

1  
00:00:02,960 --> 00:00:06,870  
hello everybody and welcome to our

2  
00:00:04,979 --> 00:00:08,519  
latest Hubble hang out my name is Tony

3  
00:00:06,870 --> 00:00:10,259  
Darnell I work at the Space Telescope

4  
00:00:08,519 --> 00:00:12,089  
Science Institute and today we have a

5  
00:00:10,259 --> 00:00:14,370  
really interesting hangout plan for you

6  
00:00:12,089 --> 00:00:16,588  
we are going to be talking about galaxy

7  
00:00:14,369 --> 00:00:18,719  
collisions in particular one galaxy

8  
00:00:16,588 --> 00:00:23,460  
collision that is had some strange

9  
00:00:18,719 --> 00:00:25,379  
unusual bizarre things in it and we've

10  
00:00:23,460 --> 00:00:27,118  
got the astronomers here to help us

11  
00:00:25,379 --> 00:00:29,038  
decipher what they're looking at and

12  
00:00:27,118 --> 00:00:30,719  
what they are we'll talk about galaxy

13  
00:00:29,039 --> 00:00:33,390  
collisions and what you know where they

14  
00:00:30,719 --> 00:00:36,119  
occur and and in particular what this

15  
00:00:33,390 --> 00:00:40,320  
strange feature that they found might

16  
00:00:36,119 --> 00:00:41,429  
actually be and so we will be starting

17  
00:00:40,320 --> 00:00:42,869  
that discussion in just a minute but

18  
00:00:41,429 --> 00:00:45,210  
before I start with introductions i want

19  
00:00:42,869 --> 00:00:49,169  
to say we're hoping you guys will leave

20  
00:00:45,210 --> 00:00:50,640  
us comments and questions on the Q&A app

21  
00:00:49,170 --> 00:00:52,829  
which we're also which we're watching

22  
00:00:50,640 --> 00:00:54,659  
the hubble hang out hashtag on twitter

23  
00:00:52,829 --> 00:00:57,480  
we're also doing come we're looking at

24  
00:00:54,659 --> 00:00:59,069  
comments on YouTube and G+ so we hope

25  
00:00:57,479 --> 00:01:00,569  
you'll interact with us and let us know

26  
00:00:59,070 --> 00:01:02,369  
what you think give us some questions

27  
00:01:00,570 --> 00:01:05,009  
and we'll get to those hopefully

28  
00:01:02,369 --> 00:01:07,618  
throughout the hang out with me to help

29

00:01:05,009 --> 00:01:09,509  
with this hang out here are my two good

30  
00:01:07,618 --> 00:01:10,739  
friends and colleagues dr. carol

31  
00:01:09,509 --> 00:01:13,650  
christian she's the Hubble Space

32  
00:01:10,739 --> 00:01:17,039  
Telescope outreach astronomer and and

33  
00:01:13,650 --> 00:01:19,140  
also with me is scott lewis from know

34  
00:01:17,040 --> 00:01:20,399  
the cosmos calm and he's just getting

35  
00:01:19,140 --> 00:01:22,739  
started doing all kinds of cool things

36  
00:01:20,399 --> 00:01:24,840  
with the Natural History Museum in Los

37  
00:01:22,739 --> 00:01:31,819  
Angeles so welcome Scott welcome Carol

38  
00:01:24,840 --> 00:01:35,640  
hey I'm going awesome a rock ready this

39  
00:01:31,819 --> 00:01:38,429  
okay so today galaxy collisions with me

40  
00:01:35,640 --> 00:01:40,468  
to the web got three astronomers who've

41  
00:01:38,430 --> 00:01:42,509  
been using the Hubble Space Telescope to

42  
00:01:40,468 --> 00:01:45,359  
look at these things I have first of all

43  
00:01:42,509 --> 00:01:47,819

dr. grant trembly he was but at the time

44

00:01:45,359 --> 00:01:49,500

the press release came out was working

45

00:01:47,819 --> 00:01:51,658

at the european southern observatory now

46

00:01:49,500 --> 00:01:55,009

he is the nasa Einstein fellow at Yale

47

00:01:51,659 --> 00:01:57,630

University welcome dr. Tremblay hi guys

48

00:01:55,009 --> 00:01:59,250

also is Jane rig I'm just doing this

49

00:01:57,629 --> 00:02:01,530

from left to right as they appear on my

50

00:01:59,250 --> 00:02:05,269

screen dr. Jane rib Rigby she's an

51

00:02:01,530 --> 00:02:09,509

astronomer at NASA Goddard hi Jane hello

52

00:02:05,269 --> 00:02:11,280

and finally we have Karen sharone she's

53

00:02:09,508 --> 00:02:13,019

a professor from the University of

54

00:02:11,280 --> 00:02:16,620

Michigan hi

55

00:02:13,020 --> 00:02:18,270

guys okay galaxy collisions you guys

56

00:02:16,620 --> 00:02:21,270

have been using the Hubble Space

57

00:02:18,270 --> 00:02:22,920

Telescope to study these things is this

58  
00:02:21,270 --> 00:02:25,320  
what you've always been doing all three

59  
00:02:22,919 --> 00:02:27,299  
this your primary area of research your

60  
00:02:25,319 --> 00:02:29,189  
grand I'll start with you well well

61  
00:02:27,300 --> 00:02:31,080  
first of all I work on clusters of

62  
00:02:29,189 --> 00:02:33,120  
galaxies in general namely star

63  
00:02:31,080 --> 00:02:35,490  
formation and black hole feedback so

64  
00:02:33,120 --> 00:02:38,969  
energy feedback from black holes ah but

65  
00:02:35,490 --> 00:02:42,000  
on this particular study I was very

66  
00:02:38,969 --> 00:02:43,889  
lucky to be sort of a guest uh in Jane

67  
00:02:42,000 --> 00:02:45,960  
and Karen's house because this is their

68  
00:02:43,889 --> 00:02:47,129  
data this is their amazing program all

69  
00:02:45,960 --> 00:02:50,610  
right they can tell you a little bit

70  
00:02:47,129 --> 00:02:52,439  
about it okay so wait a minute now you

71  
00:02:50,610 --> 00:02:53,700  
said feedback say that again feedback

72  
00:02:52,439 --> 00:02:56,490  
from black holes what kind of feedback

73  
00:02:53,699 --> 00:02:59,069  
yeah so I work on on brightest cluster

74  
00:02:56,490 --> 00:03:01,110  
galaxies in the center of rich clusters

75  
00:02:59,069 --> 00:03:02,489  
of galaxies so clusters of galaxies are

76  
00:03:01,110 --> 00:03:04,140  
giant groups of galaxies which we'll

77  
00:03:02,490 --> 00:03:05,969  
talk about today and I work on the

78  
00:03:04,139 --> 00:03:08,279  
galaxies in the very center of them and

79  
00:03:05,969 --> 00:03:09,960  
many of these galaxies have what are

80  
00:03:08,280 --> 00:03:11,669  
called active galactic nuclei so

81  
00:03:09,960 --> 00:03:14,510  
accreting supermassive black holes

82  
00:03:11,669 --> 00:03:16,919  
billion solar mass black holes ah and

83  
00:03:14,509 --> 00:03:18,449  
when you dump a lot of matter into a

84  
00:03:16,919 --> 00:03:21,599  
black hole it liberates tons of energy

85  
00:03:18,449 --> 00:03:24,629  
and I work on what effect that energy

86

00:03:21,599 --> 00:03:26,009  
has other its ambient environment good

87  
00:03:24,629 --> 00:03:27,120  
because I wanted to clarify that because

88  
00:03:26,009 --> 00:03:28,739  
it's a little counterintuitive people

89  
00:03:27,120 --> 00:03:29,939  
think of black holes is just grabbing

90  
00:03:28,740 --> 00:03:32,850  
and sucking everything in but they

91  
00:03:29,939 --> 00:03:34,469  
actually throw things back out again too

92  
00:03:32,849 --> 00:03:36,120  
so that sounds like an interesting hang

93  
00:03:34,469 --> 00:03:38,789  
out in and of itself so that's great

94  
00:03:36,120 --> 00:03:41,550  
okay how about you Jane in a Jane and

95  
00:03:38,789 --> 00:03:43,079  
Karen let's start with you Karen are you

96  
00:03:41,550 --> 00:03:44,700  
this is this your main area of research

97  
00:03:43,080 --> 00:03:46,620  
have you always been involved in

98  
00:03:44,699 --> 00:03:48,659  
galactic or galaxy clusters and

99  
00:03:46,620 --> 00:03:50,700  
collisions well I've been involved in

100  
00:03:48,659 --> 00:03:53,240

that galaxy clusters for as long as I

101

00:03:50,699 --> 00:03:55,199

have been in astronomy but uh not

102

00:03:53,240 --> 00:03:58,230

necessarily what we're talking about

103

00:03:55,199 --> 00:03:59,839

today so my main interest is in a

104

00:03:58,229 --> 00:04:02,479

phenomenon called gravitational lensing

105

00:03:59,840 --> 00:04:05,370

which is the bending of light around

106

00:04:02,479 --> 00:04:07,409

very massive object right we're going

107

00:04:05,370 --> 00:04:09,120

some of that in a little bit so right we

108

00:04:07,409 --> 00:04:12,629

got some area so we got some graphic for

109

00:04:09,120 --> 00:04:15,150

that too right so like granted we have

110

00:04:12,629 --> 00:04:17,639

this amazing project with the Hubble

111

00:04:15,150 --> 00:04:20,040

Space Telescope looking at galaxy

112

00:04:17,639 --> 00:04:22,439

clusters which are very very massive so

113

00:04:20,040 --> 00:04:24,419

that they bend the light of galaxies

114

00:04:22,439 --> 00:04:26,420

behind them and this is our main



115  
00:04:24,418 --> 00:04:29,229  
progress program with

116  
00:04:26,420 --> 00:04:31,730  
main signs with this great program

117  
00:04:29,230 --> 00:04:33,980  
however sometimes when you take a lot of

118  
00:04:31,730 --> 00:04:35,360  
pictures with a Space Telescope you find

119  
00:04:33,980 --> 00:04:38,300  
some things that you do not necessarily

120  
00:04:35,360 --> 00:04:39,530  
expect and this object that we're

121  
00:04:38,300 --> 00:04:44,000  
talking about today is one of those

122  
00:04:39,529 --> 00:04:45,469  
things right okay Jane how about so give

123  
00:04:44,000 --> 00:04:47,360  
us a little background on what you have

124  
00:04:45,470 --> 00:04:50,930  
your research interest in background

125  
00:04:47,360 --> 00:04:52,639  
sure so I'm interested in galaxies of

126  
00:04:50,930 --> 00:04:55,310  
all kinds whether they're forming stars

127  
00:04:52,639 --> 00:04:56,449  
are not especially those that have black

128  
00:04:55,310 --> 00:04:58,699  
holes in their centers that are

129  
00:04:56,449 --> 00:05:01,099  
currently feeding and fueling like grant

130  
00:04:58,699 --> 00:05:02,930  
was talking about and recently I've

131  
00:05:01,100 --> 00:05:05,180  
gotten very interested in studying

132  
00:05:02,930 --> 00:05:07,759  
galaxies using gravitational lensing

133  
00:05:05,180 --> 00:05:09,319  
which we'll talk about and so Karen and

134  
00:05:07,759 --> 00:05:11,000  
I and our colleague Mike ladders and

135  
00:05:09,319 --> 00:05:14,629  
some other astronomers have this big

136  
00:05:11,000 --> 00:05:16,850  
program to study of galaxy clusters that

137  
00:05:14,629 --> 00:05:19,250  
are really good gravitational lenses and

138  
00:05:16,850 --> 00:05:23,000  
kind of by act that's why we took this

139  
00:05:19,250 --> 00:05:26,060  
data so it's one of 37 clusters that we

140  
00:05:23,000 --> 00:05:27,740  
wanted to that we wanted to study the

141  
00:05:26,060 --> 00:05:30,230  
background galaxies they're getting lens

142  
00:05:27,740 --> 00:05:32,960  
and this was a case this paper that

143

00:05:30,230 --> 00:05:35,960  
grant invited you to our house I like

144  
00:05:32,959 --> 00:05:38,389  
that that came from was we were looking

145  
00:05:35,959 --> 00:05:41,599  
at this cluster and saying wait a minute

146  
00:05:38,389 --> 00:05:43,879  
what's not right what is that what's

147  
00:05:41,600 --> 00:05:50,060  
going on in the sermon really did do

148  
00:05:43,879 --> 00:05:51,649  
this mmm pours right ok so I had to put

149  
00:05:50,060 --> 00:05:54,920  
up a picture of the cluster we're

150  
00:05:51,649 --> 00:05:57,199  
talking about so you guys looked at this

151  
00:05:54,920 --> 00:06:01,009  
cluster known as sdss which i think

152  
00:05:57,199 --> 00:06:04,969  
stands for Sloan Digital Sky Survey j15

153  
00:06:01,009 --> 00:06:09,379  
31 + 34 14 I just love these names so

154  
00:06:04,970 --> 00:06:12,170  
here is a picture of the galaxy cluster

155  
00:06:09,379 --> 00:06:17,329  
itself I how many galaxies are in this

156  
00:06:12,170 --> 00:06:19,610  
thing do we know we have to counter a

157  
00:06:17,329 --> 00:06:28,310

lot more than just wondered if anybody

158

00:06:19,610 --> 00:06:29,870

know who is quote so first of all when

159

00:06:28,310 --> 00:06:32,000

you look at this picture you can notice

160

00:06:29,870 --> 00:06:34,459

that some of the galaxies look sort of

161

00:06:32,000 --> 00:06:36,649

the same they look like they're yellow

162

00:06:34,459 --> 00:06:38,750

orange and they sort of have about the

163

00:06:36,649 --> 00:06:40,279

same color and those are all cluster

164

00:06:38,750 --> 00:06:42,730

galaxies other

165

00:06:40,279 --> 00:06:45,138

Alexei's that can be smaller or larger

166

00:06:42,730 --> 00:06:46,970

have different color and they would

167

00:06:45,139 --> 00:06:49,160

typically be either in front of the

168

00:06:46,970 --> 00:06:51,050

cluster or behind the cluster so when

169

00:06:49,160 --> 00:06:54,530

you come galaxies please only count that

170

00:06:51,050 --> 00:06:56,389

yellow orange ones okay all right so

171

00:06:54,529 --> 00:06:58,219

what there's the first thing that

172  
00:06:56,389 --> 00:06:59,269  
strikes me when I look at this is

173  
00:06:58,220 --> 00:07:02,240  
obviously like you said there's these

174  
00:06:59,269 --> 00:07:06,079  
these orange ones these big roundish

175  
00:07:02,240 --> 00:07:07,819  
sort of oblong shaped galaxies in here

176  
00:07:06,079 --> 00:07:09,259  
is and then there's all these other

177  
00:07:07,819 --> 00:07:11,930  
squiggles all the way around these

178  
00:07:09,259 --> 00:07:13,639  
bluish kind of squiggles can you

179  
00:07:11,930 --> 00:07:15,139  
describe to us what's going on here what

180  
00:07:13,639 --> 00:07:18,110  
are we what are we looking at as far as

181  
00:07:15,139 --> 00:07:21,079  
the the colors and the shapes right so

182  
00:07:18,110 --> 00:07:23,060  
the orange galaxies those oval shaped

183  
00:07:21,079 --> 00:07:26,300  
galaxies those are members of the

184  
00:07:23,060 --> 00:07:29,269  
cluster which has hundreds and probably

185  
00:07:26,300 --> 00:07:31,790  
a few couple hundred galaxies in it some

186  
00:07:29,269 --> 00:07:33,649  
are larger some are smaller um besides

187  
00:07:31,790 --> 00:07:36,050  
those galaxies there is a whole bunch of

188  
00:07:33,649 --> 00:07:39,579  
dark matter which we can't see kind of

189  
00:07:36,050 --> 00:07:41,750  
by definition one and all that mass

190  
00:07:39,579 --> 00:07:44,810  
makes this cluster a very good

191  
00:07:41,750 --> 00:07:46,939  
gravitational lens and those uh all

192  
00:07:44,810 --> 00:07:49,879  
those round shape things that you see

193  
00:07:46,939 --> 00:07:51,769  
there okay and it looked like arcs and

194  
00:07:49,879 --> 00:07:53,899  
this is what we call them those are our

195  
00:07:51,769 --> 00:07:56,810  
background sources that are being bent

196  
00:07:53,899 --> 00:07:59,659  
and distorted by the mass of this

197  
00:07:56,810 --> 00:08:01,939  
cluster or more correctly the light from

198  
00:07:59,660 --> 00:08:06,110  
those galaxies is distorted and we see

199  
00:08:01,939 --> 00:08:09,019  
them as I those are key shapes so the

200

00:08:06,110 --> 00:08:11,330  
orangish blobs and those are actually in

201  
00:08:09,019 --> 00:08:14,870  
the foreground those are between us and

202  
00:08:11,329 --> 00:08:17,779  
the bluish stretched out shapes right

203  
00:08:14,870 --> 00:08:19,728  
yes exactly okay so does the color mean

204  
00:08:17,779 --> 00:08:21,589  
anything I mean I know that these these

205  
00:08:19,728 --> 00:08:23,149  
orange ones are orange and they're

206  
00:08:21,589 --> 00:08:24,439  
they're kind of blobby looking but the

207  
00:08:23,149 --> 00:08:28,788  
other thing everything else seems kind

208  
00:08:24,439 --> 00:08:32,059  
of blue does that signify anything yes

209  
00:08:28,788 --> 00:08:35,179  
it does okay tell us what am I waiting

210  
00:08:32,059 --> 00:08:36,228  
for Jane to us yeah well i guess i

211  
00:08:35,179 --> 00:08:37,879  
should have direct that directly at

212  
00:08:36,229 --> 00:08:40,250  
someone how about you answer that one

213  
00:08:37,879 --> 00:08:42,019  
sure so the color tells you a lot of

214  
00:08:40,250 --> 00:08:44,779

just looking at that image you can see

215

00:08:42,019 --> 00:08:47,679

that the yellow orange e blobby galaxies

216

00:08:44,779 --> 00:08:50,509

aren't forming stars they're done

217

00:08:47,679 --> 00:08:52,969

clusters of galaxies are these extreme

218

00:08:50,509 --> 00:08:54,080

environments that seems to accelerate

219

00:08:52,970 --> 00:08:56,389

the evolution

220

00:08:54,080 --> 00:08:58,670

of galaxies okay so when we look at a

221

00:08:56,389 --> 00:09:00,259

cluster of galaxies they look yellow or

222

00:08:58,669 --> 00:09:02,959

red like that because they're done

223

00:09:00,259 --> 00:09:05,000

they're not forming any stars they are

224

00:09:02,960 --> 00:09:07,460

they have their stars have already been

225

00:09:05,000 --> 00:09:10,190

formed and that's it no new star

226

00:09:07,460 --> 00:09:14,300

formation all right so we thought or so

227

00:09:10,190 --> 00:09:16,670

we thought right portion that's a review

228

00:09:14,299 --> 00:09:18,469

today okay so and then those background



229  
00:09:16,669 --> 00:09:20,000  
galaxies are forming buckets of stars

230  
00:09:18,470 --> 00:09:23,120  
and that's why they're blue because hot

231  
00:09:20,000 --> 00:09:25,070  
new stars are blue okay so let's talk

232  
00:09:23,120 --> 00:09:26,509  
let's go before we get too much into the

233  
00:09:25,070 --> 00:09:27,640  
details of this cluster let's go ahead

234  
00:09:26,509 --> 00:09:30,470  
and talk a little bit about

235  
00:09:27,639 --> 00:09:32,840  
gravitational lensing we have a diagram

236  
00:09:30,470 --> 00:09:34,279  
here and grant I was wondering if you

237  
00:09:32,840 --> 00:09:36,500  
might be able tell us a little bit about

238  
00:09:34,279 --> 00:09:38,209  
what gravitational lensing is and maybe

239  
00:09:36,500 --> 00:09:42,830  
what we're looking at here sure things

240  
00:09:38,210 --> 00:09:46,220  
sort so I if you imagine a galaxy

241  
00:09:42,830 --> 00:09:47,960  
cluster as a contact lens um it works in

242  
00:09:46,220 --> 00:09:49,940  
a lot of the same way in that if you

243  
00:09:47,960 --> 00:09:52,009  
imagine space and time as a big rubber

244  
00:09:49,940 --> 00:09:54,470  
sheet and put a big bowling ball on it

245  
00:09:52,009 --> 00:09:57,110  
and then roll marbles past that rolling

246  
00:09:54,470 --> 00:10:00,050  
ball that bowling ball the trajectory or

247  
00:09:57,110 --> 00:10:02,120  
the path of the marbles will change if a

248  
00:10:00,049 --> 00:10:04,339  
very similar thing happens in that the

249  
00:10:02,120 --> 00:10:06,740  
enormous mass of this galaxy cluster

250  
00:10:04,340 --> 00:10:09,110  
warp space and time around it so light

251  
00:10:06,740 --> 00:10:11,960  
from distant background galaxies passing

252  
00:10:09,110 --> 00:10:15,289  
near this cluster um its trajectory gets

253  
00:10:11,960 --> 00:10:18,230  
gets bent just into these arcs that you

254  
00:10:15,289 --> 00:10:20,719  
see so I mean caring and caring in Jane

255  
00:10:18,230 --> 00:10:22,639  
work on this more directly and they can

256  
00:10:20,720 --> 00:10:24,230  
also tell you some stuff about it okay

257

00:10:22,639 --> 00:10:26,929  
we have one more graphic that's a little

258  
00:10:24,230 --> 00:10:28,659  
more lesser active of the stretching out

259  
00:10:26,929 --> 00:10:30,649  
effect this just shows that there's a

260  
00:10:28,659 --> 00:10:32,809  
something in the middle that's doing the

261  
00:10:30,649 --> 00:10:35,629  
bending here's another look we have a

262  
00:10:32,809 --> 00:10:39,019  
distant background galaxy that is whose

263  
00:10:35,629 --> 00:10:40,759  
light is being distorted by the group of

264  
00:10:39,019 --> 00:10:43,549  
galaxies in front of it and you can see

265  
00:10:40,759 --> 00:10:44,720  
that these arcs are being made here Jane

266  
00:10:43,549 --> 00:10:46,909  
you want to comment on that a little bit

267  
00:10:44,720 --> 00:10:50,629  
more I'm turning this one over to Karen

268  
00:10:46,909 --> 00:10:52,959  
oh it's all good very hard to give you

269  
00:10:50,629 --> 00:10:56,840  
fun hangul i love this already you know

270  
00:10:52,960 --> 00:11:00,940  
yeah yeah so right so everything you

271  
00:10:56,840 --> 00:11:03,830

said is correct and sometimes this um

272

00:11:00,940 --> 00:11:06,170

not that gas is not are not only being

273

00:11:03,830 --> 00:11:07,440

stretched but I might the lights can

274

00:11:06,169 --> 00:11:09,569

like a funhouse mirror

275

00:11:07,440 --> 00:11:11,670

r-type effect they're being stretching

276

00:11:09,570 --> 00:11:13,980

you sometimes would see multiple images

277

00:11:11,669 --> 00:11:16,259

of the same thing so the light would

278

00:11:13,980 --> 00:11:17,850

start from a galaxy go around the

279

00:11:16,259 --> 00:11:20,700

cluster and get to you from one

280

00:11:17,850 --> 00:11:21,960

direction but also some other ray of

281

00:11:20,700 --> 00:11:23,640

light that was supposed to go in a

282

00:11:21,960 --> 00:11:25,410

completely different direction we've

283

00:11:23,639 --> 00:11:27,120

been around the cluster and get to you

284

00:11:25,409 --> 00:11:30,000

as well this is what you're seeing here

285

00:11:27,120 --> 00:11:32,399

and this uh in this graphic you see

286  
00:11:30,000 --> 00:11:33,809  
light from the galaxy going around the

287  
00:11:32,399 --> 00:11:36,299  
cluster in two different directions and

288  
00:11:33,809 --> 00:11:41,909  
gets to the Hubble Space Telescope image

289  
00:11:36,299 --> 00:11:44,309  
and I my job in this cooperation is to

290  
00:11:41,909 --> 00:11:46,799  
try to figure out what the optics of

291  
00:11:44,309 --> 00:11:49,679  
this gravitational telescope is so we're

292  
00:11:46,799 --> 00:11:53,549  
using the cluster which is far away in

293  
00:11:49,679 --> 00:11:56,339  
space to magnify light from the

294  
00:11:53,549 --> 00:11:57,959  
background universe so it's acting sort

295  
00:11:56,340 --> 00:12:00,360  
of like a cosmic telescope or a

296  
00:11:57,960 --> 00:12:02,639  
magnifying glass which we don't know the

297  
00:12:00,360 --> 00:12:04,230  
optics for and my job is to solve this

298  
00:12:02,639 --> 00:12:07,529  
problem and figure out what the optics

299  
00:12:04,230 --> 00:12:10,560  
are and then we can once we figure out

300  
00:12:07,529 --> 00:12:12,329  
the opticore the mass of the cluster

301  
00:12:10,559 --> 00:12:14,669  
that is responsible for the

302  
00:12:12,330 --> 00:12:16,440  
gravitational lensing then we can use it

303  
00:12:14,669 --> 00:12:22,949  
to start studying the background sources

304  
00:12:16,440 --> 00:12:27,720  
and now back to Jane okay hey you James

305  
00:12:22,950 --> 00:12:29,250  
factory hey guys so I guess what blows

306  
00:12:27,720 --> 00:12:31,050  
me away about what you just said though

307  
00:12:29,250 --> 00:12:33,330  
is you said it in a kind of nonchalant

308  
00:12:31,049 --> 00:12:35,939  
way my job is to figure out the optics

309  
00:12:33,330 --> 00:12:37,139  
in this and once I figured that out i we

310  
00:12:35,940 --> 00:12:38,940  
you know we can kind of tell which

311  
00:12:37,139 --> 00:12:41,759  
galaxies are which and things how do you

312  
00:12:38,940 --> 00:12:44,640  
do that how do you sort this all out

313  
00:12:41,759 --> 00:12:46,200  
you've got these smudges in an image

314

00:12:44,639 --> 00:12:47,939  
some of them are all over the way

315  
00:12:46,200 --> 00:12:49,920  
sometimes you have two images of the

316  
00:12:47,940 --> 00:12:51,930  
same galaxy in different parts you've

317  
00:12:49,919 --> 00:12:54,240  
got this big old galaxy cluster in the

318  
00:12:51,929 --> 00:12:55,649  
middle doing all of the distorting how

319  
00:12:54,240 --> 00:12:57,149  
do you sort it out what do you what do

320  
00:12:55,649 --> 00:12:59,159  
you swear do you even start all you have

321  
00:12:57,149 --> 00:13:03,169  
is an image just well I started by

322  
00:12:59,159 --> 00:13:06,449  
staring at the image really really hard

323  
00:13:03,169 --> 00:13:08,959  
part of my job I love looking at those

324  
00:13:06,450 --> 00:13:12,509  
beautiful pictures of space I think what

325  
00:13:08,960 --> 00:13:16,110  
imagine you know how like you have that

326  
00:13:12,509 --> 00:13:19,259  
that you know those what back when we

327  
00:13:16,110 --> 00:13:19,710  
had newspapers um there were those who

328  
00:13:19,259 --> 00:13:22,559

care

329

00:13:19,710 --> 00:13:26,850

hers is sorry I can't y'all pray that I

330

00:13:22,559 --> 00:13:28,349

newspapers I'm on Saturdays and it would

331

00:13:26,850 --> 00:13:30,450

be like those two pictures that you have

332

00:13:28,350 --> 00:13:33,629

to match this thing looks like this

333

00:13:30,450 --> 00:13:37,020

thing is sort of like a puzzle so I look

334

00:13:33,629 --> 00:13:39,210

at the pictures and try to find things

335

00:13:37,019 --> 00:13:40,860

that look sort of the same so they may

336

00:13:39,210 --> 00:13:43,200

look the same because they have their

337

00:13:40,860 --> 00:13:46,470

very distinctive color maybe they look

338

00:13:43,200 --> 00:13:47,850

pink or green sometimes they look the

339

00:13:46,470 --> 00:13:50,850

same because they have very similar

340

00:13:47,850 --> 00:13:53,129

morphology so they're kind of like now

341

00:13:50,850 --> 00:13:55,019

have a look like a spiral galaxy that's

342

00:13:53,129 --> 00:13:58,019

you started in one way or just starting



343  
00:13:55,019 --> 00:13:59,879  
another way and when I can find two or

344  
00:13:58,019 --> 00:14:01,829  
three or five of those it looks at stick

345  
00:13:59,879 --> 00:14:05,100  
look like they're the same I can say

346  
00:14:01,830 --> 00:14:08,430  
these are a few objects are images of

347  
00:14:05,100 --> 00:14:11,100  
the same thing in the background and I

348  
00:14:08,429 --> 00:14:14,250  
can use this information to try to

349  
00:14:11,100 --> 00:14:17,730  
figure out what sort of mass

350  
00:14:14,250 --> 00:14:21,539  
distribution could cause this distortion

351  
00:14:17,730 --> 00:14:23,129  
in space-time wow so you're kind of

352  
00:14:21,539 --> 00:14:25,620  
doing though one of these things is not

353  
00:14:23,129 --> 00:14:27,809  
like the other game for a while and then

354  
00:14:25,620 --> 00:14:29,639  
you figure you you match up some stuff

355  
00:14:27,809 --> 00:14:31,679  
from different parts of the image from

356  
00:14:29,639 --> 00:14:34,259  
that you try to figure out the gret the

357  
00:14:31,679 --> 00:14:36,209  
mass distribution now that's just a you

358  
00:14:34,259 --> 00:14:37,740  
know a way of saying where all the mass

359  
00:14:36,210 --> 00:14:39,480  
is in the cluster and how it might be

360  
00:14:37,740 --> 00:14:42,240  
bending the light and then you do right

361  
00:14:39,480 --> 00:14:44,340  
so we we have a pretty good idea of how

362  
00:14:42,240 --> 00:14:46,110  
the map mass bends the light and this

363  
00:14:44,340 --> 00:14:49,980  
comes from Einstein's relativity theory

364  
00:14:46,110 --> 00:14:52,430  
and uh we have a set of equation so we

365  
00:14:49,980 --> 00:14:55,769  
can use we know how physics fork and

366  
00:14:52,429 --> 00:14:57,959  
when I plug those it sounds kind of

367  
00:14:55,769 --> 00:15:00,960  
simple but there's a lot of physics

368  
00:14:57,960 --> 00:15:04,110  
behind it I can put those constraints in

369  
00:15:00,960 --> 00:15:05,430  
the equations and try a whole bunch of

370  
00:15:04,110 --> 00:15:06,990  
different models or different math

371

00:15:05,429 --> 00:15:09,329  
distributions and find just the right

372  
00:15:06,990 --> 00:15:12,720  
one that gives me the correct answer

373  
00:15:09,330 --> 00:15:15,000  
okay so let's go on to the so that's a

374  
00:15:12,720 --> 00:15:17,009  
little brief idea of what gravitational

375  
00:15:15,000 --> 00:15:18,570  
lensing is if you got any more questions

376  
00:15:17,009 --> 00:15:20,250  
please you know feel free to drop us

377  
00:15:18,570 --> 00:15:21,660  
some some notes in the comment box or

378  
00:15:20,250 --> 00:15:22,860  
whatever and we'll try to get to them to

379  
00:15:21,659 --> 00:15:25,740  
clarify things but I'm going to get on

380  
00:15:22,860 --> 00:15:27,629  
to the observation grant said that this

381  
00:15:25,740 --> 00:15:30,090  
was you guys this thing you and you guys

382  
00:15:27,629 --> 00:15:31,289  
were somebody you guys took the data is

383  
00:15:30,090 --> 00:15:33,570  
that Chrysler who wants to tell me about

384  
00:15:31,289 --> 00:15:35,669  
the story behind why you did this

385  
00:15:33,570 --> 00:15:38,460

and who who decided to point Hubble at

386

00:15:35,669 --> 00:15:42,299

this thing and look at the data and then

387

00:15:38,460 --> 00:15:44,190

you found this very surprising thing

388

00:15:42,299 --> 00:15:46,740

that wasn't there before I'm gonna say

389

00:15:44,190 --> 00:15:50,070

thing a few more times about you girl

390

00:15:46,740 --> 00:15:53,250

how about you Jane sure listen this

391

00:15:50,070 --> 00:15:55,020

cluster is one of 37 clusters that we

392

00:15:53,250 --> 00:15:59,100

propose to observe with the Hubble Space

393

00:15:55,019 --> 00:16:02,340

Telescope and there are about 70 bright

394

00:15:59,100 --> 00:16:05,340

big blue arcs like the one in this

395

00:16:02,340 --> 00:16:08,519

cluster that are the targets for this

396

00:16:05,340 --> 00:16:10,290

proposal so the way Hubble works is that

397

00:16:08,519 --> 00:16:13,620

if you have a really good idea you write

398

00:16:10,289 --> 00:16:17,069

a proposal and if it beats nine out of

399

00:16:13,620 --> 00:16:20,250

ten other proposals we win on that see

400  
00:16:17,070 --> 00:16:22,379  
last week passed right over it and it

401  
00:16:20,250 --> 00:16:24,269  
sadly right it's ninety percent

402  
00:16:22,379 --> 00:16:25,679  
rejection rate there's very few things

403  
00:16:24,269 --> 00:16:28,199  
that we do in our lives where we have a

404  
00:16:25,679 --> 00:16:30,179  
ten percent chance of succeeding but

405  
00:16:28,200 --> 00:16:32,250  
writing couple proposals is one of them

406  
00:16:30,179 --> 00:16:35,269  
so that was last week so we wrote this

407  
00:16:32,250 --> 00:16:38,000  
proposal because we wanted to both

408  
00:16:35,269 --> 00:16:40,439  
understand where the masses and clusters

409  
00:16:38,000 --> 00:16:42,840  
and instead understand clusters of

410  
00:16:40,440 --> 00:16:44,820  
galaxies better and it's a wood this is

411  
00:16:42,840 --> 00:16:46,680  
a way to probe dark matter I mean

412  
00:16:44,820 --> 00:16:47,820  
Karen's saying it's so cavalierly but

413  
00:16:46,679 --> 00:16:49,799  
what she does is figure out where all

414  
00:16:47,820 --> 00:16:52,290  
the dark matter is right I mean it's one

415  
00:16:49,799 --> 00:16:54,419  
of the few ways you can actually see not

416  
00:16:52,289 --> 00:16:57,389  
what dark matter is but how but but

417  
00:16:54,419 --> 00:16:58,979  
where is it how does it behave but we

418  
00:16:57,389 --> 00:17:01,949  
also wanted to study these background

419  
00:16:58,980 --> 00:17:05,130  
galaxies and that's my particular

420  
00:17:01,950 --> 00:17:08,578  
interest is that I want to study how

421  
00:17:05,130 --> 00:17:11,699  
galaxies evolve and galaxies universe is

422  
00:17:08,578 --> 00:17:14,849  
annoying in the galaxies are faint far

423  
00:17:11,699 --> 00:17:17,400  
away with any registration it just says

424  
00:17:14,849 --> 00:17:19,919  
the university's really annoying the it

425  
00:17:17,400 --> 00:17:21,930  
is annoying right that the telescopes we

426  
00:17:19,920 --> 00:17:24,539  
have that we've been able to build

427  
00:17:21,930 --> 00:17:26,490  
galaxies that are far away look faint

428

00:17:24,539 --> 00:17:27,750  
fuzzy and tiny and just can't study them

429  
00:17:26,490 --> 00:17:30,839  
the way you really want to so

430  
00:17:27,750 --> 00:17:34,079  
inconvenient well you know I in my other

431  
00:17:30,839 --> 00:17:35,909  
job I am working to build the James Webb

432  
00:17:34,079 --> 00:17:38,159  
Space Telescope so we are working to

433  
00:17:35,910 --> 00:17:40,769  
build bigger and better telescopes but

434  
00:17:38,160 --> 00:17:43,170  
being impatient I don't want to wait so

435  
00:17:40,769 --> 00:17:45,869  
using these natural telescopes is a way

436  
00:17:43,170 --> 00:17:47,500  
to for small parts of the sky that are

437  
00:17:45,869 --> 00:17:49,029  
lucky that there's a galaxy cluster

438  
00:17:47,500 --> 00:17:50,759  
the way you can study the background

439  
00:17:49,029 --> 00:17:53,589  
universe and you get these

440  
00:17:50,759 --> 00:17:55,539  
magnifications so it's like you're so it

441  
00:17:53,589 --> 00:17:57,429  
really is a natural telescope in front

442  
00:17:55,539 --> 00:17:59,019

of in front of your Hubble Space

443

00:17:57,430 --> 00:18:00,460

Telescope yeah we've talked about that a

444

00:17:59,019 --> 00:18:02,829

lot with frontier fields they're doing

445

00:18:00,460 --> 00:18:04,930

the same yeah right so that's the so

446

00:18:02,829 --> 00:18:07,089

that was the that was our hook that was

447

00:18:04,930 --> 00:18:11,080

the argument we have 37 fields on the

448

00:18:07,089 --> 00:18:13,449

sky that of that our team has found

449

00:18:11,079 --> 00:18:15,189

they're really good lenses and so we

450

00:18:13,450 --> 00:18:17,860

want to take images with Hubble and

451

00:18:15,190 --> 00:18:21,370

study background galaxies to study the

452

00:18:17,859 --> 00:18:24,339

universe at high high spatial resolution

453

00:18:21,369 --> 00:18:26,049

basically to do illegal things to be

454

00:18:24,339 --> 00:18:28,209

able to see sharper images the Hubble

455

00:18:26,049 --> 00:18:30,369

can normally see and to see fainter

456

00:18:28,210 --> 00:18:32,110

objects that Hubble can normally see so



457  
00:18:30,369 --> 00:18:35,229  
that's the program that was the project

458  
00:18:32,109 --> 00:18:39,219  
and this is one of 37 clusters that we

459  
00:18:35,230 --> 00:18:41,410  
got that we got data for so it was a 107

460  
00:18:39,220 --> 00:18:44,289  
orbit program which is a big but not

461  
00:18:41,410 --> 00:18:47,950  
huge project for Hubble we submitted it

462  
00:18:44,289 --> 00:18:51,639  
three times um so you know to get

463  
00:18:47,950 --> 00:18:54,130  
together come yeah and then time it was

464  
00:18:51,640 --> 00:18:55,480  
accepted and we got the observations and

465  
00:18:54,130 --> 00:18:57,610  
the observations just finished a couple

466  
00:18:55,480 --> 00:18:59,710  
months ago so all 37 clusters have now

467  
00:18:57,609 --> 00:19:00,939  
been observed yeah Carol I just want to

468  
00:18:59,710 --> 00:19:02,559  
ask you real quick sometimes when you're

469  
00:19:00,940 --> 00:19:04,630  
doing a Hubble proposal isn't always

470  
00:19:02,559 --> 00:19:05,740  
about the science itself is it I me

471  
00:19:04,630 --> 00:19:07,510  
sometimes it's about the timing

472  
00:19:05,740 --> 00:19:09,970  
sometimes a science is good but there's

473  
00:19:07,509 --> 00:19:12,369  
so many proposals that you know you can

474  
00:19:09,970 --> 00:19:14,200  
always work it in that's true and so the

475  
00:19:12,369 --> 00:19:16,959  
panels have to take a look at that and

476  
00:19:14,200 --> 00:19:18,850  
try to do it because I mean in the early

477  
00:19:16,960 --> 00:19:20,860  
days there were probably some proposals

478  
00:19:18,849 --> 00:19:23,709  
that weren't great now all the proposals

479  
00:19:20,859 --> 00:19:25,990  
are great we know that going in so it's

480  
00:19:23,710 --> 00:19:29,289  
trying to balance you know the different

481  
00:19:25,990 --> 00:19:31,059  
fields exoplanets the cluster lenses

482  
00:19:29,289 --> 00:19:33,909  
stellar populations all that kind of

483  
00:19:31,059 --> 00:19:36,579  
stuff against each other and lots of

484  
00:19:33,910 --> 00:19:38,759  
times people put in a proposal and they

485

00:19:36,579 --> 00:19:41,109  
might not get time that they they get

486  
00:19:38,759 --> 00:19:42,819  
magnificent scores it's just we only

487  
00:19:41,109 --> 00:19:45,669  
have so many orbits as we talked about

488  
00:19:42,819 --> 00:19:48,399  
last time we look like 3,000 Orbis I was

489  
00:19:45,670 --> 00:19:50,500  
going to comment that you know yet what

490  
00:19:48,400 --> 00:19:52,360  
you're hearing is that you're getting a

491  
00:19:50,500 --> 00:19:55,569  
lot out of these observations you're

492  
00:19:52,359 --> 00:19:58,479  
getting you're getting understanding the

493  
00:19:55,569 --> 00:20:01,298  
orange galaxies that you see what is

494  
00:19:58,480 --> 00:20:03,460  
that cluster what kind of

495  
00:20:01,298 --> 00:20:05,319  
galaxies make up that cluster then

496  
00:20:03,460 --> 00:20:07,389  
you're finding out Oh something about

497  
00:20:05,319 --> 00:20:10,058  
those background galaxies because their

498  
00:20:07,388 --> 00:20:11,829  
lens and then when you build the lens

499  
00:20:10,058 --> 00:20:13,298

you say well there's a lot of mass in

500

00:20:11,829 --> 00:20:15,038

those orange galaxies that start with

501

00:20:13,298 --> 00:20:16,960

that but then you have to add the dark

502

00:20:15,038 --> 00:20:19,239

matter because that's what really makes

503

00:20:16,960 --> 00:20:21,730

up this lens phenomenon so you're

504

00:20:19,239 --> 00:20:24,308

learning you know all those things and

505

00:20:21,730 --> 00:20:26,319

then lo and behold they saw this chain

506

00:20:24,308 --> 00:20:29,019

and they went oh there's something else

507

00:20:26,319 --> 00:20:31,359

we're learning about well just from the

508

00:20:29,019 --> 00:20:32,919

best known image so it's a it's a lot of

509

00:20:31,359 --> 00:20:34,628

information and that's why you need this

510

00:20:32,919 --> 00:20:38,830

marvelous team to work together because

511

00:20:34,628 --> 00:20:40,269

each person it has expertise and in some

512

00:20:38,829 --> 00:20:42,009

other thing and they're interested in in

513

00:20:40,269 --> 00:20:43,778

a different aspect of it and that's what

514  
00:20:42,009 --> 00:20:47,169  
makes these fields very rich because a

515  
00:20:43,778 --> 00:20:49,569  
lot of science comes out of it what the

516  
00:20:47,169 --> 00:20:52,090  
picture that you showed before well or

517  
00:20:49,569 --> 00:20:55,148  
okay go ahead you got Kelly can you put

518  
00:20:52,089 --> 00:20:58,808  
that first one after we had um that the

519  
00:20:55,148 --> 00:21:00,819  
galaxy cluster itself a lot of our mr.

520  
00:20:58,808 --> 00:21:02,079  
which will cause everyone in short

521  
00:21:00,819 --> 00:21:05,829  
because we don't want to say the entire

522  
00:21:02,079 --> 00:21:08,829  
phone number thing so what what drew us

523  
00:21:05,829 --> 00:21:12,849  
into this cluster as you can see is like

524  
00:21:08,829 --> 00:21:15,908  
the ring of stretchy arcs around the

525  
00:21:12,849 --> 00:21:18,038  
center which from the ground kind of

526  
00:21:15,909 --> 00:21:19,090  
just looked like a ring so from the

527  
00:21:18,038 --> 00:21:22,058  
ground meaning from ground-based

528  
00:21:19,089 --> 00:21:24,459  
telescopes we had nice images from that

529  
00:21:22,058 --> 00:21:29,048  
Gemini and Subaru and other telescopes

530  
00:21:24,460 --> 00:21:32,288  
and so this is a great lens this is a

531  
00:21:29,048 --> 00:21:34,269  
fantastic cluster lens because it's so

532  
00:21:32,288 --> 00:21:36,759  
around the the stuff that the features

533  
00:21:34,269 --> 00:21:39,308  
around it or so complete is that why or

534  
00:21:36,759 --> 00:21:40,960  
yeah it's very easy it's very certain

535  
00:21:39,308 --> 00:21:43,720  
that this is a gravitational lens and

536  
00:21:40,960 --> 00:21:45,340  
it's magnified and we can study those

537  
00:21:43,720 --> 00:21:47,679  
out background sources and you can see a

538  
00:21:45,339 --> 00:21:50,408  
lot of little mission klum's like little

539  
00:21:47,679 --> 00:21:54,100  
knots of blue knots on the ring itself

540  
00:21:50,409 --> 00:21:57,220  
so this is fantastic for our science so

541  
00:21:54,099 --> 00:21:58,808  
we and we also saw some little some blue

542

00:21:57,220 --> 00:22:01,329  
stuff at the center which we thought was

543  
00:21:58,808 --> 00:22:03,069  
maybe also some part of the lensing but

544  
00:22:01,329 --> 00:22:04,839  
we couldn't really resolve it we can see

545  
00:22:03,069 --> 00:22:08,048  
it well from ground-based observations

546  
00:22:04,839 --> 00:22:09,939  
because they're so blurry and then we

547  
00:22:08,048 --> 00:22:12,908  
pointed the Hubble Space Telescope on

548  
00:22:09,940 --> 00:22:14,960  
edit and we said you know what this is a

549  
00:22:12,909 --> 00:22:16,789  
fantastic cleanse just like

550  
00:22:14,960 --> 00:22:19,190  
thought it would be but wait a minute

551  
00:22:16,788 --> 00:22:21,919  
what's that over there that's a center

552  
00:22:19,190 --> 00:22:23,630  
what is this yeah okay let's pick that

553  
00:22:21,919 --> 00:22:25,788  
up let's go ahead and put that up we

554  
00:22:23,630 --> 00:22:28,429  
have a potter here we go here's a here's

555  
00:22:25,788 --> 00:22:30,470  
a slight blow up but we have an even

556  
00:22:28,429 --> 00:22:31,730

closer one coming up so yeah you're

557

00:22:30,470 --> 00:22:35,329

talking about this stuff in the center

558

00:22:31,730 --> 00:22:38,120

there we go exactly so that stuff in the

559

00:22:35,329 --> 00:22:40,158

center what is this this cannot be lent

560

00:22:38,119 --> 00:22:43,099

I'm looking at this I'm saying this is

561

00:22:40,159 --> 00:22:44,840

not lensing this is not a background

562

00:22:43,099 --> 00:22:46,759

galaxy that's being when's by the

563

00:22:44,839 --> 00:22:48,379

cluster it's way too bright to be a

564

00:22:46,759 --> 00:22:55,129

background galaxies being lens by the

565

00:22:48,380 --> 00:22:59,690

cluster space unicorns right and such a

566

00:22:55,130 --> 00:23:00,980

thing should not exist in a cluster when

567

00:22:59,690 --> 00:23:02,480

I looked at this image for the first

568

00:23:00,980 --> 00:23:04,099

time not being an extra I don't work on

569

00:23:02,480 --> 00:23:06,798

gravitational lensing like Karen and

570

00:23:04,099 --> 00:23:08,418

Jane do I saw this and said well this is



571  
00:23:06,798 --> 00:23:09,679  
unlike any star formation and field

572  
00:23:08,419 --> 00:23:11,360  
ellipticals that are in cluster

573  
00:23:09,679 --> 00:23:13,100  
ellipticals that I've ever seen so this

574  
00:23:11,359 --> 00:23:15,798  
has to be a gravitational lens this

575  
00:23:13,099 --> 00:23:17,750  
would be some really crazy gravitational

576  
00:23:15,798 --> 00:23:21,109  
lens and that's really exciting but uh

577  
00:23:17,750 --> 00:23:23,599  
that was my first hypothesis and so we

578  
00:23:21,109 --> 00:23:24,949  
ended up independently ruling that out

579  
00:23:23,599 --> 00:23:27,288  
in two different ways both with

580  
00:23:24,950 --> 00:23:30,140  
ground-based spectroscopy and with

581  
00:23:27,288 --> 00:23:31,849  
Karen's paper which goes through full

582  
00:23:30,140 --> 00:23:34,038  
detail explaining how this could not

583  
00:23:31,849 --> 00:23:36,349  
possibly be a gravitationally lensed

584  
00:23:34,038 --> 00:23:39,379  
image and so what you're left with is

585  
00:23:36,349 --> 00:23:40,939  
this amazing result that this is

586  
00:23:39,380 --> 00:23:42,830  
actually star formation taking place

587  
00:23:40,940 --> 00:23:45,350  
within these two colliding giant

588  
00:23:42,829 --> 00:23:47,058  
elliptical galaxies so Karen can you

589  
00:23:45,349 --> 00:23:50,509  
give us some idea why you're so sure

590  
00:23:47,058 --> 00:23:53,829  
it's not Lindsay oh so in a

591  
00:23:50,509 --> 00:23:56,599  
gravitational lensing theory um you can

592  
00:23:53,829 --> 00:23:58,460  
once you make a model of the cluster

593  
00:23:56,599 --> 00:24:00,589  
once you understand that the optics like

594  
00:23:58,460 --> 00:24:03,860  
I said right and make predictions of

595  
00:24:00,589 --> 00:24:06,349  
what other images of the same source

596  
00:24:03,859 --> 00:24:08,898  
look like sort of it let's say you have

597  
00:24:06,349 --> 00:24:10,849  
two mirrors in front of you I want to

598  
00:24:08,898 --> 00:24:13,759  
this ride one to the left you see an

599

00:24:10,849 --> 00:24:15,168  
image in the left mirror you can sort of

600  
00:24:13,759 --> 00:24:17,720  
predict what that image would look like

601  
00:24:15,169 --> 00:24:20,750  
in the right near right it's you know

602  
00:24:17,720 --> 00:24:23,659  
rounded or some color or some some

603  
00:24:20,750 --> 00:24:26,778  
features in it and this is sort of what

604  
00:24:23,659 --> 00:24:28,130  
the lens model can do you start with one

605  
00:24:26,778 --> 00:24:30,650  
image and you can

606  
00:24:28,130 --> 00:24:33,050  
solve the equations and figure out what

607  
00:24:30,650 --> 00:24:35,480  
the other image would look like and the

608  
00:24:33,049 --> 00:24:39,950  
other image looks a lot fainter than

609  
00:24:35,480 --> 00:24:41,329  
this the image that would appear if it

610  
00:24:39,950 --> 00:24:43,490  
had appeared at the center of the

611  
00:24:41,329 --> 00:24:45,589  
cluster would be so faint it would be

612  
00:24:43,490 --> 00:24:47,839  
fainter than the faintest thing blue

613  
00:24:45,589 --> 00:24:49,220

thing that you can see here so the blue

614

00:24:47,839 --> 00:24:52,339

stuff that we're looking at it is so

615

00:24:49,220 --> 00:24:54,230

bright here would appear fainter if this

616

00:24:52,339 --> 00:24:58,159

wasn't yeah if this was a lens

617

00:24:54,230 --> 00:25:01,190

background galaxy right here this would

618

00:24:58,160 --> 00:25:05,750

be very very very very faint probably

619

00:25:01,190 --> 00:25:07,070

200 times fainter than this ok so based

620

00:25:05,750 --> 00:25:09,200

on your models are telling you this

621

00:25:07,069 --> 00:25:11,000

can't possibly be much brighter so ok

622

00:25:09,200 --> 00:25:13,400

you you've ruled out that this is not

623

00:25:11,000 --> 00:25:17,890

lensing then what you do stare at it

624

00:25:13,400 --> 00:25:20,390

some more wet then we call our friends

625

00:25:17,890 --> 00:25:22,759

who knows about this who could write a

626

00:25:20,390 --> 00:25:25,759

paper on this yeah yeah what is this

627

00:25:22,759 --> 00:25:28,640

stuff so what we're looking at so you

628  
00:25:25,759 --> 00:25:30,109  
see the yellow stuff right too bright

629  
00:25:28,640 --> 00:25:34,009  
yellow clumps on the left and right

630  
00:25:30,109 --> 00:25:36,500  
right these are the nuclei of two giant

631  
00:25:34,009 --> 00:25:38,329  
elliptical galaxies that are crashing

632  
00:25:36,500 --> 00:25:40,309  
together and I'm try to say giant I mean

633  
00:25:38,329 --> 00:25:42,139  
huge together their projected stellar

634  
00:25:40,309 --> 00:25:44,419  
envelope is about 300,000 light-years

635  
00:25:42,140 --> 00:25:46,310  
from end to end compared to our Milky

636  
00:25:44,420 --> 00:25:51,320  
Way which is about three times the size

637  
00:25:46,309 --> 00:25:53,829  
okay uh so these galaxies are far along

638  
00:25:51,319 --> 00:25:56,240  
in the process of crashing together ah

639  
00:25:53,829 --> 00:25:58,039  
you can see that their nuclei haven't

640  
00:25:56,240 --> 00:26:01,039  
exactly coalesced yet in you that you

641  
00:25:58,039 --> 00:26:03,619  
can still see two independent clumps but

642  
00:26:01,039 --> 00:26:05,210  
then you see this blue squiggly stuff in

643  
00:26:03,619 --> 00:26:06,889  
the center which we just talked about we

644  
00:26:05,210 --> 00:26:08,840  
ruled out could be a gravitationally

645  
00:26:06,890 --> 00:26:10,130  
lens image from a background source and

646  
00:26:08,839 --> 00:26:11,899  
we've also ruled out that it could be

647  
00:26:10,130 --> 00:26:14,390  
some weird projection effect from some

648  
00:26:11,900 --> 00:26:15,890  
foreground source meaning ever all of

649  
00:26:14,390 --> 00:26:19,150  
that blue emission that you see is

650  
00:26:15,890 --> 00:26:21,410  
embedded inside the yellow emission from

651  
00:26:19,150 --> 00:26:23,150  
the hundreds of billions of stars

652  
00:26:21,410 --> 00:26:24,860  
associated with these two merging

653  
00:26:23,150 --> 00:26:27,019  
elliptical galaxies yes there's kind of

654  
00:26:24,859 --> 00:26:28,219  
a halo around this this a little bit

655  
00:26:27,019 --> 00:26:31,129  
there on the two nuclei you're talking

656

00:26:28,220 --> 00:26:32,960  
about that right yeah it's very thin

657  
00:26:31,130 --> 00:26:34,370  
orangie wispy stuff around the tube

658  
00:26:32,960 --> 00:26:36,380  
right exactly and the two elliptical

659  
00:26:34,369 --> 00:26:38,149  
galaxies actually extend far beyond

660  
00:26:36,380 --> 00:26:40,190  
where this image shows so this is like

661  
00:26:38,150 --> 00:26:41,990  
taking a magnifying glass and zooming in

662  
00:26:40,190 --> 00:26:43,580  
on the center ok so that

663  
00:26:41,990 --> 00:26:45,890  
galaxies themselves are about three

664  
00:26:43,579 --> 00:26:48,980  
times larger than this image and we're

665  
00:26:45,890 --> 00:26:54,559  
looking at the sort of central hundred

666  
00:26:48,980 --> 00:26:56,569  
kiloparsecs or so so I the the blue

667  
00:26:54,558 --> 00:26:58,670  
squiggly stuff that you see in the very

668  
00:26:56,569 --> 00:27:02,089  
center is a hundred thousand light-years

669  
00:26:58,670 --> 00:27:03,980  
from end to end and after confirming

670  
00:27:02,089 --> 00:27:05,720

that indeed this this had to be blue

671

00:27:03,980 --> 00:27:08,360

excess emission from star formation

672

00:27:05,720 --> 00:27:10,069

taking place within these galaxies this

673

00:27:08,359 --> 00:27:11,689

burned us to do a lot of follow-up

674

00:27:10,069 --> 00:27:15,200

observations to figure out what is going

675

00:27:11,690 --> 00:27:16,460

on here so what we think this is you

676

00:27:15,200 --> 00:27:18,200

know when you're sticking when you have

677

00:27:16,460 --> 00:27:20,509

coffee and you're stirring it and you

678

00:27:18,200 --> 00:27:22,840

pour milk into your coffee for a little

679

00:27:20,509 --> 00:27:25,339

while you see ribbons of milk start to

680

00:27:22,839 --> 00:27:27,709

start to spin around but then the milk

681

00:27:25,339 --> 00:27:30,949

sort of evens out and your coffee just

682

00:27:27,710 --> 00:27:33,049

becomes lighter creamy coffee right what

683

00:27:30,950 --> 00:27:35,779

we think it this is is a very

684

00:27:33,049 --> 00:27:39,259

serendipitous lucky snapshot of a very



685  
00:27:35,779 --> 00:27:41,899  
short-lived morphology for this star

686  
00:27:39,259 --> 00:27:44,179  
formation so all of this blue light that

687  
00:27:41,900 --> 00:27:46,700  
you see is about five solar masses per

688  
00:27:44,179 --> 00:27:49,519  
year worth of new baby stars forming and

689  
00:27:46,700 --> 00:27:52,069  
five solar masses per year it's so one

690  
00:27:49,519 --> 00:27:55,849  
solar mass per year is roughly one earth

691  
00:27:52,069 --> 00:27:58,279  
moon per second of mass so this

692  
00:27:55,849 --> 00:28:02,269  
confirmation is equivalent to about five

693  
00:27:58,279 --> 00:28:04,279  
moons per second worth of new stars

694  
00:28:02,269 --> 00:28:06,920  
being created about five solar masses

695  
00:28:04,279 --> 00:28:08,420  
per year which is a nun which is a lot

696  
00:28:06,920 --> 00:28:10,070  
of star formation by the way the Milky

697  
00:28:08,420 --> 00:28:13,640  
Way for example is a slightly less than

698  
00:28:10,069 --> 00:28:15,950  
one solar mass per year right and what's

699  
00:28:13,640 --> 00:28:18,440  
amazing is that elliptical galaxies like

700  
00:28:15,950 --> 00:28:21,049  
jane was talking about earlier generally

701  
00:28:18,440 --> 00:28:24,019  
not always that's how they never do this

702  
00:28:21,049 --> 00:28:25,970  
yeah nah it's I thought maybe we should

703  
00:28:24,019 --> 00:28:27,349  
happen that way that is let's say why

704  
00:28:25,970 --> 00:28:29,870  
that is elliptical galaxies are

705  
00:28:27,349 --> 00:28:31,099  
typically very old galaxies right i mean

706  
00:28:29,869 --> 00:28:33,529  
there are among the largest in the

707  
00:28:31,099 --> 00:28:34,969  
universe so why don't that's what i mean

708  
00:28:33,529 --> 00:28:37,599  
that explains our color but why aren't

709  
00:28:34,970 --> 00:28:40,069  
they having new star formation so

710  
00:28:37,599 --> 00:28:42,949  
typically yeah so what's weird about the

711  
00:28:40,069 --> 00:28:44,689  
universe is that it exhibits um big to

712  
00:28:42,950 --> 00:28:46,759  
small behavior in what should be a big

713

00:28:44,690 --> 00:28:48,860  
to bigger universe so in our universe

714  
00:28:46,759 --> 00:28:51,379  
things are hierarchical right things

715  
00:28:48,859 --> 00:28:54,049  
grow by the by the by the coalescence of

716  
00:28:51,380 --> 00:28:55,399  
ever larger clumps of stuff right hmm

717  
00:28:54,049 --> 00:28:58,819  
and so

718  
00:28:55,398 --> 00:29:01,218  
I in if if star formation followed this

719  
00:28:58,819 --> 00:29:03,229  
trend the the largest galaxies in our

720  
00:29:01,219 --> 00:29:05,359  
universe would have the most booming

721  
00:29:03,229 --> 00:29:08,239  
star formation rates and we see the

722  
00:29:05,358 --> 00:29:10,759  
actual opposite effect um so it turns

723  
00:29:08,239 --> 00:29:13,489  
out that you actually need to actively

724  
00:29:10,759 --> 00:29:16,489  
um truncate or kill off star formation

725  
00:29:13,489 --> 00:29:19,429  
as the universe evolves which is a whole

726  
00:29:16,489 --> 00:29:21,169  
lot which is that some others gets older

727  
00:29:19,429 --> 00:29:22,369

and all these galaxies collide more and

728

00:29:21,169 --> 00:29:25,009

more they get bigger and bigger you're

729

00:29:22,368 --> 00:29:27,019

saying we should be seeing higher star

730

00:29:25,009 --> 00:29:29,479

formation in these galaxies not lower

731

00:29:27,019 --> 00:29:31,190

and yet we're seeing lower so you're

732

00:29:29,479 --> 00:29:33,348

saying something must be truncating

733

00:29:31,190 --> 00:29:35,659

somebody must be saying stop don't make

734

00:29:33,348 --> 00:29:37,338

any more new stars yeah various forms of

735

00:29:35,659 --> 00:29:39,139

energetic feedback have been invoked to

736

00:29:37,338 --> 00:29:41,118

explain this feedback from accreting

737

00:29:39,138 --> 00:29:43,878

supermassive black holes feedback from

738

00:29:41,118 --> 00:29:45,288

dying stars from supernova and things

739

00:29:43,878 --> 00:29:46,759

like that and that's that's a subject

740

00:29:45,288 --> 00:29:50,838

for a whole other hubble hanging agreed

741

00:29:46,759 --> 00:29:53,509

I agree the short version is it's a case

742  
00:29:50,838 --> 00:29:56,808  
where we see something happening in the

743  
00:29:53,509 --> 00:29:59,288  
universe which is that big that galaxies

744  
00:29:56,808 --> 00:30:01,398  
and clusters are red and dead and

745  
00:29:59,288 --> 00:30:04,429  
astronomers spend a ton of time trying

746  
00:30:01,398 --> 00:30:06,348  
to make it happen in theory yes right so

747  
00:30:04,429 --> 00:30:08,839  
we spend a lot of time trying to figure

748  
00:30:06,348 --> 00:30:11,450  
out how do you keep elliptical galaxies

749  
00:30:08,838 --> 00:30:13,428  
from forming new stars how do you keep

750  
00:30:11,450 --> 00:30:14,690  
it how do you truncate the star

751  
00:30:13,429 --> 00:30:16,639  
formation of the first place so they're

752  
00:30:14,690 --> 00:30:18,349  
done and then how do you keep them from

753  
00:30:16,638 --> 00:30:19,848  
making any more because if they make

754  
00:30:18,348 --> 00:30:22,548  
even a little bit more they turn blue

755  
00:30:19,848 --> 00:30:25,759  
again and that's not what we see so this

756  
00:30:22,548 --> 00:30:28,158  
is this is yeah a different topic but a

757  
00:30:25,759 --> 00:30:30,409  
crushing star formation in elliptical

758  
00:30:28,159 --> 00:30:32,028  
galaxies is a thing that a lot of people

759  
00:30:30,409 --> 00:30:34,129  
spend a lot of time trying to figure out

760  
00:30:32,028 --> 00:30:36,288  
how does the universe do it it obviously

761  
00:30:34,128 --> 00:30:37,998  
is doing it you don't quite know how so

762  
00:30:36,288 --> 00:30:39,950  
one way we can get it to start up again

763  
00:30:37,999 --> 00:30:41,509  
is to collide to push them together it

764  
00:30:39,950 --> 00:30:45,348  
looks like right is that what we seeing

765  
00:30:41,509 --> 00:30:48,409  
here so uh we're on a related question

766  
00:30:45,348 --> 00:30:49,579  
with Adam synergy from the Q&A app so

767  
00:30:48,409 --> 00:30:51,859  
let me just go ahead and put this up

768  
00:30:49,579 --> 00:30:54,798  
he's asking is the gas fueling this

769  
00:30:51,858 --> 00:30:56,178  
burst of star formation is the gas

770

00:30:54,798 --> 00:30:58,489  
fueling this star burst of star

771  
00:30:56,179 --> 00:31:00,589  
formation believed to originate in these

772  
00:30:58,489 --> 00:31:02,899  
elliptical galaxies or does it come from

773  
00:31:00,588 --> 00:31:04,338  
a shockwave linked to the merger or

774  
00:31:02,898 --> 00:31:06,168  
perhaps from elsewhere so you want to

775  
00:31:04,338 --> 00:31:07,969  
elaborate a little on that that is an

776  
00:31:06,169 --> 00:31:08,340  
absolutely fantastic question that's

777  
00:31:07,969 --> 00:31:10,590  
actually

778  
00:31:08,339 --> 00:31:12,509  
that is a fantastic question Adams will

779  
00:31:10,589 --> 00:31:16,199  
Adams one of the he asked a lot of great

780  
00:31:12,509 --> 00:31:18,538  
questions yeah go Adam uh yeah so so

781  
00:31:16,200 --> 00:31:20,220  
first of all we think of stars as I'm

782  
00:31:18,538 --> 00:31:22,048  
incredibly brilliant and energetic

783  
00:31:20,220 --> 00:31:24,269  
things but what's kind of weird is that

784  
00:31:22,048 --> 00:31:27,808

you need to form stars out of puddles or

785

00:31:24,269 --> 00:31:30,960

reservoirs of super super cold gas so if

786

00:31:27,808 --> 00:31:33,509

you if you want to form a star you need

787

00:31:30,960 --> 00:31:35,490

to take gas and make and cool it all the

788

00:31:33,509 --> 00:31:37,859

way into these puddles or lakes or

789

00:31:35,490 --> 00:31:39,808

reservoirs of what's called very cold

790

00:31:37,859 --> 00:31:42,269

molecular gas we're talking tens of

791

00:31:39,808 --> 00:31:44,278

kelvin so super super cold dense stuff

792

00:31:42,269 --> 00:31:47,849

and then from there you can get core

793

00:31:44,278 --> 00:31:49,980

collapse in and and growth of these baby

794

00:31:47,849 --> 00:31:52,980

cellar seeds and then actually start to

795

00:31:49,980 --> 00:31:55,079

form stars so the one of Adam's

796

00:31:52,980 --> 00:31:57,808

excellent question is a very pertinent

797

00:31:55,079 --> 00:32:00,058

one was this molecular gas that is now

798

00:31:57,808 --> 00:32:02,579

forming these stars already in the



799  
00:32:00,058 --> 00:32:05,339  
galaxies before they before they crash

800  
00:32:02,579 --> 00:32:08,398  
together and has has the collision of

801  
00:32:05,339 --> 00:32:10,918  
the galaxies sort of stirred up this

802  
00:32:08,398 --> 00:32:12,719  
molecular gas so like like water in a

803  
00:32:10,919 --> 00:32:14,970  
bathtub which is just sitting there if

804  
00:32:12,720 --> 00:32:16,980  
you if you if you have them I don't know

805  
00:32:14,970 --> 00:32:20,009  
you crash the bathtub into something

806  
00:32:16,980 --> 00:32:22,079  
else you get waves in the bathtub and do

807  
00:32:20,009 --> 00:32:27,028  
we form stars now along these waves or

808  
00:32:22,079 --> 00:32:29,970  
um are we continuously raining cooling

809  
00:32:27,028 --> 00:32:32,069  
gasps from the ambient hot x-ray halo

810  
00:32:29,970 --> 00:32:34,710  
that surrounds these these two galaxies

811  
00:32:32,069 --> 00:32:37,408  
um so I've skipped a step there because

812  
00:32:34,710 --> 00:32:40,590  
yes giant elliptical galaxy sit in a

813  
00:32:37,409 --> 00:32:45,120  
bath of ambient plasma tens of millions

814  
00:32:40,589 --> 00:32:47,730  
of degrees hot um and very often when

815  
00:32:45,119 --> 00:32:50,579  
the central density of this plasma is

816  
00:32:47,730 --> 00:32:53,278  
high enough that central plasma can cool

817  
00:32:50,579 --> 00:32:54,808  
very rapidly we're talking on 300

818  
00:32:53,278 --> 00:32:57,319  
million year time skills which to an

819  
00:32:54,808 --> 00:33:02,069  
astronomer is a very short time scale um

820  
00:32:57,319 --> 00:33:05,639  
so uh enough to form stars yeah so we so

821  
00:33:02,069 --> 00:33:07,408  
to address Adams question this this

822  
00:33:05,640 --> 00:33:09,210  
these stars could be forming I mean

823  
00:33:07,409 --> 00:33:11,130  
molecular gas that was already in the

824  
00:33:09,210 --> 00:33:12,630  
galaxies to begin with and has now just

825  
00:33:11,130 --> 00:33:15,330  
been stirred up because the galaxies

826  
00:33:12,630 --> 00:33:18,720  
have collided together or this could be

827

00:33:15,329 --> 00:33:21,899  
like a slow rain of cooling gasps from

828  
00:33:18,720 --> 00:33:26,549  
the ambient x-ray atmosphere that forms

829  
00:33:21,900 --> 00:33:29,670  
puddles and I and the the merging

830  
00:33:26,549 --> 00:33:31,889  
process is associated with huge

831  
00:33:29,670 --> 00:33:35,070  
gravitational torques enormous amounts

832  
00:33:31,890 --> 00:33:38,340  
of sheer um and and so maybe this rain

833  
00:33:35,069 --> 00:33:40,079  
is falling into this rather violent

834  
00:33:38,339 --> 00:33:41,759  
process of two galaxies coming together

835  
00:33:40,079 --> 00:33:43,529  
and that's what's creates this this

836  
00:33:41,759 --> 00:33:46,920  
really bizarre morphology that we see in

837  
00:33:43,529 --> 00:33:50,460  
the in the star formation uh plus or

838  
00:33:46,920 --> 00:33:54,140  
minus its up a material that you're

839  
00:33:50,460 --> 00:33:56,670  
suggesting that police from the other

840  
00:33:54,140 --> 00:34:01,500  
hey Tony I think you're going through a

841  
00:33:56,670 --> 00:34:04,470

pole right now ah yeah Tony

842

00:34:01,500 --> 00:34:06,210  
gravitationally lens yeah we're getting

843

00:34:04,470 --> 00:34:12,179  
spaghettification of your data stream

844

00:34:06,210 --> 00:34:15,869  
yes can we fix that okay known to deface

845

00:34:12,179 --> 00:34:18,329  
it I put something on the chat and we

846

00:34:15,869 --> 00:34:20,759  
can ask the question okay yeah all right

847

00:34:18,329 --> 00:34:22,590  
I'll speak for you uh hello am i back

848

00:34:20,760 --> 00:34:24,690  
yet yes you're sending much much better

849

00:34:22,590 --> 00:34:26,149  
okay good so my question was are you

850

00:34:24,690 --> 00:34:30,349  
leaning I think the press release

851

00:34:26,148 --> 00:34:33,239  
indicated that it might be more of a

852

00:34:30,349 --> 00:34:34,648  
rain of material explanation do you have

853

00:34:33,239 --> 00:34:37,939  
a preference over one of these

854

00:34:34,648 --> 00:34:40,500  
explanations of over the other yeah so I

855

00:34:37,940 --> 00:34:43,019  
our initial look at this cluster formed

856  
00:34:40,500 --> 00:34:45,510  
three basic hypothesis to test all of

857  
00:34:43,019 --> 00:34:49,079  
these hypotheses you need follow-up data

858  
00:34:45,510 --> 00:34:50,790  
so I it this could very possibly be

859  
00:34:49,079 --> 00:34:53,668  
arranged from the hot x-ray atmosphere

860  
00:34:50,789 --> 00:34:56,579  
but we note we won't know until we get

861  
00:34:53,668 --> 00:34:58,109  
um a Chandra x-ray observation of this

862  
00:34:56,579 --> 00:35:00,750  
source which has now been approved it

863  
00:34:58,110 --> 00:35:03,300  
was approved last month and it will take

864  
00:35:00,750 --> 00:35:05,519  
place sometime during this year okay so

865  
00:35:03,300 --> 00:35:08,039  
Chandra will look at this thing for 130

866  
00:35:05,519 --> 00:35:11,280  
killa seconds which is a number of days

867  
00:35:08,039 --> 00:35:13,320  
I think or it's quite a while 130,000

868  
00:35:11,280 --> 00:35:16,130  
seconds yeah it will stare right at this

869  
00:35:13,320 --> 00:35:18,450  
source and we'll get a very exquisite

870  
00:35:16,130 --> 00:35:21,269  
high-resolution x-ray image which we can

871  
00:35:18,449 --> 00:35:24,659  
then overlay on our beautiful HST image

872  
00:35:21,269 --> 00:35:26,670  
and we can do a multitude of tests so

873  
00:35:24,659 --> 00:35:28,889  
what we can do spatially resolved

874  
00:35:26,670 --> 00:35:32,070  
spectroscopy to get the temperature of

875  
00:35:28,889 --> 00:35:35,000  
the hot x-ray plasma and we can do a

876  
00:35:32,070 --> 00:35:37,789  
density entropy pressure maps

877  
00:35:35,000 --> 00:35:40,400  
that those are buzz words uh for for

878  
00:35:37,789 --> 00:35:42,710  
what ultimately is we'll find out if

879  
00:35:40,400 --> 00:35:45,170  
this could be a waterfall of cooling

880  
00:35:42,710 --> 00:35:47,750  
gasps from the x-ray atmosphere or a

881  
00:35:45,170 --> 00:35:50,059  
shock in the in the colliding hot x-ray

882  
00:35:47,750 --> 00:35:52,400  
halos between these two galaxies if you

883  
00:35:50,059 --> 00:35:54,230  
if you collide two galaxies together you

884

00:35:52,400 --> 00:35:59,360  
also collide they're two halos together

885  
00:35:54,230 --> 00:36:02,360  
so maybe you're a shot colliding they're

886  
00:35:59,360 --> 00:36:05,630  
too hot x-ray plasma halos then you

887  
00:36:02,360 --> 00:36:08,059  
create this high-density sheet of x-ray

888  
00:36:05,630 --> 00:36:10,460  
gas between the two galaxies and when

889  
00:36:08,059 --> 00:36:13,639  
you increase x-ray gas density you also

890  
00:36:10,460 --> 00:36:15,500  
increase its cooling rate so the very

891  
00:36:13,639 --> 00:36:18,379  
act of these galaxies colliding together

892  
00:36:15,500 --> 00:36:20,389  
could have set up kind of a waterfall a

893  
00:36:18,380 --> 00:36:22,730  
sheet of cooling gas between the

894  
00:36:20,389 --> 00:36:24,379  
galaxies and then what you're seeing in

895  
00:36:22,730 --> 00:36:26,840  
this blue emission is like rocks at the

896  
00:36:24,380 --> 00:36:28,880  
bottom of the waterfall this is this

897  
00:36:26,840 --> 00:36:30,769  
this sheet of cooling gas forms these

898  
00:36:28,880 --> 00:36:32,119

puddles of cold molecular gas and then

899

00:36:30,769 --> 00:36:33,500

this is where your form the stars so

900

00:36:32,119 --> 00:36:35,869

that's another hypothesis that we can

901

00:36:33,500 --> 00:36:38,059

test with this follow-up data is as

902

00:36:35,869 --> 00:36:41,269

usual it's always more observations are

903

00:36:38,059 --> 00:36:42,769

needed yeah it's sure as always so good

904

00:36:41,269 --> 00:36:44,989

I well I look forward to hearing more

905

00:36:42,769 --> 00:36:46,940

about that when Chandra is able to look

906

00:36:44,989 --> 00:36:48,319

at it a little bit as well now this is

907

00:36:46,940 --> 00:36:50,539

something that the press release called

908

00:36:48,320 --> 00:36:53,180

a beads on a string feature or

909

00:36:50,539 --> 00:36:55,670

phenomenon and and while it seems to be

910

00:36:53,179 --> 00:36:58,339

unusual in elliptical galaxies it's not

911

00:36:55,670 --> 00:37:02,559

so unusual in galaxy collisions in

912

00:36:58,340 --> 00:37:07,309

general is that correct judge game or



913  
00:37:02,559 --> 00:37:08,719  
should I ask grant can you hear me yeah

914  
00:37:07,309 --> 00:37:12,710  
grant why don't you take that one all

915  
00:37:08,719 --> 00:37:15,649  
right yeah so um so what you're seeing

916  
00:37:12,710 --> 00:37:18,260  
here is so if you can see the image what

917  
00:37:15,650 --> 00:37:20,440  
you see are not only blue filaments but

918  
00:37:18,260 --> 00:37:23,090  
you see clumps along these filaments and

919  
00:37:20,440 --> 00:37:25,340  
these clumps appear to be at least in

920  
00:37:23,090 --> 00:37:27,140  
projection relatively equally spaced

921  
00:37:25,340 --> 00:37:28,760  
from one another so it kind of looks

922  
00:37:27,139 --> 00:37:32,869  
like a pearl necklace that's kind of

923  
00:37:28,760 --> 00:37:36,080  
laid out on a table right okay so this

924  
00:37:32,869 --> 00:37:37,400  
is not something new so in 1983 a group

925  
00:37:36,079 --> 00:37:39,799  
of astronomers we're looking at images

926  
00:37:37,400 --> 00:37:41,960  
of spiral galaxies and they published a

927  
00:37:39,800 --> 00:37:44,090  
paper saying hey if you actually look at

928  
00:37:41,960 --> 00:37:45,590  
the arms of spiral galaxies star

929  
00:37:44,090 --> 00:37:48,140  
formation in those arms doesn't happen

930  
00:37:45,590 --> 00:37:51,680  
in uniform filaments it happens

931  
00:37:48,139 --> 00:37:53,750  
equally spaced corners and all of these

932  
00:37:51,679 --> 00:37:55,940  
clumps appear to be separated by about

933  
00:37:53,750 --> 00:37:57,980  
one kiloparsecs one kiloparsecs about

934  
00:37:55,940 --> 00:37:59,480  
3,000 light-years these clumps appear to

935  
00:37:57,980 --> 00:38:02,059  
be separated by 3,000 light-years from

936  
00:37:59,480 --> 00:38:04,250  
one another so they turn this beads on a

937  
00:38:02,059 --> 00:38:07,250  
string morphology and it turns out that

938  
00:38:04,250 --> 00:38:09,500  
this is not actually particularly its

939  
00:38:07,250 --> 00:38:11,480  
profound but it's not profound in the

940  
00:38:09,500 --> 00:38:13,730  
sense that it's that surprising because

941

00:38:11,480 --> 00:38:15,740  
it's really just a kiloparsecs scale

942  
00:38:13,730 --> 00:38:18,320  
manifestation of something called the

943  
00:38:15,739 --> 00:38:21,109  
jeans length which is related to the

944  
00:38:18,320 --> 00:38:22,850  
jeans instability which is which would

945  
00:38:21,110 --> 00:38:25,370  
be another hubble hang out to talk about

946  
00:38:22,849 --> 00:38:29,179  
but you can think of but it 10 words or

947  
00:38:25,369 --> 00:38:31,880  
less you have to tell us so in 10 words

948  
00:38:29,179 --> 00:38:34,549  
of less is this rain falling from clouds

949  
00:38:31,880 --> 00:38:36,530  
in the sky doesn't occur in continuous

950  
00:38:34,550 --> 00:38:38,800  
filaments that are unbroken from the

951  
00:38:36,530 --> 00:38:42,280  
ground to the sky rain falls and drops

952  
00:38:38,800 --> 00:38:46,550  
why does rain falling drops because a

953  
00:38:42,280 --> 00:38:49,130  
cylinder of a fluid will prefer to

954  
00:38:46,550 --> 00:38:50,750  
contract into a series of droplets just

955  
00:38:49,130 --> 00:38:52,820

because those spherical droplets are a

956

00:38:50,750 --> 00:38:56,480

lower energy configuration so just like

957

00:38:52,820 --> 00:38:59,780

wow that was outstanding words but it

958

00:38:56,480 --> 00:39:01,610

was a great explanation though I want to

959

00:38:59,780 --> 00:39:03,380

be careful here for our more advanced

960

00:39:01,610 --> 00:39:05,510

audience like Adam because Adam is about

961

00:39:03,380 --> 00:39:07,789

to complain yes the genes like is it

962

00:39:05,510 --> 00:39:09,650

does involve a bit slightly different

963

00:39:07,789 --> 00:39:11,239

physics well when you actually boil it

964

00:39:09,650 --> 00:39:13,400

down to the fundamental processes of

965

00:39:11,239 --> 00:39:15,139

what's going on the the physics that

966

00:39:13,400 --> 00:39:18,440

dictates the morphology of this star

967

00:39:15,139 --> 00:39:20,539

formation arm is not much different from

968

00:39:18,440 --> 00:39:23,329

the reason why when you turn your water

969

00:39:20,539 --> 00:39:25,909

faucet on in your kitchen the the it

970  
00:39:23,329 --> 00:39:27,619  
really slowly the water will will

971  
00:39:25,909 --> 00:39:28,940  
contract and fall into a series of

972  
00:39:27,619 --> 00:39:31,039  
droplets by the time it reaches the

973  
00:39:28,940 --> 00:39:34,519  
bottom of your sink it's the same

974  
00:39:31,039 --> 00:39:36,409  
physics I have a question actually but

975  
00:39:34,519 --> 00:39:38,420  
it's not exactly what you were talking

976  
00:39:36,409 --> 00:39:41,529  
about it wasn't a fat jeans length um

977  
00:39:38,420 --> 00:39:44,480  
you were talking about the tool

978  
00:39:41,530 --> 00:39:47,210  
elliptical galaxies and the fact that

979  
00:39:44,480 --> 00:39:49,429  
they may be merging and or they may be

980  
00:39:47,210 --> 00:39:51,170  
getting material rain down on them and

981  
00:39:49,429 --> 00:39:53,599  
you were talking about the morphology

982  
00:39:51,170 --> 00:39:55,940  
the halos in the image we are looking at

983  
00:39:53,599 --> 00:39:58,190  
right now it looks like it doesn't look

984  
00:39:55,940 --> 00:40:02,150  
like a double load halo it looks like a

985  
00:39:58,190 --> 00:40:06,889  
single spherical halo and if you go back

986  
00:40:02,150 --> 00:40:09,858  
to the larger view um it looks like the

987  
00:40:06,889 --> 00:40:12,019  
the ring of Arc's is actually at a

988  
00:40:09,858 --> 00:40:15,679  
slightly different orientation but it

989  
00:40:12,019 --> 00:40:21,559  
does encircle it cause any circle those

990  
00:40:15,679 --> 00:40:24,318  
two objects is that completely unrelated

991  
00:40:21,559 --> 00:40:25,910  
I mean that is the mass distribution

992  
00:40:24,318 --> 00:40:28,068  
that's causing the lens and it's also

993  
00:40:25,909 --> 00:40:30,139  
the mass distribution plus maybe gas

994  
00:40:28,068 --> 00:40:32,599  
that's causing the star formation is

995  
00:40:30,139 --> 00:40:39,828  
does one tell you anything about the

996  
00:40:32,599 --> 00:40:42,440  
other earning so first of all don't let

997  
00:40:39,829 --> 00:40:44,630  
that appearance of those are extra cute

998

00:40:42,440 --> 00:40:48,440  
of thinking that the mass is distributed

999  
00:40:44,630 --> 00:40:54,500  
in the same direction as those arcs it's

1000  
00:40:48,440 --> 00:40:57,200  
not necessarily always follow mm-hmm in

1001  
00:40:54,500 --> 00:41:00,528  
this particular case the mass is aligned

1002  
00:40:57,199 --> 00:41:03,230  
along the line that connects those two

1003  
00:41:00,528 --> 00:41:07,190  
galaxies to each other released in

1004  
00:41:03,230 --> 00:41:12,920  
projection so the cluster is elongated

1005  
00:41:07,190 --> 00:41:15,170  
in the direction of the merger okay okay

1006  
00:41:12,920 --> 00:41:16,880  
thank you so let I got a couple of good

1007  
00:41:15,170 --> 00:41:19,338  
questions here on the Q&A app let me

1008  
00:41:16,880 --> 00:41:21,950  
bring one up here from Ayman Fantin he's

1009  
00:41:19,338 --> 00:41:24,980  
going optical lenses have a focal length

1010  
00:41:21,949 --> 00:41:26,750  
if the hidden galaxy is exactly at the

1011  
00:41:24,980 --> 00:41:30,139  
focal length would you get a perfect

1012  
00:41:26,750 --> 00:41:32,650

image of that galaxy so I guess he's

1013

00:41:30,139 --> 00:41:35,420

asking would we is there is there a

1014

00:41:32,650 --> 00:41:36,950

configuration a way in which we can look

1015

00:41:35,420 --> 00:41:42,139

at these lens galaxies which would be

1016

00:41:36,949 --> 00:41:44,028

perfectly in focus yeah so um there is

1017

00:41:42,139 --> 00:41:46,308

such a thing and it's called an Einstein

1018

00:41:44,028 --> 00:41:48,889

ring and this generally would happen

1019

00:41:46,309 --> 00:41:52,250

when there's a very simple lens like one

1020

00:41:48,889 --> 00:41:54,469

galaxy that is very massive and an

1021

00:41:52,250 --> 00:41:57,739

object like a another galaxy that is

1022

00:41:54,469 --> 00:41:59,838

exactly exactly behind it and then

1023

00:41:57,739 --> 00:42:02,118

instead of getting let's say two images

1024

00:41:59,838 --> 00:42:05,179

of the same thing or 3d images are the

1025

00:42:02,119 --> 00:42:07,010

same thing you'll get infinite images of

1026

00:42:05,179 --> 00:42:11,269

the same thing and that would form a



1027  
00:42:07,010 --> 00:42:14,420  
perfect Einstein ring we have there are

1028  
00:42:11,269 --> 00:42:15,530  
a lot of examples of those things this

1029  
00:42:14,420 --> 00:42:17,539  
usually doesn't happen

1030  
00:42:15,530 --> 00:42:20,450  
in clusters because they are very

1031  
00:42:17,539 --> 00:42:23,029  
complicated there's a lot of mass and

1032  
00:42:20,449 --> 00:42:25,189  
the distribution of mass is not just one

1033  
00:42:23,030 --> 00:42:27,019  
object yeah we've talked about that at

1034  
00:42:25,190 --> 00:42:28,970  
length with our frontier fields hanging

1035  
00:42:27,019 --> 00:42:32,090  
out we're like here's an example oh yeah

1036  
00:42:28,969 --> 00:42:34,459  
it's got sample of one of the lensing

1037  
00:42:32,090 --> 00:42:36,910  
models that they're using for frontier

1038  
00:42:34,460 --> 00:42:40,130  
fields and this would be sort of what

1039  
00:42:36,909 --> 00:42:42,049  
you're describing Karen with the optics

1040  
00:42:40,130 --> 00:42:43,099  
you know the mathematical representation

1041  
00:42:42,050 --> 00:42:44,500  
of what are the optics with this system

1042  
00:42:43,099 --> 00:42:48,949  
this is one of the frontier fields

1043  
00:42:44,500 --> 00:42:50,690  
models but this as you can see they're

1044  
00:42:48,949 --> 00:42:52,899  
pretty complicated right you want to

1045  
00:42:50,690 --> 00:42:56,139  
comment on this just a little bit maybe

1046  
00:42:52,900 --> 00:42:58,760  
yeah so clusters of galaxies have

1047  
00:42:56,139 --> 00:43:01,519  
galaxies in them they also have a lot of

1048  
00:42:58,760 --> 00:43:05,450  
dark matter and they're actually nodes

1049  
00:43:01,519 --> 00:43:08,690  
in the cosmic web of things coming

1050  
00:43:05,449 --> 00:43:10,879  
together so unlike one galaxy which is

1051  
00:43:08,690 --> 00:43:13,429  
which could be very isolated from the

1052  
00:43:10,880 --> 00:43:16,099  
rest of its environment this really

1053  
00:43:13,429 --> 00:43:19,339  
feeds on dark matter and gas and

1054  
00:43:16,099 --> 00:43:22,369  
galaxies from the entire cosmic web so

1055

00:43:19,340 --> 00:43:23,950  
it's not very smooth and symmetrical

1056  
00:43:22,369 --> 00:43:26,779  
looking sometimes it could look like

1057  
00:43:23,949 --> 00:43:31,750  
this picture that you have on now like a

1058  
00:43:26,780 --> 00:43:35,600  
weird amoeba thing right um so it's it's

1059  
00:43:31,750 --> 00:43:37,639  
more complicated yeah so these these

1060  
00:43:35,599 --> 00:43:40,610  
things can get quite quite messy when it

1061  
00:43:37,639 --> 00:43:42,079  
comes to galaxy clusters okay Hugo

1062  
00:43:40,610 --> 00:43:45,440  
Burnham he's always great he's got a

1063  
00:43:42,079 --> 00:43:49,730  
comment here 130 k seconds equals 36

1064  
00:43:45,440 --> 00:43:52,909  
hours plus change thank you Matt in my

1065  
00:43:49,730 --> 00:43:55,460  
head and my guys not happening oh yeah

1066  
00:43:52,909 --> 00:43:59,089  
so thank you I was often we appreciate

1067  
00:43:55,460 --> 00:44:00,769  
your helping us out there I have one

1068  
00:43:59,090 --> 00:44:04,220  
other another comment also from Iman

1069  
00:44:00,769 --> 00:44:06,650

phantom uh will gravitational lensing

1070

00:44:04,219 --> 00:44:09,109

effect the redshifts of the objects

1071

00:44:06,650 --> 00:44:12,530

being lanced what are the implications

1072

00:44:09,110 --> 00:44:15,050

or uses if redshift is affected can the

1073

00:44:12,530 --> 00:44:17,180

distance to the lens galaxies be

1074

00:44:15,050 --> 00:44:19,220

measured accurately so two questions

1075

00:44:17,179 --> 00:44:21,529

there one is does it affect the

1076

00:44:19,219 --> 00:44:24,079

redshifts of the object being lens and

1077

00:44:21,530 --> 00:44:26,360

the other is can the distance of these

1078

00:44:24,079 --> 00:44:27,929

lens galaxies be measured accurately who

1079

00:44:26,360 --> 00:44:30,120

wants to take that one

1080

00:44:27,929 --> 00:44:33,299

yeah so the redshift is something that

1081

00:44:30,119 --> 00:44:37,049

you measure and it has to do with the

1082

00:44:33,300 --> 00:44:39,120

expansion of the universe and how it the

1083

00:44:37,050 --> 00:44:42,240

galaxy would seem like they're getting

1084  
00:44:39,119 --> 00:44:44,670  
farther and farther away from us there

1085  
00:44:42,239 --> 00:44:46,619  
we the wavelength of the light that

1086  
00:44:44,670 --> 00:44:48,240  
comes to us becomes red shifted so this

1087  
00:44:46,619 --> 00:44:50,279  
is something that is that can be

1088  
00:44:48,239 --> 00:44:53,549  
measured and it's not affected by

1089  
00:44:50,280 --> 00:44:55,590  
gravitational lensing the distance can

1090  
00:44:53,550 --> 00:44:59,160  
actually be measured from gravitational

1091  
00:44:55,590 --> 00:45:02,720  
lensing because the geometry of the lens

1092  
00:44:59,159 --> 00:45:07,230  
or how powerful the lens is is affected

1093  
00:45:02,719 --> 00:45:10,679  
or is related to that this the geometry

1094  
00:45:07,230 --> 00:45:13,320  
so how far the lens is from you how far

1095  
00:45:10,679 --> 00:45:14,849  
the background source is from you and

1096  
00:45:13,320 --> 00:45:18,269  
how far the background source is from

1097  
00:45:14,849 --> 00:45:22,519  
the lens so all those three distances

1098  
00:45:18,269 --> 00:45:25,619  
and and yes you can send you can

1099  
00:45:22,519 --> 00:45:29,159  
independently measure the redshift and

1100  
00:45:25,619 --> 00:45:31,230  
measure the distances and this can in

1101  
00:45:29,159 --> 00:45:34,710  
theory give you information about the

1102  
00:45:31,230 --> 00:45:37,199  
above the zoology and about the geometry

1103  
00:45:34,710 --> 00:45:39,360  
of the universe great good question

1104  
00:45:37,199 --> 00:45:42,269  
thank you aim that was good so Judy

1105  
00:45:39,360 --> 00:45:44,130  
Schmidt has a comment those J 1 2 3 4

1106  
00:45:42,269 --> 00:45:46,349  
plus blah blah blah names are just

1107  
00:45:44,130 --> 00:45:47,849  
shorthand coordinates as a layperson I

1108  
00:45:46,349 --> 00:45:49,799  
just wanted to mention it because it's a

1109  
00:45:47,849 --> 00:45:51,659  
simple thing that is not obvious but

1110  
00:45:49,800 --> 00:45:52,950  
helpful to understand why they are named

1111  
00:45:51,659 --> 00:45:54,960  
like they are that's correct they're

1112

00:45:52,949 --> 00:45:58,019  
mostly just coordinating so thank you

1113  
00:45:54,960 --> 00:46:00,300  
point UT uh that that's an important

1114  
00:45:58,019 --> 00:46:03,630  
thing to point out and here's one from a

1115  
00:46:00,300 --> 00:46:05,760  
bond kasim I think and inside maybe this

1116  
00:46:03,630 --> 00:46:09,480  
one's for you grant I don't know where

1117  
00:46:05,760 --> 00:46:15,180  
does all energy go inside a black hole

1118  
00:46:09,480 --> 00:46:17,030  
exactly exactly exactly that is that is

1119  
00:46:15,179 --> 00:46:21,089  
a thing that is a very good question

1120  
00:46:17,030 --> 00:46:23,730  
first of all um you can't grow a black

1121  
00:46:21,090 --> 00:46:25,650  
hole for free so when you dump matter on

1122  
00:46:23,730 --> 00:46:27,869  
to a black hole you also at the same

1123  
00:46:25,650 --> 00:46:30,750  
time liberate an enormous amount of

1124  
00:46:27,869 --> 00:46:32,549  
gravitational energy that is why you see

1125  
00:46:30,750 --> 00:46:34,949  
things like radio galaxies and quasars

1126  
00:46:32,550 --> 00:46:38,930

and things that I'm sure you've talked

1127

00:46:34,949 --> 00:46:38,929  
about in other public outs um

1128

00:46:39,349 --> 00:46:44,690  
well where the where the energy goes

1129

00:46:42,070 --> 00:46:46,789  
within a black hole is absolutely a

1130

00:46:44,690 --> 00:46:49,820  
subject that would be actually very nice

1131

00:46:46,789 --> 00:46:53,090  
hang out mm-hm um it's a yeah that's a

1132

00:46:49,820 --> 00:46:55,400  
very long and a complicated answer okay

1133

00:46:53,090 --> 00:46:58,280  
well have Jane into that one she's way

1134

00:46:55,400 --> 00:47:00,829  
more elegant than I am why we see the

1135

00:46:58,280 --> 00:47:02,930  
that you know energy is mass and masses

1136

00:47:00,829 --> 00:47:06,079  
energy and once mass goes down the point

1137

00:47:02,929 --> 00:47:07,789  
of no return of the black hole it's gone

1138

00:47:06,079 --> 00:47:10,340  
it's not accessible and the same is true

1139

00:47:07,789 --> 00:47:12,079  
for energy and at some level that gets

1140

00:47:10,340 --> 00:47:14,720  
no a philosophical question is it's



1141  
00:47:12,079 --> 00:47:17,119  
still in our universe then I can't touch

1142  
00:47:14,719 --> 00:47:19,879  
it if you can't get it back if you can't

1143  
00:47:17,119 --> 00:47:22,039  
you can't even send you a signal right

1144  
00:47:19,880 --> 00:47:26,119  
it becomes causally disconnected from us

1145  
00:47:22,039 --> 00:47:28,849  
yeah um yeah so but but I think I'd you

1146  
00:47:26,119 --> 00:47:30,349  
can't lend the ABS important sorry okay

1147  
00:47:28,849 --> 00:47:32,349  
I was just going to finish the thought

1148  
00:47:30,349 --> 00:47:35,029  
that because of mass-energy equivalence

1149  
00:47:32,349 --> 00:47:37,250  
energy that does get down there adds to

1150  
00:47:35,030 --> 00:47:38,780  
the mass of the black hole yes when we

1151  
00:47:37,250 --> 00:47:40,909  
talk about you know on the black hole

1152  
00:47:38,780 --> 00:47:43,640  
that weighs a billion times the mass of

1153  
00:47:40,909 --> 00:47:45,079  
the Sun that you could equally say it

1154  
00:47:43,639 --> 00:47:49,159  
has that much energy right that's just

1155  
00:47:45,079 --> 00:47:51,079  
how much stuff is in there okay I have

1156  
00:47:49,159 --> 00:47:53,359  
something from YouTube now this is craig

1157  
00:47:51,079 --> 00:47:56,659  
landon he's asking and i have it up on

1158  
00:47:53,360 --> 00:47:59,300  
my screen here could this be an event

1159  
00:47:56,659 --> 00:48:02,839  
similar to the bullet cluster collisions

1160  
00:47:59,300 --> 00:48:05,240  
with dark matter haloes colliding that

1161  
00:48:02,840 --> 00:48:08,269  
yes that is absolutely a fantastic

1162  
00:48:05,239 --> 00:48:10,969  
question so um I guess we don't have an

1163  
00:48:08,269 --> 00:48:13,280  
image of the bullet cluster Illi got you

1164  
00:48:10,969 --> 00:48:14,959  
covered hold on just so I scrubbing the

1165  
00:48:13,280 --> 00:48:17,240  
internet for us oh yeah let's get it

1166  
00:48:14,960 --> 00:48:20,050  
okay so there's a combined HST and

1167  
00:48:17,239 --> 00:48:23,359  
Chandra image of the bullet cluster um I

1168  
00:48:20,050 --> 00:48:25,910  
to answer your question this so not only

1169

00:48:23,360 --> 00:48:27,920  
do galaxies merge together but clusters

1170  
00:48:25,909 --> 00:48:31,819  
of galaxies also sometimes crash

1171  
00:48:27,920 --> 00:48:34,159  
together to this absolutely could be the

1172  
00:48:31,820 --> 00:48:36,410  
late stages of a cluster cluster merger

1173  
00:48:34,159 --> 00:48:39,049  
what we could be seeing is that those

1174  
00:48:36,409 --> 00:48:42,500  
two colliding galaxies at the center of

1175  
00:48:39,050 --> 00:48:45,289  
this image are actually the heads of two

1176  
00:48:42,500 --> 00:48:48,889  
smaller colliding clusters of galaxies

1177  
00:48:45,289 --> 00:48:50,509  
there's there's a bit of evidence for

1178  
00:48:48,889 --> 00:48:51,980  
this in the redshift distribution for

1179  
00:48:50,510 --> 00:48:53,360  
galaxies in the cluster you see what's

1180  
00:48:51,980 --> 00:48:55,280  
about a bit

1181  
00:48:53,360 --> 00:48:57,340  
bifurcation and redshift space meaning a

1182  
00:48:55,280 --> 00:49:00,890  
slight by modality and redshift space um

1183  
00:48:57,340 --> 00:49:02,150

for only about thirteen of the of the

1184

00:49:00,889 --> 00:49:03,440  
galaxies in this cluster so we're

1185

00:49:02,150 --> 00:49:05,059  
talking about low statistics and

1186

00:49:03,440 --> 00:49:07,329  
therefore low confidence in that in the

1187

00:49:05,059 --> 00:49:09,949  
hypothesis but this could absolutely be

1188

00:49:07,329 --> 00:49:11,269  
the late stages of a cluster merger kind

1189

00:49:09,949 --> 00:49:13,039  
of like what you're seeing here with the

1190

00:49:11,269 --> 00:49:16,849  
bullet cluster Scott's got it up now

1191

00:49:13,039 --> 00:49:18,860  
yeah I think spoke a great uh and we

1192

00:49:16,849 --> 00:49:21,710  
will be able to test this hypothesis

1193

00:49:18,860 --> 00:49:23,450  
with a Chandra observation and with

1194

00:49:21,710 --> 00:49:26,960  
follow-up observations from the ground

1195

00:49:23,449 --> 00:49:30,710  
for example if we get um optical

1196

00:49:26,960 --> 00:49:32,960  
spectroscopy for more many many more of

1197

00:49:30,710 --> 00:49:34,730  
the galaxies in this cluster we can more

1198  
00:49:32,960 --> 00:49:36,889  
accurately map the redshift distribution

1199  
00:49:34,730 --> 00:49:39,139  
and therefore it kind of sculpt out the

1200  
00:49:36,889 --> 00:49:41,239  
3d geometry of galaxies in this cluster

1201  
00:49:39,139 --> 00:49:43,639  
and try to work out what's happening

1202  
00:49:41,239 --> 00:49:44,839  
here this absolutely could be a cluster

1203  
00:49:43,639 --> 00:49:46,250  
merchant why don't you give us just a

1204  
00:49:44,840 --> 00:49:47,390  
real quick description of this what

1205  
00:49:46,250 --> 00:49:49,940  
we're looking at with the bullet cluster

1206  
00:49:47,389 --> 00:49:51,469  
here yeah so let me pull up Scott's

1207  
00:49:49,940 --> 00:49:54,079  
image that I can do it just just click

1208  
00:49:51,469 --> 00:49:56,329  
on it there exactly so so the bullet

1209  
00:49:54,079 --> 00:49:58,309  
cluster is is like that famous picture

1210  
00:49:56,329 --> 00:50:01,400  
of a bullet going through an apple right

1211  
00:49:58,309 --> 00:50:03,349  
so uh two massive clusters of galaxies

1212  
00:50:01,400 --> 00:50:06,139  
that were once relatively independent

1213  
00:50:03,349 --> 00:50:08,480  
have crashed together and one has now

1214  
00:50:06,139 --> 00:50:10,519  
passed through the other just like just

1215  
00:50:08,480 --> 00:50:12,260  
like the bullet that you know that slow

1216  
00:50:10,519 --> 00:50:15,019  
motion bullet through an apple the

1217  
00:50:12,260 --> 00:50:18,980  
famous image right yeah um and what you

1218  
00:50:15,019 --> 00:50:21,949  
see in that kind of um v-shaped or

1219  
00:50:18,980 --> 00:50:25,539  
l-shaped pink material off to the right

1220  
00:50:21,949 --> 00:50:29,899  
I guess that's kind of obvious right um

1221  
00:50:25,539 --> 00:50:31,789  
that's that is a shock in the x-ray gas

1222  
00:50:29,900 --> 00:50:34,840  
that has been associated with this

1223  
00:50:31,789 --> 00:50:37,269  
bullet this this much faster cluster

1224  
00:50:34,840 --> 00:50:41,360  
plowing through at very high velocity

1225  
00:50:37,269 --> 00:50:43,880  
this more massive cluster um that you

1226

00:50:41,360 --> 00:50:45,440  
see to the left so it's taken one full

1227  
00:50:43,880 --> 00:50:47,210  
passage through the cluster and it's

1228  
00:50:45,440 --> 00:50:49,670  
created this sort of shock wave in the

1229  
00:50:47,210 --> 00:50:53,840  
x-ray gas um that you see in pink

1230  
00:50:49,670 --> 00:50:55,490  
they're nice all right very good grant

1231  
00:50:53,840 --> 00:50:58,100  
you know I'm really glad that this

1232  
00:50:55,489 --> 00:51:04,099  
question came up because if you look

1233  
00:50:58,099 --> 00:51:07,219  
back at our our cluster 1531 uh the lens

1234  
00:51:04,099 --> 00:51:10,309  
model sorry that should be up

1235  
00:51:07,219 --> 00:51:11,779  
already in the vineyards up um so grant

1236  
00:51:10,309 --> 00:51:15,608  
the lens model does indicate that

1237  
00:51:11,780 --> 00:51:18,619  
there's a more mass to the you know

1238  
00:51:15,608 --> 00:51:21,920  
southeast which is the left ten side of

1239  
00:51:18,619 --> 00:51:24,740  
this picture the lens model does want

1240  
00:51:21,920 --> 00:51:27,800

this cluster to have mass in that

1241

00:51:24,739 --> 00:51:29,868  
direction that could indicate some

1242

00:51:27,800 --> 00:51:32,930  
stages of merger or past merger that

1243

00:51:29,869 --> 00:51:34,789  
happened well we should i we should talk

1244

00:51:32,929 --> 00:51:35,868  
about this more the three of us are

1245

00:51:34,789 --> 00:51:37,789  
going to have fun when we get this

1246

00:51:35,869 --> 00:51:39,079  
Chandra observation well sounds like it

1247

00:51:37,789 --> 00:51:41,000  
yeah that sounds like we should check

1248

00:51:39,079 --> 00:51:42,529  
back in with you guys to to see to see

1249

00:51:41,000 --> 00:51:44,269  
what develops out of that because uh

1250

00:51:42,530 --> 00:51:45,560  
that sounds like you you're going to be

1251

00:51:44,269 --> 00:51:47,929  
able to answer some big questions with

1252

00:51:45,559 --> 00:51:51,079  
this um so here's one from Dan Buddha on

1253

00:51:47,929 --> 00:51:53,059  
the quick the question Q&A app if the

1254

00:51:51,079 --> 00:51:56,000  
galaxies are getting far and farther



1255  
00:51:53,059 --> 00:51:59,570  
away from one another why do we have

1256  
00:51:56,000 --> 00:52:00,920  
clusters and so if all the galaxies in

1257  
00:51:59,570 --> 00:52:03,109  
the universe is expanding and getting

1258  
00:52:00,920 --> 00:52:04,700  
far away why are there clusters well in

1259  
00:52:03,108 --> 00:52:09,380  
some places the expansion of the

1260  
00:52:04,699 --> 00:52:11,750  
universe can overcome gravity gravity if

1261  
00:52:09,380 --> 00:52:14,570  
things are very very massive they just

1262  
00:52:11,750 --> 00:52:16,849  
gravitate towards each other and create

1263  
00:52:14,570 --> 00:52:18,740  
very massive objects that just be couple

1264  
00:52:16,849 --> 00:52:21,289  
from the expansion of the universe so

1265  
00:52:18,739 --> 00:52:23,118  
they in some sense they don't expand

1266  
00:52:21,289 --> 00:52:26,119  
with the universe kind of like the cells

1267  
00:52:23,119 --> 00:52:28,519  
in your body they stick together with

1268  
00:52:26,119 --> 00:52:30,500  
other forces and they don't expand with

1269  
00:52:28,519 --> 00:52:32,719  
the universe that's right even though

1270  
00:52:30,500 --> 00:52:36,409  
although I think Scott's head expands

1271  
00:52:32,719 --> 00:52:39,439  
with the universe so yeah accelerating

1272  
00:52:36,409 --> 00:52:41,420  
at least what rain expansion is

1273  
00:52:39,440 --> 00:52:43,130  
accelerating correctly so that's a good

1274  
00:52:41,420 --> 00:52:44,930  
point i mean even though space-time is

1275  
00:52:43,130 --> 00:52:46,338  
getting you know there's more of it and

1276  
00:52:44,929 --> 00:52:49,039  
it's getting further and further apart

1277  
00:52:46,338 --> 00:52:50,889  
it pushed the biggies galaxies or the

1278  
00:52:49,039 --> 00:52:52,880  
universe is getting further apart

1279  
00:52:50,889 --> 00:52:54,799  
locally there sometimes when you have

1280  
00:52:52,880 --> 00:52:57,140  
big clumps of things together like a

1281  
00:52:54,800 --> 00:53:00,440  
bunch of galaxies their gravity is not

1282  
00:52:57,139 --> 00:53:01,819  
overcome by this by this expansion so

1283

00:53:00,440 --> 00:53:06,230  
that's a good distinction thank you for

1284  
00:53:01,820 --> 00:53:08,630  
the question so let's see Michael jobin

1285  
00:53:06,230 --> 00:53:12,019  
is going could the dark matter in the

1286  
00:53:08,630 --> 00:53:13,760  
Galactic barrier could it could tart

1287  
00:53:12,019 --> 00:53:16,338  
matter be the Galactic barrier mentioned

1288  
00:53:13,760 --> 00:53:18,380  
in Star Trek oh yeah sure hey y'all I'll

1289  
00:53:16,338 --> 00:53:19,730  
take that one yeah I'm just going to

1290  
00:53:18,380 --> 00:53:21,170  
take that when is that going to turn my

1291  
00:53:19,730 --> 00:53:24,199  
eyes white

1292  
00:53:21,170 --> 00:53:26,659  
and yes no totally jealous psychic

1293  
00:53:24,199 --> 00:53:29,149  
powers cuz that would be great yeah I

1294  
00:53:26,659 --> 00:53:31,098  
could maybe to that I'm gonna be cute

1295  
00:53:29,150 --> 00:53:33,410  
I'll see your fingers you're going q

1296  
00:53:31,099 --> 00:53:39,740  
what is absolutely yes you're expanding

1297  
00:53:33,409 --> 00:53:41,629

head space and space okay we're getting

1298

00:53:39,739 --> 00:53:43,848

a couple more here on the Q&A app here's

1299

00:53:41,630 --> 00:53:45,950

one more here's one from Tom common with

1300

00:53:43,849 --> 00:53:47,780

those two colliding ellipticals could

1301

00:53:45,949 --> 00:53:50,088

the blue stuff in there be superimposed

1302

00:53:47,780 --> 00:53:52,579

signals because they are near the same

1303

00:53:50,088 --> 00:53:55,670

line of sight and not actually collide

1304

00:53:52,579 --> 00:53:59,390

that changed the detection from orange

1305

00:53:55,670 --> 00:54:02,659

to blue um I'm not sure how to well no I

1306

00:53:59,389 --> 00:54:04,909

I think look Jenna okay that's actually

1307

00:54:02,659 --> 00:54:06,980

a fantastic question so everything we

1308

00:54:04,909 --> 00:54:09,558

see on the sky is three-dimensional

1309

00:54:06,980 --> 00:54:11,389

stuff that's been projected into two

1310

00:54:09,559 --> 00:54:13,190

dimensional space so we're really

1311

00:54:11,389 --> 00:54:15,769

watching a universal puppet show in

1312  
00:54:13,190 --> 00:54:18,139  
shadows right shadow hand puppet show

1313  
00:54:15,769 --> 00:54:19,969  
right so it's very important that when

1314  
00:54:18,139 --> 00:54:21,588  
you're looking at a 2d image you

1315  
00:54:19,969 --> 00:54:24,108  
understand the 3d structure of what

1316  
00:54:21,588 --> 00:54:25,909  
you're looking at and so when we got

1317  
00:54:24,108 --> 00:54:27,828  
this HSC image of the cluster this

1318  
00:54:25,909 --> 00:54:30,199  
Hubble image of the cluster one of the

1319  
00:54:27,829 --> 00:54:32,359  
first questions you ask yourself is well

1320  
00:54:30,199 --> 00:54:34,519  
am I just seeing a projection effect of

1321  
00:54:32,358 --> 00:54:36,318  
stuff along the line of sight maybe all

1322  
00:54:34,519 --> 00:54:38,869  
of this blue squiggly stuff in the in

1323  
00:54:36,318 --> 00:54:40,789  
that we see in the center is completely

1324  
00:54:38,869 --> 00:54:42,798  
unrelated to these two galaxies and

1325  
00:54:40,789 --> 00:54:44,539  
maybe it's just sort of in the in front

1326  
00:54:42,798 --> 00:54:47,088  
of me or even as we were talking about

1327  
00:54:44,539 --> 00:54:49,250  
earlier behind the cluster and maybe

1328  
00:54:47,088 --> 00:54:50,808  
it's a gravitationally lensed image so

1329  
00:54:49,250 --> 00:54:53,719  
this is one of the first things that we

1330  
00:54:50,809 --> 00:54:56,000  
tested um and were able to rule this out

1331  
00:54:53,719 --> 00:54:58,639  
so we we rule out this possibility with

1332  
00:54:56,000 --> 00:55:00,650  
ground-based optical spectroscopy which

1333  
00:54:58,639 --> 00:55:02,568  
means you take the light from this

1334  
00:55:00,650 --> 00:55:04,670  
cluster and turn it into a rainbow you

1335  
00:55:02,568 --> 00:55:07,818  
disperse it and you can see things like

1336  
00:55:04,670 --> 00:55:10,818  
emission lines um uh one of them is

1337  
00:55:07,818 --> 00:55:14,119  
called H alpha for example and you see

1338  
00:55:10,818 --> 00:55:18,529  
uh emission lines maps to a certain

1339  
00:55:14,119 --> 00:55:21,619  
redshift arm redshift is just the way

1340

00:55:18,530 --> 00:55:23,170  
astronomers think about the 3d structure

1341  
00:55:21,619 --> 00:55:25,068  
of space right you can think about

1342  
00:55:23,170 --> 00:55:27,349  
distances from you in terms of redshift

1343  
00:55:25,068 --> 00:55:28,608  
and it turns out that everything that

1344  
00:55:27,349 --> 00:55:30,440  
you're seeing in that image in the

1345  
00:55:28,608 --> 00:55:32,690  
central regions at least meaning the two

1346  
00:55:30,440 --> 00:55:35,059  
giant yellow elliptical galaxies that

1347  
00:55:32,690 --> 00:55:36,860  
you see and the blue squiggles

1348  
00:55:35,059 --> 00:55:39,320  
everything is exactly at the same red

1349  
00:55:36,860 --> 00:55:41,329  
shift which means that this can't be a

1350  
00:55:39,320 --> 00:55:43,580  
3d projection effect from stuff along

1351  
00:55:41,329 --> 00:55:45,529  
the line of sight and indeed everything

1352  
00:55:43,579 --> 00:55:47,840  
needs to be basically on the same plane

1353  
00:55:45,530 --> 00:55:49,880  
so the two merging galaxies indeed are

1354  
00:55:47,840 --> 00:55:52,789

merging and are in are deeply embedded

1355

00:55:49,880 --> 00:55:55,250  
in one another over 20 so 60,000

1356

00:55:52,789 --> 00:55:56,929  
Lightyear scales basically and the blue

1357

00:55:55,250 --> 00:55:59,059  
squiggles that you see indeed are

1358

00:55:56,929 --> 00:56:00,529  
embedded in the cellar halos of those

1359

00:55:59,059 --> 00:56:02,119  
two merging galaxies so this is not a

1360

00:56:00,530 --> 00:56:03,410  
projection effect but that is a great

1361

00:56:02,119 --> 00:56:05,630  
question because it's one of the first

1362

00:56:03,409 --> 00:56:07,069  
that we asked yeah I'm very important

1363

00:56:05,630 --> 00:56:09,019  
what yeah that's that was a good

1364

00:56:07,070 --> 00:56:10,309  
question thank you Tom well take one

1365

00:56:09,019 --> 00:56:12,800  
more than a mascot if I'm missing

1366

00:56:10,309 --> 00:56:16,159  
anything um here's one from Julio says

1367

00:56:12,800 --> 00:56:18,289  
our burrito from the Q&A app what mate

1368

00:56:16,159 --> 00:56:20,599  
what makes the Milky Way Center take a



1369  
00:56:18,289 --> 00:56:25,130  
bar form and can it be the Jets of a

1370  
00:56:20,599 --> 00:56:29,869  
supermassive black hole anybody so I can

1371  
00:56:25,130 --> 00:56:32,079  
take that um the milk you the black hole

1372  
00:56:29,869 --> 00:56:36,349  
the center of our Milky Way is a slacker

1373  
00:56:32,079 --> 00:56:39,769  
um it's really disappointing as someone

1374  
00:56:36,349 --> 00:56:42,619  
who likes active black holes and

1375  
00:56:39,769 --> 00:56:44,030  
galaxies I continue to be disappointed

1376  
00:56:42,619 --> 00:56:46,339  
by the Milky Way so if the universe is

1377  
00:56:44,030 --> 00:56:51,440  
annoying the Milky Way's black hole is

1378  
00:56:46,340 --> 00:56:55,940  
just disappointed right why I just lost

1379  
00:56:51,440 --> 00:56:58,610  
our way to everything out but faucets in

1380  
00:56:55,940 --> 00:57:00,860  
the way yeah yeah i mean i'm glad i'm

1381  
00:56:58,610 --> 00:57:04,340  
not being continually irradiated but you

1382  
00:57:00,860 --> 00:57:11,090  
know it's so dinky grumpiest hangout

1383  
00:57:04,340 --> 00:57:13,460  
ever right high bar right here purse out

1384  
00:57:11,090 --> 00:57:15,170  
on the problems so this is serious so

1385  
00:57:13,460 --> 00:57:16,900  
the serious problem is that there's tons

1386  
00:57:15,170 --> 00:57:19,880  
of gas in the center of our Milky Way

1387  
00:57:16,900 --> 00:57:21,889  
and there's a black hole there's a

1388  
00:57:19,880 --> 00:57:23,990  
several million solar mass black hole

1389  
00:57:21,889 --> 00:57:25,969  
and yet the black hole refuses to

1390  
00:57:23,989 --> 00:57:27,619  
perform it's like when I asked my kid to

1391  
00:57:25,969 --> 00:57:31,519  
say bubble he just looks at me he's like

1392  
00:57:27,619 --> 00:57:34,039  
I don't perform mom ya know our Milky

1393  
00:57:31,519 --> 00:57:36,530  
Way black hole doesn't feel so it's got

1394  
00:57:34,039 --> 00:57:38,900  
you know its massive it's a center of a

1395  
00:57:36,530 --> 00:57:40,340  
whole lot of gas and it chooses not for

1396  
00:57:38,900 --> 00:57:42,470  
interesting reasons that we don't really

1397

00:57:40,340 --> 00:57:44,510  
understand to eat any of that gas or at

1398  
00:57:42,469 --> 00:57:47,179  
least not to be very so it doesn't have

1399  
00:57:44,510 --> 00:57:48,020  
big jets and it isn't bright and it's

1400  
00:57:47,179 --> 00:57:50,359  
really face

1401  
00:57:48,019 --> 00:57:55,489  
you have to observe with with Chandra

1402  
00:57:50,360 --> 00:57:57,110  
for four days to get a signal so so this

1403  
00:57:55,489 --> 00:58:00,469  
is a long way of saying that the Milky

1404  
00:57:57,110 --> 00:58:01,940  
Way our black hole is so underperforming

1405  
00:58:00,469 --> 00:58:05,089  
that it's not really capable right now

1406  
00:58:01,940 --> 00:58:07,340  
of doing much of anything to change the

1407  
00:58:05,090 --> 00:58:09,800  
structure in the past if it was more

1408  
00:58:07,340 --> 00:58:12,890  
energetic there these neat Fermi bubbles

1409  
00:58:09,800 --> 00:58:14,660  
that show that in the past the black

1410  
00:58:12,889 --> 00:58:16,759  
hole tercera actually shot these big

1411  
00:58:14,659 --> 00:58:19,190

bubbles of gas out through the galaxy um

1412

00:58:16,760 --> 00:58:22,360

the spiral I'm not quite sure about

1413

00:58:19,190 --> 00:58:25,849

because it's used to think about that

1414

00:58:22,360 --> 00:58:28,099

yeah so uh is it but didn't hear

1415

00:58:25,849 --> 00:58:29,509

something about a stream of gas in the

1416

00:58:28,099 --> 00:58:31,880

center of the Milky Way that's like

1417

00:58:29,510 --> 00:58:34,190

heading towards the black hole or

1418

00:58:31,880 --> 00:58:38,119

something like that or my you know

1419

00:58:34,190 --> 00:58:40,220

something yes soon soon something might

1420

00:58:38,119 --> 00:58:41,750

be happening right soon something might

1421

00:58:40,219 --> 00:58:45,789

be happening that is a story of the

1422

00:58:41,750 --> 00:58:48,500

universe right there maybe you know

1423

00:58:45,789 --> 00:58:50,900

there is there is a small gas cloud

1424

00:58:48,500 --> 00:58:53,900

which has now passed behind CJ star our

1425

00:58:50,900 --> 00:58:55,309

Sanjay stars the name are very prosaic

1426  
00:58:53,900 --> 00:58:58,309  
making for the black hole in center of

1427  
00:58:55,309 --> 00:59:00,799  
our galaxy right there is us a small I

1428  
00:58:58,309 --> 00:59:03,799  
think million solar mass are on a

1429  
00:59:00,800 --> 00:59:06,530  
hundred thousand solar mass cloud of gas

1430  
00:59:03,800 --> 00:59:10,880  
that has passed around and is coming

1431  
00:59:06,530 --> 00:59:12,920  
back um toward us around sad j star so

1432  
00:59:10,880 --> 00:59:14,840  
it's a small gas cloud it apparently

1433  
00:59:12,920 --> 00:59:16,400  
didn't a creek and it also apparently

1434  
00:59:14,840 --> 00:59:18,860  
didn't shear a part in the way that

1435  
00:59:16,400 --> 00:59:21,769  
astronomers were expecting oh let it

1436  
00:59:18,860 --> 00:59:26,059  
pass me again another disappointment for

1437  
00:59:21,769 --> 00:59:28,699  
Jane nothing interesting happened engine

1438  
00:59:26,059 --> 00:59:29,929  
went around it's like yeah it's still an

1439  
00:59:28,699 --> 00:59:31,929  
amazing result these are papers by

1440  
00:59:29,929 --> 00:59:36,169  
stefan glisten you know I know it's it

1441  
00:59:31,929 --> 00:59:39,230  
um but yeah one science but

1442  
00:59:36,170 --> 00:59:40,670  
disappointing yeah yeah ok so that was

1443  
00:59:39,230 --> 00:59:41,510  
that's been new since i heard i knew it

1444  
00:59:40,670 --> 00:59:42,980  
was discovered and there was a

1445  
00:59:41,510 --> 00:59:44,060  
possibility that am i going to buy coal

1446  
00:59:42,980 --> 00:59:45,980  
but it sounds like that's not gonna

1447  
00:59:44,059 --> 00:59:49,099  
happen well it remains very exciting and

1448  
00:59:45,980 --> 00:59:51,320  
indeed this is this is uh something yeah

1449  
00:59:49,099 --> 00:59:53,329  
but when we're talking about accreting

1450  
00:59:51,320 --> 00:59:55,100  
supermassive black holes we're talking

1451  
00:59:53,329 --> 00:59:56,360  
about things that are order orders of

1452  
00:59:55,099 --> 00:59:58,759  
magnitude more massive than the black

1453  
00:59:56,360 --> 01:00:00,230  
hole in the Milky Way so the the Milky

1454

00:59:58,760 --> 01:00:01,300  
Way black hole is about four million

1455  
01:00:00,230 --> 01:00:03,429  
solar masses

1456  
01:00:01,300 --> 01:00:05,170  
the black holes at the center of these

1457  
01:00:03,429 --> 01:00:06,609  
two emerging elliptical galaxies might

1458  
01:00:05,170 --> 01:00:09,909  
be on the order of a billion solar

1459  
01:00:06,610 --> 01:00:11,200  
masses each wow that is when you're

1460  
01:00:09,909 --> 01:00:13,869  
right you're I chain we have pretty

1461  
01:00:11,199 --> 01:00:19,149  
wimpy one then those even for its mess

1462  
01:00:13,869 --> 01:00:22,029  
it should be punching harder I'm gonna

1463  
01:00:19,150 --> 01:00:23,769  
gets weight class is just yeah yeah I

1464  
01:00:22,030 --> 01:00:25,120  
can't believe with you didn't know what

1465  
01:00:23,769 --> 01:00:27,550  
you're gonna give an inferiority complex

1466  
01:00:25,119 --> 01:00:30,730  
and then something terrible is going to

1467  
01:00:27,550 --> 01:00:33,280  
happen cute right at us and I would I'm

1468  
01:00:30,730 --> 01:00:34,750

gonna just like I'm gonna just messaged

1469

01:00:33,280 --> 01:00:38,980

you on facebook like Jane look what you

1470

01:00:34,750 --> 01:00:40,980

did to our place please Coco go down so

1471

01:00:38,980 --> 01:00:43,269

that's all right that's my face okay

1472

01:00:40,980 --> 01:00:48,400

internet will looking on and probably

1473

01:00:43,269 --> 01:00:50,050

earth so Nana so Scott if I missed

1474

01:00:48,400 --> 01:00:52,360

anything is there something else I

1475

01:00:50,050 --> 01:00:55,269

didn't catch you know that there's been

1476

01:00:52,360 --> 01:00:57,640

there's been a lot of just great tweets

1477

01:00:55,269 --> 01:00:59,259

going on from everywhere not really

1478

01:00:57,639 --> 01:01:01,599

questions but a lot of just really good

1479

01:00:59,260 --> 01:01:04,300

commenting on what people are learning

1480

01:01:01,599 --> 01:01:07,119

all on Twitter use novel hang out so I

1481

01:01:04,300 --> 01:01:10,570

do recommend those watching this later

1482

01:01:07,119 --> 01:01:12,909

go to Twitter just look up the Hubble



1483  
01:01:10,570 --> 01:01:14,980  
hang out hashtag you can see the great

1484  
01:01:12,909 --> 01:01:16,389  
conversation going on with it the right

1485  
01:01:14,980 --> 01:01:19,690  
a good good point thanks for pointing

1486  
01:01:16,389 --> 01:01:22,629  
that out Hugo dude I love you because he

1487  
01:01:19,690 --> 01:01:25,659  
goes we live in a lazy galaxy what can

1488  
01:01:22,630 --> 01:01:29,500  
you do other than keep looking up I

1489  
01:01:25,659 --> 01:01:34,329  
sorry that Jake just like downtown Tony

1490  
01:01:29,500 --> 01:01:36,579  
God's lockdown thank you you go okay

1491  
01:01:34,329 --> 01:01:40,389  
well I guess with that it's our time is

1492  
01:01:36,579 --> 01:01:41,799  
more or less up unless I Carol do you

1493  
01:01:40,389 --> 01:01:43,779  
have any parting comments or anything

1494  
01:01:41,800 --> 01:01:48,100  
you want to say Oryx Carly no I'm so

1495  
01:01:43,780 --> 01:01:49,720  
depressed now yeah we're gonna have to

1496  
01:01:48,099 --> 01:01:53,230  
take a moment and maybe think about

1497  
01:01:49,719 --> 01:01:55,179  
really dark job yeah I was so excited to

1498  
01:01:53,230 --> 01:01:58,510  
see Jane and the longest time and now

1499  
01:01:55,179 --> 01:02:00,809  
I'm just like wow Oh change it down RJ

1500  
01:01:58,510 --> 01:02:04,030  
mention she has a really high bar

1501  
01:02:00,809 --> 01:02:05,349  
fortunate you have high skaters yeah

1502  
01:02:04,030 --> 01:02:08,110  
let's flip that around it's not that

1503  
01:02:05,349 --> 01:02:11,259  
genes disappointed easily is that she is

1504  
01:02:08,110 --> 01:02:14,829  
it's up there yeah yes high expectations

1505  
01:02:11,260 --> 01:02:18,430  
that's right even Jane

1506  
01:02:14,829 --> 01:02:20,199  
love you doing this image yes Alexia is

1507  
01:02:18,429 --> 01:02:24,519  
not under performing right there's one

1508  
01:02:20,199 --> 01:02:25,809  
impressed gene so yeah right all right i

1509  
01:02:24,519 --> 01:02:27,579  
want to thank you guys thank you grin

1510  
01:02:25,809 --> 01:02:29,079  
thank you Jane thank you okay so much

1511

01:02:27,579 --> 01:02:30,279  
for joining us this has been a great

1512  
01:02:29,079 --> 01:02:32,170  
hanging out as a really interesting

1513  
01:02:30,280 --> 01:02:33,340  
stuff I kind of want to reconnect with

1514  
01:02:32,170 --> 01:02:34,750  
you guys once you get the Chandra

1515  
01:02:33,340 --> 01:02:37,210  
observations so we can see what you

1516  
01:02:34,750 --> 01:02:39,699  
learned about this about this cluster in

1517  
01:02:37,210 --> 01:02:41,860  
this particular string of pearls what it

1518  
01:02:39,699 --> 01:02:45,699  
might be what I might be doing to us or

1519  
01:02:41,860 --> 01:02:48,010  
them or the galaxy image in general so

1520  
01:02:45,699 --> 01:02:50,379  
next week i miss or last week i misspoke

1521  
01:02:48,010 --> 01:02:52,330  
when i said that our hangout are booked

1522  
01:02:50,380 --> 01:02:54,970  
this week would have been about the hot

1523  
01:02:52,329 --> 01:02:56,769  
Jupiters and water vapor that was stored

1524  
01:02:54,969 --> 01:02:58,929  
on them it turns out that that is going

1525  
01:02:56,769 --> 01:03:01,179

to be next week's hang out so we will be

1526

01:02:58,929 --> 01:03:03,429

around next Thursday same bat-time same

1527

01:03:01,179 --> 01:03:06,849

know what am i saying saying Hubble time

1528

01:03:03,429 --> 01:03:08,409

same Hubble channel where we will be

1529

01:03:06,849 --> 01:03:09,909

talking about hot Jupiters and water

1530

01:03:08,409 --> 01:03:12,219

vapor and observations with the Hubble

1531

01:03:09,909 --> 01:03:13,960

Space Telescope so thank you guys all

1532

01:03:12,219 --> 01:03:15,549

for watching make sure you bookmark it

1533

01:03:13,960 --> 01:03:17,619

i'll be making the event here later

1534

01:03:15,550 --> 01:03:21,430

today so we'll hope you will hope you'll

1535

01:03:17,619 --> 01:03:23,230

attend Carol Scott thank you as always a

1536

01:03:21,429 --> 01:03:25,329

great job thank you for driving the

1537

01:03:23,230 --> 01:03:26,920

Internet Scott did great job you need

1538

01:03:25,329 --> 01:03:30,579

might want to get that expanding

1539

01:03:26,920 --> 01:03:32,680

headspace looked at so yeah no I just

1540

01:03:30,579 --> 01:03:35,170

get bigger hats at this figure okay

1541

01:03:32,679 --> 01:03:36,819

that's one way to look at it my folks

1542

01:03:35,170 --> 01:03:40,409

thank you all for watching and as always

1543

01:03:36,820 --> 01:03:40,410

keep up