravitational lensing theory um you can

592
00:23:58,450 --> 00:23:56,600
once you make a model of the cluster

593
00:24:00,580 --> 00:23:58,460
once you understand that the optics like

594
00:24:03,850 --> 00:24:00,590
I said right and make predictions of

595
00:24:06,340 --> 00:24:03,860
what other images of the same source

596
00:24:08,889 --> 00:24:06,350
look like sort of it let's say you have

597
00:24:10,840 --> 00:24:08,899
two mirrors in front of you I want to

598
00:24:13,750 --> 00:24:10,850
this ride one to the left you see an

599
00:24:15,159 --> 00:24:13,760
image in the left mirror you can sort of

600
00:24:17,710 --> 00:24:15,169
predict what that image would look like

601
00:24:20,740 --> 00:24:17,720
in the right near right it's you know

602
00:24:23,649 --> 00:24:20,750
rounded or some color or some some

603
00:24:26,769 --> 00:24:23,659
features in it and this is sort of what

604
00:24:28,120 --> 00:24:26,779
the lens model can do you start with one

605
00:24:30,640 --> 00:24:28,130
image and you can

606
00:24:33,040 --> 00:24:30,650
solve the equations and figure out what

607
00:24:35,470 --> 00:24:33,050
the other image would look like and the

608
00:24:39,940 --> 00:24:35,480
other image looks a lot fainter than

609
00:24:41,320 --> 00:24:39,950
this the image that would appear if it

610
00:24:43,480 --> 00:24:41,330
had appeared at the center of the

611
00:24:45,580 --> 00:24:43,490
cluster would be so faint it would be

612
00:24:47,830 --> 00:24:45,590
fainter than the faintest thing blue

613
00:24:49,210 --> 00:24:47,840

thing that you can see here so the blue

614
00:24:52,330 --> 00:24:49,220
stuff that we're looking at it is so

615
00:24:54,220 --> 00:24:52,340
bright here would appear fainter if this

616
00:24:58,150 --> 00:24:54,230
wasn't yeah if this was a lens

617
00:25:01,180 --> 00:24:58,160
background galaxy right here this would

618
00:25:05,740 --> 00:25:01,190
be very very very very faint probably

619
00:25:07,060 --> 00:25:05,750
200 times fainter than this ok so based

620
00:25:09,190 --> 00:25:07,070
on your models are telling you this

621
00:25:10,990 --> 00:25:09,200
can't possibly be much brighter so ok

622
00:25:13,390 --> 00:25:11,000
you you've ruled out that this is not

623
00:25:17,880 --> 00:25:13,400
lensing then what you do stare at it

624
00:25:20,380 --> 00:25:17,890
some more wet then we call our friends

625
00:25:22,750 --> 00:25:20,390
who knows about this who could write a

626
00:25:25,750 --> 00:25:22,760
paper on this yeah yeah what is this

627
00:25:28,630 --> 00:25:25,760
stuff so what we're looking at so you

628
00:25:30,100 --> 00:25:28,640
see the yellow stuff right too bright

629
00:25:34,000 --> 00:25:30,110
yellow clumps on the left and right

630
00:25:36,490 --> 00:25:34,010
right these are the nuclei of two giant

631
00:25:38,320 --> 00:25:36,500
elliptical galaxies that are crashing

632
00:25:40,300 --> 00:25:38,330
together and I'm try to say giant I mean

633
00:25:42,130 --> 00:25:40,310
huge together their projected stellar

634
00:25:44,410 --> 00:25:42,140
envelope is about 300,000 light-years

635
00:25:46,300 --> 00:25:44,420
from end to end compared to our Milky

636
00:25:51,310 --> 00:25:46,310
Way which is about three times the size

637
00:25:53,820 --> 00:25:51,320
okay uh so these galaxies are far along

638
00:25:56,230 --> 00:25:53,830

in the process of crashing together ah

639
00:25:58,030 --> 00:25:56,240
you can see that their nuclei haven't

640
00:26:01,030 --> 00:25:58,040
exactly coalesced yet in you that you

641
00:26:03,610 --> 00:26:01,040
can still see two independent clumps but

642
00:26:05,200 --> 00:26:03,620
then you see this blue squiggly stuff in

643
00:26:06,880 --> 00:26:05,210
the center which we just talked about we

644
00:26:08,830 --> 00:26:06,890
ruled out could be a gravitationally

645
00:26:10,120 --> 00:26:08,840
lens image from a background source and

646
00:26:11,890 --> 00:26:10,130
we've also ruled out that it could be

647
00:26:14,380 --> 00:26:11,900
some weird projection effect from some

648
00:26:15,880 --> 00:26:14,390
foreground source meaning ever all of

649
00:26:19,140 --> 00:26:15,890
that blue emission that you see is

650
00:26:21,400 --> 00:26:19,150
embedded inside the yellow emission from

651
00:26:23,140 --> 00:26:21,410
the hundreds of billions of stars

652
00:26:24,850 --> 00:26:23,150
associated with these two merging

653
00:26:27,010 --> 00:26:24,860
elliptical galaxies yes there's kind of

654
00:26:28,210 --> 00:26:27,020
a halo around this this a little bit

655
00:26:31,120 --> 00:26:28,220
there on the two nuclei you're talking

656
00:26:32,950 --> 00:26:31,130
about that right yeah it's very thin

657
00:26:34,360 --> 00:26:32,960
orangie wispy stuff around the tube

658
00:26:36,370 --> 00:26:34,370
right exactly and the two elliptical

659
00:26:38,140 --> 00:26:36,380
galaxies actually extend far beyond

660
00:26:40,180 --> 00:26:38,150
where this image shows so this is like

661
00:26:41,980 --> 00:26:40,190
taking a magnifying glass and zooming in

662
00:26:43,570 --> 00:26:41,990
on the center ok so that

663
00:26:45,880 --> 00:26:43,580

galaxies themselves are about three

664
00:26:48,970 --> 00:26:45,890
times larger than this image and we're

665
00:26:54,549 --> 00:26:48,980
looking at the sort of central hundred

666
00:26:56,560 --> 00:26:54,559
kiloparsecs or so so I the the blue

667
00:26:58,660 --> 00:26:56,570
squiggly stuff that you see in the very

668
00:27:02,080 --> 00:26:58,670
center is a hundred thousand light-years

669
00:27:03,970 --> 00:27:02,090
from end to end and after confirming

670
00:27:05,710 --> 00:27:03,980
that indeed this this had to be blue

671
00:27:08,350 --> 00:27:05,720
excess emission from star formation

672
00:27:10,060 --> 00:27:08,360
taking place within these galaxies this

673
00:27:11,680 --> 00:27:10,070
burned us to do a lot of follow-up

674
00:27:15,190 --> 00:27:11,690
observations to figure out what is going

675
00:27:16,450 --> 00:27:15,200
on here so what we think this is you

676
00:27:18,190 --> 00:27:16,460
know when you're sticking when you have

677
00:27:20,500 --> 00:27:18,200
coffee and you're stirring it and you

678
00:27:22,830 --> 00:27:20,510
pour milk into your coffee for a little

679
00:27:25,330 --> 00:27:22,840
while you see ribbons of milk start to

680
00:27:27,700 --> 00:27:25,340
start to spin around but then the milk

681
00:27:30,940 --> 00:27:27,710
sort of evens out and your coffee just

682
00:27:33,040 --> 00:27:30,950
becomes lighter creamy coffee right what

683
00:27:35,770 --> 00:27:33,050
we think it this is is a very

684
00:27:39,250 --> 00:27:35,780
serendipitous lucky snapshot of a very

685
00:27:41,890 --> 00:27:39,260
short-lived morphology for this star

686
00:27:44,169 --> 00:27:41,900
formation so all of this blue light that

687
00:27:46,690 --> 00:27:44,179
you see is about five solar masses per

688
00:27:49,510 --> 00:27:46,700

year worth of new baby stars forming and

689
00:27:52,060 --> 00:27:49,520
five solar masses per year it's so one

690
00:27:55,840 --> 00:27:52,070
solar mass per year is roughly one earth

691
00:27:58,270 --> 00:27:55,850
moon per second of mess so this

692
00:28:02,260 --> 00:27:58,280
confirmation is equivalent to about five

693
00:28:04,270 --> 00:28:02,270
moons per second worth of new stars

694
00:28:06,910 --> 00:28:04,280
being created about five solar masses

695
00:28:08,410 --> 00:28:06,920
per year which is a nun which is a lot

696
00:28:10,060 --> 00:28:08,420
of star formation by the way the Milky

697
00:28:13,630 --> 00:28:10,070
Way for example is a slightly less than

698
00:28:15,940 --> 00:28:13,640
one solar mass per year right and what's

699
00:28:18,430 --> 00:28:15,950
amazing is that elliptical galaxies like

700
00:28:21,040 --> 00:28:18,440
jane was talking about earlier generally

701
00:28:24,010 --> 00:28:21,050
not always that's how they never do this

702
00:28:25,960 --> 00:28:24,020
yeah nah it's I thought maybe we should

703
00:28:27,340 --> 00:28:25,970
happen that way that is let's say why

704
00:28:29,860 --> 00:28:27,350
that is elliptical galaxies are

705
00:28:31,090 --> 00:28:29,870
typically very old galaxies right i mean

706
00:28:33,520 --> 00:28:31,100
there are among the largest in the

707
00:28:34,960 --> 00:28:33,530
universe so why don't that's what i mean

708
00:28:37,590 --> 00:28:34,970
that explains our color but why aren't

709
00:28:40,060 --> 00:28:37,600
they having new star formation so

710
00:28:42,940 --> 00:28:40,070
typically yeah so what's weird about the

711
00:28:44,680 --> 00:28:42,950
universe is that it exhibits um big to

712
00:28:46,750 --> 00:28:44,690
small behavior in what should be a big

713
00:28:48,850 --> 00:28:46,760

to bigger universe so in our universe

714
00:28:51,370 --> 00:28:48,860
things are hierarchical right things

715
00:28:54,040 --> 00:28:51,380
grow by the by the by the coalescence of

716
00:28:55,389 --> 00:28:54,050
ever larger clumps of stuff right hmm

717
00:28:58,810 --> 00:28:55,399
and so

718
00:29:01,209 --> 00:28:58,820
I in if if star formation followed this

719
00:29:03,219 --> 00:29:01,219
trend the the largest galaxies in our

720
00:29:05,349 --> 00:29:03,229
universe would have the most booming

721
00:29:08,229 --> 00:29:05,359
star formation rates and we see the

722
00:29:10,749 --> 00:29:08,239
actual opposite effect um so it turns

723
00:29:13,479 --> 00:29:10,759
out that you actually need to actively

724
00:29:16,479 --> 00:29:13,489
um truncate or kill off star formation

725
00:29:19,419 --> 00:29:16,489
as the universe evolves which is a whole

726
00:29:21,159 --> 00:29:19,429
lot which is that some others gets older

727
00:29:22,359 --> 00:29:21,169
and all these galaxies collide more and

728
00:29:24,999 --> 00:29:22,369
more they get bigger and bigger you're

729
00:29:27,009 --> 00:29:25,009
saying we should be seeing higher star

730
00:29:29,469 --> 00:29:27,019
formation in these galaxies not lower

731
00:29:31,180 --> 00:29:29,479
and yet we're seeing lower so you're

732
00:29:33,339 --> 00:29:31,190
saying something must be truncating

733
00:29:35,649 --> 00:29:33,349
somebody must be saying stop don't make

734
00:29:37,329 --> 00:29:35,659
any more new stars yeah various forms of

735
00:29:39,129 --> 00:29:37,339
energetic feedback have been invoked to

736
00:29:41,109 --> 00:29:39,139
explain this feedback from accreting

737
00:29:43,869 --> 00:29:41,119
supermassive black holes feedback from

738
00:29:45,279 --> 00:29:43,879

dying stars from supernova and things

739
00:29:46,749 --> 00:29:45,289
like that and that's that's a subject

740
00:29:50,829 --> 00:29:46,759
for a whole other hubble hanging agreed

741
00:29:53,499 --> 00:29:50,839
I agree the short version is it's a case

742
00:29:56,799 --> 00:29:53,509
where we see something happening in the

743
00:29:59,279 --> 00:29:56,809
universe which is that big that galaxies

744
00:30:01,389 --> 00:29:59,289
and clusters are red and dead and

745
00:30:04,419 --> 00:30:01,399
astronomers spend a ton of time trying

746
00:30:06,339 --> 00:30:04,429
to make it happen in theory yes right so

747
00:30:08,829 --> 00:30:06,349
we spend a lot of time trying to figure

748
00:30:11,440 --> 00:30:08,839
out how do you keep elliptical galaxies

749
00:30:13,419 --> 00:30:11,450
from forming new stars how do you keep

750
00:30:14,680 --> 00:30:13,429
it how do you truncate the star

751
00:30:16,629 --> 00:30:14,690
formation of the first place so they're

752
00:30:18,339 --> 00:30:16,639
done and then how do you keep them from

753
00:30:19,839 --> 00:30:18,349
making any more because if they make

754
00:30:22,539 --> 00:30:19,849
even a little bit more they turn blue

755
00:30:25,749 --> 00:30:22,549
again and that's not what we see so this

756
00:30:28,149 --> 00:30:25,759
is this is yeah a different topic but a

757
00:30:30,399 --> 00:30:28,159
crushing star formation in elliptical

758
00:30:32,019 --> 00:30:30,409
galaxies is a thing that a lot of people

759
00:30:34,119 --> 00:30:32,029
spend a lot of time trying to figure out

760
00:30:36,279 --> 00:30:34,129
how does the universe do it it obviously

761
00:30:37,989 --> 00:30:36,289
is doing it you don't quite know how so

762
00:30:39,940 --> 00:30:37,999
one way we can get it to start up again

763
00:30:41,499 --> 00:30:39,950

is to collide to push them together it

764
00:30:45,339 --> 00:30:41,509
looks like right is that what we seeing

765
00:30:48,399 --> 00:30:45,349
here so uh we're on a related question

766
00:30:49,570 --> 00:30:48,409
with Adam synergy from the Q&A app so

767
00:30:51,849 --> 00:30:49,580
let me just go ahead and put this up

768
00:30:54,789 --> 00:30:51,859
he's asking is the gas fueling this

769
00:30:56,169 --> 00:30:54,799
burst of star formation is the gas

770
00:30:58,479 --> 00:30:56,179
fueling this star burst of star

771
00:31:00,579 --> 00:30:58,489
formation believed to originate in these

772
00:31:02,889 --> 00:31:00,589
elliptical galaxies or does it come from

773
00:31:04,329 --> 00:31:02,899
a shockwave linked to the merger or

774
00:31:06,159 --> 00:31:04,339
perhaps from elsewhere so you want to

775
00:31:07,959 --> 00:31:06,169
elaborate a little on that that is an

776
00:31:08,330 --> 00:31:07,969
absolutely fantastic question that's

777
00:31:10,580 --> 00:31:08,340
actually

778
00:31:12,500 --> 00:31:10,590
that is a fantastic question Adams will

779
00:31:16,190 --> 00:31:12,510
Adams one of the he asked a lot of great

780
00:31:18,529 --> 00:31:16,200
questions yeah go Adam uh yeah so so

781
00:31:20,210 --> 00:31:18,539
first of all we think of stars as I'm

782
00:31:22,039 --> 00:31:20,220
incredibly brilliant and energetic

783
00:31:24,260 --> 00:31:22,049
things but what's kind of weird is that

784
00:31:27,799 --> 00:31:24,270
you need to form stars out of puddles or

785
00:31:30,950 --> 00:31:27,809
reservoirs of super super cold gas so if

786
00:31:33,500 --> 00:31:30,960
you if you want to form a star you need

787
00:31:35,480 --> 00:31:33,510
to take gas and make and cool it all the

788
00:31:37,850 --> 00:31:35,490

way into these puddles or lakes or

789
00:31:39,799 --> 00:31:37,860
reservoirs of what's called very cold

790
00:31:42,260 --> 00:31:39,809
molecular gas we're talking tens of

791
00:31:44,269 --> 00:31:42,270
kelvin so super super cold dense stuff

792
00:31:47,840 --> 00:31:44,279
and then from there you can get core

793
00:31:49,970 --> 00:31:47,850
collapse in and and growth of these baby

794
00:31:52,970 --> 00:31:49,980
cellar seeds and then actually start to

795
00:31:55,070 --> 00:31:52,980
form stars so the one of Adam's

796
00:31:57,799 --> 00:31:55,080
excellent question is a very pertinent

797
00:32:00,049 --> 00:31:57,809
one was this molecular gas that is now

798
00:32:02,570 --> 00:32:00,059
forming these stars already in the

799
00:32:05,330 --> 00:32:02,580
galaxies before they before they crash

800
00:32:08,389 --> 00:32:05,340
together and has has the collision of

801
00:32:10,909 --> 00:32:08,399
the galaxies sort of stirred up this

802
00:32:12,710 --> 00:32:10,919
molecular gas so like like water in a

803
00:32:14,960 --> 00:32:12,720
bathtub which is just sitting there if

804
00:32:16,970 --> 00:32:14,970
you if you if you have them I don't know

805
00:32:20,000 --> 00:32:16,980
you crash the bathtub into something

806
00:32:22,070 --> 00:32:20,010
else you get waves in the bathtub and do

807
00:32:27,019 --> 00:32:22,080
we form stars now along these waves or

808
00:32:29,960 --> 00:32:27,029
um are we continuously raining cooling

809
00:32:32,060 --> 00:32:29,970
gasps from the ambient hot x-ray halo

810
00:32:34,700 --> 00:32:32,070
that surrounds these these two galaxies

811
00:32:37,399 --> 00:32:34,710
um so I've skipped a step there because

812
00:32:40,580 --> 00:32:37,409
yes giant elliptical galaxy sit in a

813
00:32:45,110 --> 00:32:40,590

bath of ambient plasma tens of millions

814
00:32:47,720 --> 00:32:45,120
of degrees hot um and very often when

815
00:32:50,570 --> 00:32:47,730
the central density of this plasma is

816
00:32:53,269 --> 00:32:50,580
high enough that central plasma can cool

817
00:32:54,799 --> 00:32:53,279
very rapidly we're talking on 300

818
00:32:57,310 --> 00:32:54,809
million year time skills which to an

819
00:33:02,060 --> 00:32:57,320
astronomer is a very short time scale um

820
00:33:05,630 --> 00:33:02,070
so uh enough to form stars yeah so we so

821
00:33:07,399 --> 00:33:05,640
to address Adams question this this

822
00:33:09,200 --> 00:33:07,409
these stars could be forming I mean

823
00:33:11,120 --> 00:33:09,210
molecular gas that was already in the

824
00:33:12,620 --> 00:33:11,130
galaxies to begin with and has now just

825
00:33:15,320 --> 00:33:12,630
been stirred up because the galaxies

826
00:33:18,710 --> 00:33:15,330
have collided together or this could be

827
00:33:21,890 --> 00:33:18,720
like a slow rain of cooling gasps from

828
00:33:26,540 --> 00:33:21,900
the ambient x-ray atmosphere that forms

829
00:33:29,660 --> 00:33:26,550
puddles and I and the the merging

830
00:33:31,880 --> 00:33:29,670
process is associated with huge

831
00:33:35,060 --> 00:33:31,890
gravitational torques enormous amounts

832
00:33:38,330 --> 00:33:35,070
of sheer um and and so maybe this rain

833
00:33:40,070 --> 00:33:38,340
is falling into this rather violent

834
00:33:41,750 --> 00:33:40,080
process of two galaxies coming together

835
00:33:43,520 --> 00:33:41,760
and that's what's creates this this

836
00:33:46,910 --> 00:33:43,530
really bizarre morphology that we see in

837
00:33:50,450 --> 00:33:46,920
the in the star formation uh plus or

838
00:33:54,130 --> 00:33:50,460

minus its up a material that you're

839
00:33:56,660 --> 00:33:54,140
suggesting that police from the other

840
00:34:01,490 --> 00:33:56,670
hey Tony I think you're going through a

841
00:34:04,460 --> 00:34:01,500
pole right now ah yeah Tony

842
00:34:06,200 --> 00:34:04,470
gravitationally lens yeah we're getting

843
00:34:12,169 --> 00:34:06,210
spaghettification of your data stream

844
00:34:15,860 --> 00:34:12,179
yes can we fix that okay known to deface

845
00:34:18,320 --> 00:34:15,870
it I put something on the chat and we

846
00:34:20,750 --> 00:34:18,330
can ask the question okay yeah all right

847
00:34:22,580 --> 00:34:20,760
I'll speak for you uh hello am i back

848
00:34:24,680 --> 00:34:22,590
yet yes you're sending much much better

849
00:34:26,139 --> 00:34:24,690
okay good so my question was are you

850
00:34:30,340 --> 00:34:26,149
leaning I think the press release

851
00:34:33,230 --> 00:34:30,350
indicated that it might be more of a

852
00:34:34,639 --> 00:34:33,240
rain of material explanation do you have

853
00:34:37,930 --> 00:34:34,649
a preference over one of these

854
00:34:40,490 --> 00:34:37,940
explanations of over the other yeah so I

855
00:34:43,010 --> 00:34:40,500
our initial look at this cluster formed

856
00:34:45,500 --> 00:34:43,020
three basic hypothesis to test all of

857
00:34:49,070 --> 00:34:45,510
these hypotheses you need follow-up data

858
00:34:50,780 --> 00:34:49,080
so I it this could very possibly be

859
00:34:53,659 --> 00:34:50,790
arranged from the hot x-ray atmosphere

860
00:34:56,570 --> 00:34:53,669
but we note we won't know until we get

861
00:34:58,100 --> 00:34:56,580
um a Chandra x-ray observation of this

862
00:35:00,740 --> 00:34:58,110
source which has now been approved it

863
00:35:03,290 --> 00:35:00,750

was approved last month and it will take

864
00:35:05,510 --> 00:35:03,300
place sometime during this year okay so

865
00:35:08,030 --> 00:35:05,520
Chandra will look at this thing for 130

866
00:35:11,270 --> 00:35:08,040
killa seconds which is a number of days

867
00:35:13,310 --> 00:35:11,280
I think or it's quite a while 130,000

868
00:35:16,120 --> 00:35:13,320
seconds yeah it will stare right at this

869
00:35:18,440 --> 00:35:16,130
source and we'll get a very exquisite

870
00:35:21,260 --> 00:35:18,450
high-resolution x-ray image which we can

871
00:35:24,650 --> 00:35:21,270
then overlay on our beautiful HST image

872
00:35:26,660 --> 00:35:24,660
and we can do a multitude of tests so

873
00:35:28,880 --> 00:35:26,670
what we can do spatially resolved

874
00:35:32,060 --> 00:35:28,890
spectroscopy to get the temperature of

875
00:35:34,990 --> 00:35:32,070
the hot x-ray plasma and we can do a

876
00:35:37,780 --> 00:35:35,000
density entropy pressure maps

877
00:35:40,390 --> 00:35:37,790
that those are buzz words uh for for

878
00:35:42,700 --> 00:35:40,400
what ultimately is we'll find out if

879
00:35:45,160 --> 00:35:42,710
this could be a waterfall of cooling

880
00:35:47,740 --> 00:35:45,170
gasps from the x-ray atmosphere or a

881
00:35:50,050 --> 00:35:47,750
shock in the in the colliding hot x-ray

882
00:35:52,390 --> 00:35:50,060
halos between these two galaxies if you

883
00:35:54,220 --> 00:35:52,400
if you collide two galaxies together you

884
00:35:59,350 --> 00:35:54,230
also collide they're two halos together

885
00:36:02,350 --> 00:35:59,360
so maybe you're a shot colliding they're

886
00:36:05,620 --> 00:36:02,360
too hot x-ray plasma halos then you

887
00:36:08,050 --> 00:36:05,630
create this high-density sheet of x-ray

888
00:36:10,450 --> 00:36:08,060

gas between the two galaxies and when

889
00:36:13,630 --> 00:36:10,460
you increase x-ray gas density you also

890
00:36:15,490 --> 00:36:13,640
increase its cooling rate so the very

891
00:36:18,370 --> 00:36:15,500
act of these galaxies colliding together

892
00:36:20,380 --> 00:36:18,380
could have set up kind of a waterfall a

893
00:36:22,720 --> 00:36:20,390
sheet of cooling gas between the

894
00:36:24,370 --> 00:36:22,730
galaxies and then what you're seeing in

895
00:36:26,830 --> 00:36:24,380
this blue emission is like rocks at the

896
00:36:28,870 --> 00:36:26,840
bottom of the waterfall this is this

897
00:36:30,760 --> 00:36:28,880
this sheet of cooling gas forms these

898
00:36:32,110 --> 00:36:30,770
puddles of cold molecular gas and then

899
00:36:33,490 --> 00:36:32,120
this is where your form the stars so

900
00:36:35,860 --> 00:36:33,500
that's another hypothesis that we can

901
00:36:38,050 --> 00:36:35,870
test with this follow-up data is as

902
00:36:41,260 --> 00:36:38,060
usual it's always more observations are

903
00:36:42,760 --> 00:36:41,270
needed yeah it's sure as always so good

904
00:36:44,980 --> 00:36:42,770
I well I look forward to hearing more

905
00:36:46,930 --> 00:36:44,990
about that when Chandra is able to look

906
00:36:48,310 --> 00:36:46,940
at it a little bit as well now this is

907
00:36:50,530 --> 00:36:48,320
something that the press release called

908
00:36:53,170 --> 00:36:50,540
a beads on a string feature or

909
00:36:55,660 --> 00:36:53,180
phenomenon and and while it seems to be

910
00:36:58,330 --> 00:36:55,670
unusual in elliptical galaxies it's not

911
00:37:02,550 --> 00:36:58,340
so unusual in galaxy collisions in

912
00:37:07,300 --> 00:37:02,560
general is that correct judge game or

913
00:37:08,710 --> 00:37:07,310

should I ask grant can you hear me yeah

914
00:37:12,700 --> 00:37:08,720
grant why don't you take that one all

915
00:37:15,640 --> 00:37:12,710
right yeah so um so what you're seeing

916
00:37:18,250 --> 00:37:15,650
here is so if you can see the image what

917
00:37:20,430 --> 00:37:18,260
you see are not only blue filaments but

918
00:37:23,080 --> 00:37:20,440
you see clumps along these filaments and

919
00:37:25,330 --> 00:37:23,090
these clumps appear to be at least in

920
00:37:27,130 --> 00:37:25,340
projection relatively equally spaced

921
00:37:28,750 --> 00:37:27,140
from one another so it kind of looks

922
00:37:32,860 --> 00:37:28,760
like a pearl necklace that's kind of

923
00:37:36,070 --> 00:37:32,870
laid out on a table right okay so this

924
00:37:37,390 --> 00:37:36,080
is not something new so in 1983 a group

925
00:37:39,790 --> 00:37:37,400
of astronomers we're looking at images

926
00:37:41,950 --> 00:37:39,800
of spiral galaxies and they published a

927
00:37:44,080 --> 00:37:41,960
paper saying hey if you actually look at

928
00:37:45,580 --> 00:37:44,090
the arms of spiral galaxies star

929
00:37:48,130 --> 00:37:45,590
formation in those arms doesn't happen

930
00:37:51,670 --> 00:37:48,140
in uniform filaments it happens

931
00:37:53,740 --> 00:37:51,680
equally spaced corners and all of these

932
00:37:55,930 --> 00:37:53,750
clumps appear to be separated by about

933
00:37:57,970 --> 00:37:55,940
one kiloparsecs one kiloparsecs about

934
00:37:59,470 --> 00:37:57,980
3,000 light-years these clumps appear to

935
00:38:02,050 --> 00:37:59,480
be separated by 3,000 light-years from

936
00:38:04,240 --> 00:38:02,060
one another so they turn this beads on a

937
00:38:07,240 --> 00:38:04,250
string morphology and it turns out that

938
00:38:09,490 --> 00:38:07,250

this is not actually particularly its

939
00:38:11,470 --> 00:38:09,500
profound but it's not profound in the

940
00:38:13,720 --> 00:38:11,480
sense that it's that surprising because

941
00:38:15,730 --> 00:38:13,730
it's really just a kiloparsecs scale

942
00:38:18,310 --> 00:38:15,740
manifestation of something called the

943
00:38:21,100 --> 00:38:18,320
jeans length which is related to the

944
00:38:22,840 --> 00:38:21,110
jeans instability which is which would

945
00:38:25,360 --> 00:38:22,850
be another hubble hang out to talk about

946
00:38:29,170 --> 00:38:25,370
but you can think of but it 10 words or

947
00:38:31,870 --> 00:38:29,180
less you have to tell us so in 10 words

948
00:38:34,540 --> 00:38:31,880
of less is this rain falling from clouds

949
00:38:36,520 --> 00:38:34,550
in the sky doesn't occur in continuous

950
00:38:38,790 --> 00:38:36,530
filaments that are unbroken from the

951
00:38:42,270 --> 00:38:38,800
ground to the sky rain falls and drops

952
00:38:46,540 --> 00:38:42,280
why does rain falling drops because a

953
00:38:49,120 --> 00:38:46,550
cylinder of a fluid will prefer to

954
00:38:50,740 --> 00:38:49,130
contract into a series of droplets just

955
00:38:52,810 --> 00:38:50,750
because those spherical droplets are a

956
00:38:56,470 --> 00:38:52,820
lower energy configuration so just like

957
00:38:59,770 --> 00:38:56,480
wow that was outstanding words but it

958
00:39:01,600 --> 00:38:59,780
was a great explanation though I want to

959
00:39:03,370 --> 00:39:01,610
be careful here for our more advanced

960
00:39:05,500 --> 00:39:03,380
audience like Adam because Adam is about

961
00:39:07,780 --> 00:39:05,510
to complain yes the genes like is it

962
00:39:09,640 --> 00:39:07,790
does involve a bit slightly different

963
00:39:11,230 --> 00:39:09,650

physics well when you actually boil it

964
00:39:13,390 --> 00:39:11,240
down to the fundamental processes of

965
00:39:15,130 --> 00:39:13,400
what's going on the the physics that

966
00:39:18,430 --> 00:39:15,140
dictates the morphology of this star

967
00:39:20,530 --> 00:39:18,440
formation arm is not much different from

968
00:39:23,320 --> 00:39:20,540
the reason why when you turn your water

969
00:39:25,900 --> 00:39:23,330
faucet on in your kitchen the the it

970
00:39:27,610 --> 00:39:25,910
really slowly the water will will

971
00:39:28,930 --> 00:39:27,620
contract and fall into a series of

972
00:39:31,030 --> 00:39:28,940
droplets by the time it reaches the

973
00:39:34,510 --> 00:39:31,040
bottom of your sink it's the same

974
00:39:36,400 --> 00:39:34,520
physics I have a question actually but

975
00:39:38,410 --> 00:39:36,410
it's not exactly what you were talking

976
00:39:41,520 --> 00:39:38,420
about it wasn't a fat jeans length um

977
00:39:44,470 --> 00:39:41,530
you were talking about the tool

978
00:39:47,200 --> 00:39:44,480
elliptical galaxies and the fact that

979
00:39:49,420 --> 00:39:47,210
they may be merging and or they may be

980
00:39:51,160 --> 00:39:49,430
getting material rain down on them and

981
00:39:53,590 --> 00:39:51,170
you were talking about the morphology

982
00:39:55,930 --> 00:39:53,600
the halos in the image we are looking at

983
00:39:58,180 --> 00:39:55,940
right now it looks like it doesn't look

984
00:40:02,140 --> 00:39:58,190
like a double load halo it looks like a

985
00:40:06,880 --> 00:40:02,150
single spherical halo and if you go back

986
00:40:09,849 --> 00:40:06,890
to the larger view um it looks like the

987
00:40:12,010 --> 00:40:09,859
the ring of Arc's is actually at a

988
00:40:15,670 --> 00:40:12,020

slightly different orientation but it

989
00:40:21,549 --> 00:40:15,680
does encircle it cause any circle those

990
00:40:24,309 --> 00:40:21,559
two objects is that completely unrelated

991
00:40:25,900 --> 00:40:24,319
I mean that is the mass distribution

992
00:40:28,059 --> 00:40:25,910
that's causing the lens and it's also

993
00:40:30,130 --> 00:40:28,069
the mass distribution plus maybe gas

994
00:40:32,589 --> 00:40:30,140
that's causing the star formation is

995
00:40:39,819 --> 00:40:32,599
does one tell you anything about the

996
00:40:42,430 --> 00:40:39,829
other earning so first of all don't let

997
00:40:44,620 --> 00:40:42,440
that appearance of those are extra cute

998
00:40:48,430 --> 00:40:44,630
of thinking that the mass is distributed

999
00:40:54,490 --> 00:40:48,440
in the same direction as those arcs it's

1000
00:40:57,190 --> 00:40:54,500
not necessarily always follow mm-hmm in

1001
00:41:00,519 --> 00:40:57,200
this particular case the mass is aligned

1002
00:41:03,220 --> 00:41:00,529
along the line that connects those two

1003
00:41:07,180 --> 00:41:03,230
galaxies to each other released in

1004
00:41:12,910 --> 00:41:07,190
projection so the cluster is elongated

1005
00:41:15,160 --> 00:41:12,920
in the direction of the merger okay okay

1006
00:41:16,870 --> 00:41:15,170
thank you so let I got a couple of good

1007
00:41:19,329 --> 00:41:16,880
questions here on the Q&A app let me

1008
00:41:21,940 --> 00:41:19,339
bring one up here from Ayman Fantin he's

1009
00:41:24,970 --> 00:41:21,950
going optical lenses have a focal length

1010
00:41:26,740 --> 00:41:24,980
if the hidden galaxy is exactly at the

1011
00:41:30,130 --> 00:41:26,750
focal length would you get a perfect

1012
00:41:32,640 --> 00:41:30,140
image of that galaxy so I guess he's

1013
00:41:35,410 --> 00:41:32,650

asking would we is there is there a

1014
00:41:36,940 --> 00:41:35,420
configuration a way in which we can look

1015
00:41:42,130 --> 00:41:36,950
at these lens galaxies which would be

1016
00:41:44,019 --> 00:41:42,140
perfectly in focus yeah so um there is

1017
00:41:46,299 --> 00:41:44,029
such a thing and it's called an Einstein

1018
00:41:48,880 --> 00:41:46,309
ring and this generally would happen

1019
00:41:52,240 --> 00:41:48,890
when there's a very simple lens like one

1020
00:41:54,460 --> 00:41:52,250
galaxy that is very massive and an

1021
00:41:57,730 --> 00:41:54,470
object like a another galaxy that is

1022
00:41:59,829 --> 00:41:57,740
exactly exactly behind it and then

1023
00:42:02,109 --> 00:41:59,839
instead of getting let's say two images

1024
00:42:05,170 --> 00:42:02,119
of the same thing or 3d images are the

1025
00:42:07,000 --> 00:42:05,180
same thing you'll get infinite images of

1026
00:42:11,260 --> 00:42:07,010
the same thing and that would form a

1027
00:42:14,410 --> 00:42:11,270
perfect Einstein ring we have there are

1028
00:42:15,520 --> 00:42:14,420
a lot of examples of those things this

1029
00:42:17,530 --> 00:42:15,530
usually doesn't happen

1030
00:42:20,440 --> 00:42:17,540
in clusters because they are very

1031
00:42:23,020 --> 00:42:20,450
complicated there's a lot of mass and

1032
00:42:25,180 --> 00:42:23,030
the distribution of mass is not just one

1033
00:42:27,010 --> 00:42:25,190
object yeah we've talked about that at

1034
00:42:28,960 --> 00:42:27,020
length with our frontier fields hanging

1035
00:42:32,080 --> 00:42:28,970
out we're like here's an example oh yeah

1036
00:42:34,450 --> 00:42:32,090
it's got sample of one of the lensing

1037
00:42:36,900 --> 00:42:34,460
models that they're using for frontier

1038
00:42:40,120 --> 00:42:36,910

fields and this would be sort of what

1039
00:42:42,040 --> 00:42:40,130
you're describing Karen with the optics

1040
00:42:43,090 --> 00:42:42,050
you know the mathematical representation

1041
00:42:44,490 --> 00:42:43,100
of what are the optics with this system

1042
00:42:48,940 --> 00:42:44,500
this is one of the frontier fields

1043
00:42:50,680 --> 00:42:48,950
models but this as you can see they're

1044
00:42:52,890 --> 00:42:50,690
pretty complicated right you want to

1045
00:42:56,130 --> 00:42:52,900
comment on this just a little bit maybe

1046
00:42:58,750 --> 00:42:56,140
yeah so clusters of galaxies have

1047
00:43:01,510 --> 00:42:58,760
galaxies in them they also have a lot of

1048
00:43:05,440 --> 00:43:01,520
dark matter and they're actually nodes

1049
00:43:08,680 --> 00:43:05,450
in the cosmic web of things coming

1050
00:43:10,870 --> 00:43:08,690
together so unlike one galaxy which is

1051
00:43:13,420 --> 00:43:10,880
which could be very isolated from the

1052
00:43:16,090 --> 00:43:13,430
rest of its environment this really

1053
00:43:19,330 --> 00:43:16,100
feeds on dark matter and gas and

1054
00:43:22,360 --> 00:43:19,340
galaxies from the entire cosmic web so

1055
00:43:23,940 --> 00:43:22,370
it's not very smooth and symmetrical

1056
00:43:26,770 --> 00:43:23,950
looking sometimes it could look like

1057
00:43:31,740 --> 00:43:26,780
this picture that you have on now like a

1058
00:43:35,590 --> 00:43:31,750
weird amoeba thing right um so it's it's

1059
00:43:37,630 --> 00:43:35,600
more complicated yeah so these these

1060
00:43:40,600 --> 00:43:37,640
things can get quite quite messy when it

1061
00:43:42,070 --> 00:43:40,610
comes to galaxy clusters okay Hugo

1062
00:43:45,430 --> 00:43:42,080
Burnham he's always great he's got a

1063
00:43:49,720 --> 00:43:45,440

comment here 130 k seconds equals 36

1064
00:43:52,900 --> 00:43:49,730
hours plus change thank you Matt in my

1065
00:43:55,450 --> 00:43:52,910
head and my guys not happening oh yeah

1066
00:43:59,080 --> 00:43:55,460
so thank you I was often we appreciate

1067
00:44:00,760 --> 00:43:59,090
your helping us out there I have one

1068
00:44:04,210 --> 00:44:00,770
other another comment also from Iman

1069
00:44:06,640 --> 00:44:04,220
phanton uh will gravitational lensing

1070
00:44:09,100 --> 00:44:06,650
effect the redshifts of the objects

1071
00:44:12,520 --> 00:44:09,110
being lanced what are the implications

1072
00:44:15,040 --> 00:44:12,530
or uses if redshift is affected can the

1073
00:44:17,170 --> 00:44:15,050
distance to the lens galaxies be

1074
00:44:19,210 --> 00:44:17,180
measured accurately so two questions

1075
00:44:21,520 --> 00:44:19,220
there one is does it affect the

1076
00:44:24,070 --> 00:44:21,530
redshifts of the object being lens and

1077
00:44:26,350 --> 00:44:24,080
the other is can the distance of these

1078
00:44:27,920 --> 00:44:26,360
lens galaxies be measured accurately who

1079
00:44:30,110 --> 00:44:27,930
wants to take that one

1080
00:44:33,290 --> 00:44:30,120
yeah so the redshift is something that

1081
00:44:37,040 --> 00:44:33,300
you measure and it has to do with the

1082
00:44:39,110 --> 00:44:37,050
expansion of the universe and how it the

1083
00:44:42,230 --> 00:44:39,120
galaxy would seem like they're getting

1084
00:44:44,660 --> 00:44:42,240
farther and farther away from us there

1085
00:44:46,610 --> 00:44:44,670
we the wavelength of the light that

1086
00:44:48,230 --> 00:44:46,620
comes to us becomes red shifted so this

1087
00:44:50,270 --> 00:44:48,240
is something that is that can be

1088
00:44:53,540 --> 00:44:50,280

measured and it's not affected by

1089
00:44:55,580 --> 00:44:53,550
gravitational lensing the distance can

1090
00:44:59,150 --> 00:44:55,590
actually be measured from gravitational

1091
00:45:02,710 --> 00:44:59,160
lensing because the geometry of the lens

1092
00:45:07,220 --> 00:45:02,720
or how powerful the lens is is affected

1093
00:45:10,670 --> 00:45:07,230
or is related to that this the geometry

1094
00:45:13,310 --> 00:45:10,680
so how far the lens is from you how far

1095
00:45:14,840 --> 00:45:13,320
the background source is from you and

1096
00:45:18,260 --> 00:45:14,850
how far the background source is from

1097
00:45:22,510 --> 00:45:18,270
the lens so all those three distances

1098
00:45:25,610 --> 00:45:22,520
and and yes you can send you can

1099
00:45:29,150 --> 00:45:25,620
independently measure the redshift and

1100
00:45:31,220 --> 00:45:29,160
measure the distances and this can in

1101
00:45:34,700 --> 00:45:31,230
theory give you information about the

1102
00:45:37,190 --> 00:45:34,710
above the zoology and about the geometry

1103
00:45:39,350 --> 00:45:37,200
of the universe great good question

1104
00:45:42,260 --> 00:45:39,360
thank you aim that was good so Judy

1105
00:45:44,120 --> 00:45:42,270
Schmidt has a comment those J 1 2 3 4

1106
00:45:46,340 --> 00:45:44,130
plus blah blah blah names are just

1107
00:45:47,840 --> 00:45:46,350
shorthand coordinates as a layperson I

1108
00:45:49,790 --> 00:45:47,850
just wanted to mention it because it's a

1109
00:45:51,650 --> 00:45:49,800
simple thing that is not obvious but

1110
00:45:52,940 --> 00:45:51,660
helpful to understand why they are named

1111
00:45:54,950 --> 00:45:52,950
like they are that's correct they're

1112
00:45:58,010 --> 00:45:54,960
mostly just coordinating so thank you

1113
00:46:00,290 --> 00:45:58,020

point UT uh that that's an important

1114
00:46:03,620 --> 00:46:00,300
thing to point out and here's one from a

1115
00:46:05,750 --> 00:46:03,630
bond kasim I think and inside maybe this

1116
00:46:09,470 --> 00:46:05,760
one's for you grant I don't know where

1117
00:46:15,170 --> 00:46:09,480
does all energy go inside a black hole

1118
00:46:17,020 --> 00:46:15,180
exactly exactly exactly that is that is

1119
00:46:21,080 --> 00:46:17,030
a thing that is a very good question

1120
00:46:23,720 --> 00:46:21,090
first of all um you can't grow a black

1121
00:46:25,640 --> 00:46:23,730
hole for free so when you dump matter on

1122
00:46:27,860 --> 00:46:25,650
to a black hole you also at the same

1123
00:46:30,740 --> 00:46:27,870
time liberate an enormous amount of

1124
00:46:32,540 --> 00:46:30,750
gravitational energy that is why you see

1125
00:46:34,940 --> 00:46:32,550
things like radio galaxies and quasars

1126
00:46:39,340 --> 00:46:34,950
and things that I'm sure you've talked

1127
00:46:44,680 --> 00:46:42,060
well where the where the energy goes

1128
00:46:46,780 --> 00:46:44,690
within a black hole is absolutely a

1129
00:46:49,810 --> 00:46:46,790
subject that would be actually very nice

1130
00:46:53,080 --> 00:46:49,820
hang out mm-hm um it's a yeah that's a

1131
00:46:55,390 --> 00:46:53,090
very long and a complicated answer okay

1132
00:46:58,270 --> 00:46:55,400
well have Jane into that one she's way

1133
00:47:00,820 --> 00:46:58,280
more elegant than I am why we see the

1134
00:47:02,920 --> 00:47:00,830
that you know energy is mass and masses

1135
00:47:06,070 --> 00:47:02,930
energy and once mass goes down the point

1136
00:47:07,780 --> 00:47:06,080
of no return of the black hole it's gone

1137
00:47:10,330 --> 00:47:07,790
it's not accessible and the same is true

1138
00:47:12,070 --> 00:47:10,340

for energy and at some level that gets

1139
00:47:14,710 --> 00:47:12,080
no a philosophical question is it's

1140
00:47:17,110 --> 00:47:14,720
still in our universe then I can't touch

1141
00:47:19,870 --> 00:47:17,120
it if you can't get it back if you can't

1142
00:47:22,030 --> 00:47:19,880
you can't even send you a signal right

1143
00:47:26,110 --> 00:47:22,040
it becomes causally disconnected from us

1144
00:47:28,840 --> 00:47:26,120
yeah um yeah so but but I think I'd you

1145
00:47:30,340 --> 00:47:28,850
can't lend the ABS important sorry okay

1146
00:47:32,340 --> 00:47:30,350
I was just going to finish the thought

1147
00:47:35,020 --> 00:47:32,350
that because of mass-energy equivalence

1148
00:47:37,240 --> 00:47:35,030
energy that does get down there adds to

1149
00:47:38,770 --> 00:47:37,250
the mass of the black hole yes when we

1150
00:47:40,900 --> 00:47:38,780
talk about you know on the black hole

1151
00:47:43,630 --> 00:47:40,910
that weighs a billion times the mass of

1152
00:47:45,070 --> 00:47:43,640
the Sun that you could equally say it

1153
00:47:49,150 --> 00:47:45,080
has that much energy right that's just

1154
00:47:51,070 --> 00:47:49,160
how much stuff is in there okay I have

1155
00:47:53,350 --> 00:47:51,080
something from YouTube now this is craig

1156
00:47:56,650 --> 00:47:53,360
landon he's asking and i have it up on

1157
00:47:59,290 --> 00:47:56,660
my screen here could this be an event

1158
00:48:02,830 --> 00:47:59,300
similar to the bullet cluster collisions

1159
00:48:05,230 --> 00:48:02,840
with dark matter haloes colliding that

1160
00:48:08,260 --> 00:48:05,240
yes that is absolutely a fantastic

1161
00:48:10,960 --> 00:48:08,270
question so um I guess we don't have an

1162
00:48:13,270 --> 00:48:10,970
image of the bullet cluster IIIi got you

1163
00:48:14,950 --> 00:48:13,280

covered hold on just so I scrubbing the

1164
00:48:17,230 --> 00:48:14,960
internet for us oh yeah let's get it

1165
00:48:20,040 --> 00:48:17,240
okay so there's a combined HST and

1166
00:48:23,350 --> 00:48:20,050
Chandra image of the bullet cluster um I

1167
00:48:25,900 --> 00:48:23,360
to answer your question this so not only

1168
00:48:27,910 --> 00:48:25,910
do galaxies merge together but clusters

1169
00:48:31,810 --> 00:48:27,920
of galaxies also sometimes crash

1170
00:48:34,150 --> 00:48:31,820
together to this absolutely could be the

1171
00:48:36,400 --> 00:48:34,160
late stages of a cluster cluster merger

1172
00:48:39,040 --> 00:48:36,410
what we could be seeing is that those

1173
00:48:42,490 --> 00:48:39,050
two colliding galaxies at the center of

1174
00:48:45,280 --> 00:48:42,500
this image are actually the heads of two

1175
00:48:48,880 --> 00:48:45,290
smaller colliding clusters of galaxies

1176
00:48:50,500 --> 00:48:48,890
there's there's a bit of evidence for

1177
00:48:51,970 --> 00:48:50,510
this in the redshift distribution for

1178
00:48:53,350 --> 00:48:51,980
galaxies in the cluster you see what's

1179
00:48:55,270 --> 00:48:53,360
about a bit

1180
00:48:57,330 --> 00:48:55,280
bifurcation and redshift space meaning a

1181
00:49:00,880 --> 00:48:57,340
slight by modality and redshift space um

1182
00:49:02,140 --> 00:49:00,890
for only about thirteen of the of the

1183
00:49:03,430 --> 00:49:02,150
galaxies in this cluster so we're

1184
00:49:05,050 --> 00:49:03,440
talking about low statistics and

1185
00:49:07,320 --> 00:49:05,060
therefore low confidence in that in the

1186
00:49:09,940 --> 00:49:07,330
hypothesis but this could absolutely be

1187
00:49:11,260 --> 00:49:09,950
the late stages of a cluster merger kind

1188
00:49:13,030 --> 00:49:11,270

of like what you're seeing here with the

1189
00:49:16,840 --> 00:49:13,040
bullet cluster Scott's got it up now

1190
00:49:18,850 --> 00:49:16,850
yeah I think spoke a great uh and we

1191
00:49:21,700 --> 00:49:18,860
will be able to test this hypothesis

1192
00:49:23,440 --> 00:49:21,710
with a Chandra observation and with

1193
00:49:26,950 --> 00:49:23,450
follow-up observations from the ground

1194
00:49:30,700 --> 00:49:26,960
for example if we get um optical

1195
00:49:32,950 --> 00:49:30,710
spectroscopy for more many many more of

1196
00:49:34,720 --> 00:49:32,960
the galaxies in this cluster we can more

1197
00:49:36,880 --> 00:49:34,730
accurately map the redshift distribution

1198
00:49:39,130 --> 00:49:36,890
and therefore it kind of sculpt out the

1199
00:49:41,230 --> 00:49:39,140
3d geometry of galaxies in this cluster

1200
00:49:43,630 --> 00:49:41,240
and try to work out what's happening

1201
00:49:44,830 --> 00:49:43,640
here this absolutely could be a cluster

1202
00:49:46,240 --> 00:49:44,840
merchant why don't you give us just a

1203
00:49:47,380 --> 00:49:46,250
real quick description of this what

1204
00:49:49,930 --> 00:49:47,390
we're looking at with the bullet cluster

1205
00:49:51,460 --> 00:49:49,940
here yeah so let me pull up Scott's

1206
00:49:54,070 --> 00:49:51,470
image that I can do it just just click

1207
00:49:56,320 --> 00:49:54,080
on it there exactly so so the bullet

1208
00:49:58,300 --> 00:49:56,330
cluster is is like that famous picture

1209
00:50:01,390 --> 00:49:58,310
of a bullet going through an apple right

1210
00:50:03,340 --> 00:50:01,400
so uh two massive clusters of galaxies

1211
00:50:06,130 --> 00:50:03,350
that were once relatively independent

1212
00:50:08,470 --> 00:50:06,140
have crashed together and one has now

1213
00:50:10,510 --> 00:50:08,480

passed through the other just like just

1214
00:50:12,250 --> 00:50:10,520
like the bullet that you know that slow

1215
00:50:15,010 --> 00:50:12,260
motion bullet through an apple the

1216
00:50:18,970 --> 00:50:15,020
famous image right yeah um and what you

1217
00:50:21,940 --> 00:50:18,980
see in that kind of um v-shaped or

1218
00:50:25,530 --> 00:50:21,950
l-shaped pink material off to the right

1219
00:50:29,890 --> 00:50:25,540
I guess that's kind of obvious right um

1220
00:50:31,780 --> 00:50:29,900
that's that is a shock in the x-ray gas

1221
00:50:34,830 --> 00:50:31,790
that has been associated with this

1222
00:50:37,260 --> 00:50:34,840
bullet this this much faster cluster

1223
00:50:41,350 --> 00:50:37,270
plowing through at very high velocity

1224
00:50:43,870 --> 00:50:41,360
this more massive cluster um that you

1225
00:50:45,430 --> 00:50:43,880
see to the left so it's taken one full

1226
00:50:47,200 --> 00:50:45,440
passage through the cluster and it's

1227
00:50:49,660 --> 00:50:47,210
created this sort of shock wave in the

1228
00:50:53,830 --> 00:50:49,670
x-ray gas um that you see in pink

1229
00:50:55,480 --> 00:50:53,840
they're nice all right very good grant

1230
00:50:58,090 --> 00:50:55,490
you know I'm really glad that this

1231
00:51:04,090 --> 00:50:58,100
question came up because if you look

1232
00:51:07,210 --> 00:51:04,100
back at our our cluster 1531 uh the lens

1233
00:51:10,300 --> 00:51:07,220
model sorry that should be up

1234
00:51:11,770 --> 00:51:10,310
already in the vineyards up um so grant

1235
00:51:15,599 --> 00:51:11,780
the lens model does indicate that

1236
00:51:18,609 --> 00:51:15,609
there's a more mass to the you know

1237
00:51:21,910 --> 00:51:18,619
southeast which is the left ten side of

1238
00:51:24,730 --> 00:51:21,920

this picture the lens model does want

1239
00:51:27,790 --> 00:51:24,740
this cluster to have mass in that

1240
00:51:29,859 --> 00:51:27,800
direction that could indicate some

1241
00:51:32,920 --> 00:51:29,869
stages of merger or past murder that

1242
00:51:34,780 --> 00:51:32,930
happened well we should i we should talk

1243
00:51:35,859 --> 00:51:34,790
about this more the three of us are

1244
00:51:37,780 --> 00:51:35,869
going to have fun when we get this

1245
00:51:39,070 --> 00:51:37,790
Chandra observation well sounds like it

1246
00:51:40,990 --> 00:51:39,080
yeah that sounds like we should check

1247
00:51:42,520 --> 00:51:41,000
back in with you guys to to see to see

1248
00:51:44,260 --> 00:51:42,530
what develops out of that because uh

1249
00:51:45,550 --> 00:51:44,270
that sounds like you you're going to be

1250
00:51:47,920 --> 00:51:45,560
able to answer some big questions with

1251
00:51:51,070 --> 00:51:47,930
this um so here's one from Dan Buddha on

1252
00:51:53,050 --> 00:51:51,080
the quick the question Q&A app if the

1253
00:51:55,990 --> 00:51:53,060
galaxies are getting far and farther

1254
00:51:59,560 --> 00:51:56,000
away from one another why do we have

1255
00:52:00,910 --> 00:51:59,570
clusters and so if all the galaxies in

1256
00:52:03,099 --> 00:52:00,920
the universe is expanding and getting

1257
00:52:04,690 --> 00:52:03,109
far away why are there clusters well in

1258
00:52:09,370 --> 00:52:04,700
some places the expansion of the

1259
00:52:11,740 --> 00:52:09,380
universe can overcome gravity gravity if

1260
00:52:14,560 --> 00:52:11,750
things are very very massive they just

1261
00:52:16,839 --> 00:52:14,570
gravitate towards each other and create

1262
00:52:18,730 --> 00:52:16,849
very massive objects that just be couple

1263
00:52:21,280 --> 00:52:18,740

from the expansion of the universe so

1264
00:52:23,109 --> 00:52:21,290
they in some sense they don't expand

1265
00:52:26,109 --> 00:52:23,119
with the universe kind of like the cells

1266
00:52:28,510 --> 00:52:26,119
in your body they stick together with

1267
00:52:30,490 --> 00:52:28,520
other forces and they don't expand with

1268
00:52:32,710 --> 00:52:30,500
the universe that's right even though

1269
00:52:36,400 --> 00:52:32,720
although I think Scott's head expands

1270
00:52:39,430 --> 00:52:36,410
with the universe so yeah accelerating

1271
00:52:41,410 --> 00:52:39,440
at least what rain expansion is

1272
00:52:43,120 --> 00:52:41,420
accelerating correctly so that's a good

1273
00:52:44,920 --> 00:52:43,130
point i mean even though space-time is

1274
00:52:46,329 --> 00:52:44,930
getting you know there's more of it and

1275
00:52:49,030 --> 00:52:46,339
it's getting further and further apart

1276
00:52:50,880 --> 00:52:49,040
it pushed the biggies galaxies or the

1277
00:52:52,870 --> 00:52:50,890
universe is getting further apart

1278
00:52:54,790 --> 00:52:52,880
locally there sometimes when you have

1279
00:52:57,130 --> 00:52:54,800
big clumps of things together like a

1280
00:53:00,430 --> 00:52:57,140
bunch of galaxies their gravity is not

1281
00:53:01,810 --> 00:53:00,440
overcome by this by this expansion so

1282
00:53:06,220 --> 00:53:01,820
that's a good distinction thank you for

1283
00:53:08,620 --> 00:53:06,230
the question so let's see Michael jobin

1284
00:53:12,010 --> 00:53:08,630
is going could the dark matter in the

1285
00:53:13,750 --> 00:53:12,020
Galactic barrier could it could tart

1286
00:53:16,329 --> 00:53:13,760
matter be the Galactic barrier mentioned

1287
00:53:18,370 --> 00:53:16,339
in Star Trek oh yeah sure hey y'all I'll

1288
00:53:19,720 --> 00:53:18,380

take that one yeah I'm just going to

1289
00:53:21,160 --> 00:53:19,730
take that when is that going to turn my

1290
00:53:24,190 --> 00:53:21,170
eyes white

1291
00:53:26,650 --> 00:53:24,200
and yes no totally jealous psychic

1292
00:53:29,140 --> 00:53:26,660
powers cuz that would be great yeah I

1293
00:53:31,089 --> 00:53:29,150
could maybe to that I'm gonna be cute

1294
00:53:33,400 --> 00:53:31,099
I'll see your fingers you're going q

1295
00:53:39,730 --> 00:53:33,410
what is absolutely yes you're expanding

1296
00:53:41,620 --> 00:53:39,740
head space and space okay we're getting

1297
00:53:43,839 --> 00:53:41,630
a couple more here on the Q&A app here's

1298
00:53:45,940 --> 00:53:43,849
one more here's one from Tom common with

1299
00:53:47,770 --> 00:53:45,950
those two colliding ellipticals could

1300
00:53:50,079 --> 00:53:47,780
the blue stuff in there be superimposed

1301
00:53:52,569 --> 00:53:50,089
signals because they are near the same

1302
00:53:55,660 --> 00:53:52,579
line of sight and not actually collide

1303
00:53:59,380 --> 00:53:55,670
that changed the detection from orange

1304
00:54:02,650 --> 00:53:59,390
to blue um I'm not sure how to well no I

1305
00:54:04,900 --> 00:54:02,660
I think look Jenna okay that's actually

1306
00:54:06,970 --> 00:54:04,910
a fantastic question so everything we

1307
00:54:09,549 --> 00:54:06,980
see on the sky is three-dimensional

1308
00:54:11,380 --> 00:54:09,559
stuff that's been projected into two

1309
00:54:13,180 --> 00:54:11,390
dimensional space so we're really

1310
00:54:15,760 --> 00:54:13,190
watching a universal puppet show in

1311
00:54:18,130 --> 00:54:15,770
shadows right shadow hand puppet show

1312
00:54:19,960 --> 00:54:18,140
right so it's very important that when

1313
00:54:21,579 --> 00:54:19,970

you're looking at a 2d image you

1314
00:54:24,099 --> 00:54:21,589
understand the 3d structure of what

1315
00:54:25,900 --> 00:54:24,109
you're looking at and so when we got

1316
00:54:27,819 --> 00:54:25,910
this HSC image of the cluster this

1317
00:54:30,190 --> 00:54:27,829
Hubble image of the cluster one of the

1318
00:54:32,349 --> 00:54:30,200
first questions you ask yourself is well

1319
00:54:34,510 --> 00:54:32,359
am I just seeing a projection effect of

1320
00:54:36,309 --> 00:54:34,520
stuff along the line of sight maybe all

1321
00:54:38,859 --> 00:54:36,319
of this blue squiggly stuff in the in

1322
00:54:40,780 --> 00:54:38,869
that we see in the center is completely

1323
00:54:42,789 --> 00:54:40,790
unrelated to these two galaxies and

1324
00:54:44,530 --> 00:54:42,799
maybe it's just sort of in the in front

1325
00:54:47,079 --> 00:54:44,540
of me or even as we were talking about

1326
00:54:49,240 --> 00:54:47,089
earlier behind the cluster and maybe

1327
00:54:50,799 --> 00:54:49,250
it's a gravitationally lensed image so

1328
00:54:53,710 --> 00:54:50,809
this is one of the first things that we

1329
00:54:55,990 --> 00:54:53,720
tested um and were able to rule this out

1330
00:54:58,630 --> 00:54:56,000
so we we rule out this possibility with

1331
00:55:00,640 --> 00:54:58,640
ground-based optical spectroscopy which

1332
00:55:02,559 --> 00:55:00,650
means you take the light from this

1333
00:55:04,660 --> 00:55:02,569
cluster and turn it into a rainbow you

1334
00:55:07,809 --> 00:55:04,670
disperse it and you can see things like

1335
00:55:10,809 --> 00:55:07,819
emission lines um uh one of them is

1336
00:55:14,109 --> 00:55:10,819
called H alpha for example and you see

1337
00:55:18,520 --> 00:55:14,119
uh emission lines maps to a certain

1338
00:55:21,609 --> 00:55:18,530

redshift arm redshift is just the way

1339
00:55:23,160 --> 00:55:21,619
astronomers think about the 3d structure

1340
00:55:25,059 --> 00:55:23,170
of space right you can think about

1341
00:55:27,339 --> 00:55:25,069
distances from you in terms of redshift

1342
00:55:28,599 --> 00:55:27,349
and it turns out that everything that

1343
00:55:30,430 --> 00:55:28,609
you're seeing in that image in the

1344
00:55:32,680 --> 00:55:30,440
central regions at least meaning the two

1345
00:55:35,050 --> 00:55:32,690
giant yellow elliptical galaxies that

1346
00:55:36,850 --> 00:55:35,060
you see and the blue squigglies

1347
00:55:39,310 --> 00:55:36,860
everything is exactly at the same red

1348
00:55:41,320 --> 00:55:39,320
shift which means that this can't be a

1349
00:55:43,570 --> 00:55:41,330
3d projection effect from stuff along

1350
00:55:45,520 --> 00:55:43,580
the line of sight and indeed everything

1351
00:55:47,830 --> 00:55:45,530
needs to be basically on the same plane

1352
00:55:49,870 --> 00:55:47,840
so the two merging galaxies indeed are

1353
00:55:52,780 --> 00:55:49,880
merging and are in are deeply embedded

1354
00:55:55,240 --> 00:55:52,790
in one another over 20 so 60,000

1355
00:55:56,920 --> 00:55:55,250
Lightyear scales basically and the blue

1356
00:55:59,050 --> 00:55:56,930
squigglies that you see indeed are

1357
00:56:00,520 --> 00:55:59,060
embedded in the cellar halos of those

1358
00:56:02,110 --> 00:56:00,530
two merging galaxies so this is not a

1359
00:56:03,400 --> 00:56:02,120
projection effect but that is a great

1360
00:56:05,620 --> 00:56:03,410
question because it's one of the first

1361
00:56:07,060 --> 00:56:05,630
that we asked yeah I'm very important

1362
00:56:09,010 --> 00:56:07,070
what yeah that's that was a good

1363
00:56:10,300 --> 00:56:09,020

question thank you Tom well take one

1364
00:56:12,790 --> 00:56:10,310
more than a mascot if I'm missing

1365
00:56:16,150 --> 00:56:12,800
anything um here's one from Julio says

1366
00:56:18,280 --> 00:56:16,160
our burrito from the Q&A app what mate

1367
00:56:20,590 --> 00:56:18,290
what makes the Milky Way Center take a

1368
00:56:25,120 --> 00:56:20,600
bar form and can it be the Jets of a

1369
00:56:29,860 --> 00:56:25,130
supermassive black hole anybody so I can

1370
00:56:32,070 --> 00:56:29,870
take that um the milk you the black hole

1371
00:56:36,340 --> 00:56:32,080
the center of our Milky Way is a slacker

1372
00:56:39,760 --> 00:56:36,350
um it's really disappointing as someone

1373
00:56:42,610 --> 00:56:39,770
who likes active black holes and

1374
00:56:44,020 --> 00:56:42,620
galaxies I continue to be disappointed

1375
00:56:46,330 --> 00:56:44,030
by the Milky Way so if the universe is

1376
00:56:51,430 --> 00:56:46,340
annoying the Milky Way's black hole is

1377
00:56:55,930 --> 00:56:51,440
just disappointed right why I just lost

1378
00:56:58,600 --> 00:56:55,940
our way to everything out but faucets in

1379
00:57:00,850 --> 00:56:58,610
the way yeah yeah i mean i'm glad i'm

1380
00:57:04,330 --> 00:57:00,860
not being continually irradiated but you

1381
00:57:11,080 --> 00:57:04,340
know it's so dinky grumpiest hangout

1382
00:57:13,450 --> 00:57:11,090
ever right high bar right here purse out

1383
00:57:15,160 --> 00:57:13,460
on the problems so this is serious so

1384
00:57:16,890 --> 00:57:15,170
the serious problem is that there's tons

1385
00:57:19,870 --> 00:57:16,900
of gas in the center of our Milky Way

1386
00:57:21,880 --> 00:57:19,880
and there's a black hole there's a

1387
00:57:23,980 --> 00:57:21,890
several million solar mass black hole

1388
00:57:25,960 --> 00:57:23,990

and yet the black hole refuses to

1389
00:57:27,610 --> 00:57:25,970
perform it's like when I asked my kid to

1390
00:57:31,510 --> 00:57:27,620
say bubble he just looks at me he's like

1391
00:57:34,030 --> 00:57:31,520
I don't perform mom ya know our Milky

1392
00:57:36,520 --> 00:57:34,040
Way black hole doesn't feel so it's got

1393
00:57:38,890 --> 00:57:36,530
you know its massive it's a center of a

1394
00:57:40,330 --> 00:57:38,900
whole lot of gas and it chooses not for

1395
00:57:42,460 --> 00:57:40,340
interesting reasons that we don't really

1396
00:57:44,500 --> 00:57:42,470
understand to eat any of that gas or at

1397
00:57:47,170 --> 00:57:44,510
least not to be very so it doesn't have

1398
00:57:48,010 --> 00:57:47,180
big jets and it isn't bright and it's

1399
00:57:50,350 --> 00:57:48,020
really face

1400
00:57:55,480 --> 00:57:50,360
you have to observe with with Chandra

1401
00:57:57,100 --> 00:57:55,490
for four days to get a signal so so this

1402
00:58:00,460 --> 00:57:57,110
is a long way of saying that the Milky

1403
00:58:01,930 --> 00:58:00,470
Way our black hole is so underperforming

1404
00:58:05,080 --> 00:58:01,940
that it's not really capable right now

1405
00:58:07,330 --> 00:58:05,090
of doing much of anything to change the

1406
00:58:09,790 --> 00:58:07,340
structure in the past if it was more

1407
00:58:12,880 --> 00:58:09,800
energetic there these neat Fermi bubbles

1408
00:58:14,650 --> 00:58:12,890
that show that in the past the black

1409
00:58:16,750 --> 00:58:14,660
hole tercera actually shot these big

1410
00:58:19,180 --> 00:58:16,760
bubbles of gas out through the galaxy um

1411
00:58:22,350 --> 00:58:19,190
the spiral I'm not quite sure about

1412
00:58:25,840 --> 00:58:22,360
because it's used to think about that

1413
00:58:28,090 --> 00:58:25,850

yeah so uh is it but didn't hear

1414
00:58:29,500 --> 00:58:28,100
something about a stream of gas in the

1415
00:58:31,870 --> 00:58:29,510
center of the Milky Way that's like

1416
00:58:34,180 --> 00:58:31,880
heading towards the black hole or

1417
00:58:38,110 --> 00:58:34,190
something like that or my you know

1418
00:58:40,210 --> 00:58:38,120
something yes soon soon something might

1419
00:58:41,740 --> 00:58:40,220
be happening right soon something might

1420
00:58:45,780 --> 00:58:41,750
be happening that is a story of the

1421
00:58:48,490 --> 00:58:45,790
universe right there maybe you know

1422
00:58:50,890 --> 00:58:48,500
there is there is a small gas cloud

1423
00:58:53,890 --> 00:58:50,900
which has now passed behind CJ star our

1424
00:58:55,300 --> 00:58:53,900
Sanjay stars the name are very prosaic

1425
00:58:58,300 --> 00:58:55,310
making for the black hole in center of

1426
00:59:00,790 --> 00:58:58,310
our galaxy right there is us a small I

1427
00:59:03,790 --> 00:59:00,800
think million solar mass are on a

1428
00:59:06,520 --> 00:59:03,800
hundred thousand solar mass cloud of gas

1429
00:59:10,870 --> 00:59:06,530
that has passed around and is coming

1430
00:59:12,910 --> 00:59:10,880
back um toward us around sad j star so

1431
00:59:14,830 --> 00:59:12,920
it's a small gas cloud it apparently

1432
00:59:16,390 --> 00:59:14,840
didn't a creek and it also apparently

1433
00:59:18,850 --> 00:59:16,400
didn't shear a part in the way that

1434
00:59:21,760 --> 00:59:18,860
astronomers were expecting oh let it

1435
00:59:26,050 --> 00:59:21,770
pass me again another disappointment for

1436
00:59:28,690 --> 00:59:26,060
Jane nothing interesting happened engine

1437
00:59:29,920 --> 00:59:28,700
went around it's like yeah it's still an

1438
00:59:31,920 --> 00:59:29,930

amazing result these are papers by

1439
00:59:36,160 --> 00:59:31,930
stefan glisten you know I know it's it

1440
00:59:39,220 --> 00:59:36,170
um but yeah one science but

1441
00:59:40,660 --> 00:59:39,230
disappointing yeah yeah ok so that was

1442
00:59:41,500 --> 00:59:40,670
that's been new since i heard i knew it

1443
00:59:42,970 --> 00:59:41,510
was discovered and there was a

1444
00:59:44,050 --> 00:59:42,980
possibility that am i going to buy coal

1445
00:59:45,970 --> 00:59:44,060
but it sounds like that's not gonna

1446
00:59:49,090 --> 00:59:45,980
happen well it remains very exciting and

1447
00:59:51,310 --> 00:59:49,100
indeed this is this is uh something yeah

1448
00:59:53,320 --> 00:59:51,320
but when we're talking about accreting

1449
00:59:55,090 --> 00:59:53,330
supermassive black holes we're talking

1450
00:59:56,350 --> 00:59:55,100
about things that are order orders of

1451
00:59:58,750 --> 00:59:56,360
magnitude more massive than the black

1452
01:00:00,220 --> 00:59:58,760
hole in the Milky Way so the the Milky

1453
01:00:01,290 --> 01:00:00,230
Way black hole is about four million

1454
01:00:03,420 --> 01:00:01,300
solar masses

1455
01:00:05,160 --> 01:00:03,430
the black holes at the center of these

1456
01:00:06,600 --> 01:00:05,170
two emerging elliptical galaxies might

1457
01:00:09,900 --> 01:00:06,610
be on the order of a billion solar

1458
01:00:11,190 --> 01:00:09,910
masses each wow that is when you're

1459
01:00:13,860 --> 01:00:11,200
right you're I chain we have pretty

1460
01:00:19,140 --> 01:00:13,870
wimpy one then those even for its mess

1461
01:00:22,020 --> 01:00:19,150
it should be punching harder I'm gonna

1462
01:00:23,760 --> 01:00:22,030
gets weight class is just yeah yeah I

1463
01:00:25,110 --> 01:00:23,770

can't believe with you didn't know what

1464
01:00:27,540 --> 01:00:25,120
you're gonna give an inferiority complex

1465
01:00:30,720 --> 01:00:27,550
and then something terrible is going to

1466
01:00:33,270 --> 01:00:30,730
happen cute right at us and I would I'm

1467
01:00:34,740 --> 01:00:33,280
gonna just like I'm gonna just messaged

1468
01:00:38,970 --> 01:00:34,750
you on facebook like Jane look what you

1469
01:00:40,970 --> 01:00:38,980
did to our place please Coco go down so

1470
01:00:43,260 --> 01:00:40,980
that's all right that's my face okay

1471
01:00:48,390 --> 01:00:43,270
internet will looking on and probably

1472
01:00:50,040 --> 01:00:48,400
earth so Nana so Scott if I missed

1473
01:00:52,350 --> 01:00:50,050
anything is there something else I

1474
01:00:55,260 --> 01:00:52,360
didn't catch you know that there's been

1475
01:00:57,630 --> 01:00:55,270
there's been a lot of just great tweets

1476
01:00:59,250 --> 01:00:57,640
going on from everywhere not really

1477
01:01:01,590 --> 01:00:59,260
questions but a lot of just really good

1478
01:01:04,290 --> 01:01:01,600
commenting on what people are learning

1479
01:01:07,110 --> 01:01:04,300
all on Twitter use novel hang out so I

1480
01:01:10,560 --> 01:01:07,120
do recommend those watching this later

1481
01:01:12,900 --> 01:01:10,570
go to Twitter just look up the Hubble

1482
01:01:14,970 --> 01:01:12,910
hang out hashtag you can see the great

1483
01:01:16,380 --> 01:01:14,980
conversation going on with it the right

1484
01:01:19,680 --> 01:01:16,390
a good good point thanks for pointing

1485
01:01:22,620 --> 01:01:19,690
that out Hugo dude I love you because he

1486
01:01:25,650 --> 01:01:22,630
goes we live in a lazy galaxy what can

1487
01:01:29,490 --> 01:01:25,660
you do other than keep looking up I

1488
01:01:34,320 --> 01:01:29,500

sorry that Jake just like downtown Tony

1489
01:01:36,570 --> 01:01:34,330
God's lockdown thank you you go okay

1490
01:01:40,380 --> 01:01:36,580
well I guess with that it's our time is

1491
01:01:41,790 --> 01:01:40,390
more or less up unless I Carol do you

1492
01:01:43,770 --> 01:01:41,800
have any parting comments or anything

1493
01:01:48,090 --> 01:01:43,780
you want to say Oryx Carly no I'm so

1494
01:01:49,710 --> 01:01:48,100
depressed now yeah we're gonna have to

1495
01:01:53,220 --> 01:01:49,720
take a moment and maybe think about

1496
01:01:55,170 --> 01:01:53,230
really dark job yeah I was so excited to

1497
01:01:58,500 --> 01:01:55,180
see Jane and the longest time and now

1498
01:02:00,800 --> 01:01:58,510
I'm just like wow Oh change it down RJ

1499
01:02:04,020 --> 01:02:00,810
mention she has a really high bar

1500
01:02:05,340 --> 01:02:04,030
fortunate you have high skaters yeah

1501
01:02:08,100 --> 01:02:05,350
let's flip that around it's not that

1502
01:02:11,250 --> 01:02:08,110
genes disappointed easily is that she is

1503
01:02:14,820 --> 01:02:11,260
it's up there yeah yes high expectations

1504
01:02:18,420 --> 01:02:14,830
that's right even Jane

1505
01:02:20,190 --> 01:02:18,430
love you doing this image yes Alexia is

1506
01:02:24,510 --> 01:02:20,200
not under performing right there's one

1507
01:02:25,800 --> 01:02:24,520
impressed gene so yeah right all right i

1508
01:02:27,570 --> 01:02:25,810
want to thank you guys thank you grin

1509
01:02:29,070 --> 01:02:27,580
thank you Jane thank you okay so much

1510
01:02:30,270 --> 01:02:29,080
for joining us this has been a great

1511
01:02:32,160 --> 01:02:30,280
hanging out as a really interesting

1512
01:02:33,330 --> 01:02:32,170
stuff I kind of want to reconnect with

1513
01:02:34,740 --> 01:02:33,340

you guys once you get the Chandra

1514
01:02:37,200 --> 01:02:34,750
observations so we can see what you

1515
01:02:39,690 --> 01:02:37,210
learned about this about this cluster in

1516
01:02:41,850 --> 01:02:39,700
this particular string of pearls what it

1517
01:02:45,690 --> 01:02:41,860
might be what I might be doing to us or

1518
01:02:48,000 --> 01:02:45,700
them or the galaxy image in general so

1519
01:02:50,370 --> 01:02:48,010
next week i miss or last week i misspoke

1520
01:02:52,320 --> 01:02:50,380
when i said that our hangout are booked

1521
01:02:54,960 --> 01:02:52,330
this week would have been about the hot

1522
01:02:56,760 --> 01:02:54,970
Jupiters and water vapor that was stored

1523
01:02:58,920 --> 01:02:56,770
on them it turns out that that is going

1524
01:03:01,170 --> 01:02:58,930
to be next week's hang out so we will be

1525
01:03:03,420 --> 01:03:01,180
around next Thursday same bat-time same

1526
01:03:06,840 --> 01:03:03,430
know what am i saying saying Hubble time

1527
01:03:08,400 --> 01:03:06,850
same Hubble channel where we will be

1528
01:03:09,900 --> 01:03:08,410
talking about hot Jupiters and water

1529
01:03:12,210 --> 01:03:09,910
vapor and observations with the Hubble

1530
01:03:13,950 --> 01:03:12,220
Space Telescope so thank you guys all

1531
01:03:15,540 --> 01:03:13,960
for watching make sure you bookmark it

1532
01:03:17,610 --> 01:03:15,550
i'll be making the event here later

1533
01:03:21,420 --> 01:03:17,620
today so we'll hope you will hope you'll

1534
01:03:23,220 --> 01:03:21,430
attend Carol Scott thank you as always a

1535
01:03:25,320 --> 01:03:23,230
great job thank you for driving the

1536
01:03:26,910 --> 01:03:25,330
Internet Scott did great job you need

1537
01:03:30,570 --> 01:03:26,920
might want to get that expanding

1538
01:03:32,670 --> 01:03:30,580

headspace looked at so yeah no I just

1539
01:03:35,160 --> 01:03:32,680
get bigger hats at this figure okay

1540
01:03:36,810 --> 01:03:35,170
that's one way to look at it my folks