

1
00:00:04,439 --> 00:00:09,638
hello everybody and welcome to this

2
00:00:07,479 --> 00:00:11,650
week's Hubbell hangout we are back from

3
00:00:09,638 --> 00:00:13,329
summer hiatus and this week we have

4
00:00:11,650 --> 00:00:15,969
another great hangout plan for you today

5
00:00:13,330 --> 00:00:17,980
astronomers using Hubble's archived data

6
00:00:15,968 --> 00:00:21,129
among other data sets have been looking

7
00:00:17,980 --> 00:00:23,109
into a mystery of how certain supernovae

8
00:00:21,129 --> 00:00:24,549
are exploding sooner than they should

9
00:00:23,109 --> 00:00:26,109
have our least than they were believed

10
00:00:24,550 --> 00:00:27,310
to and we've got an astronomer here from

11
00:00:26,109 --> 00:00:28,629
the University of Illinois to show us

12
00:00:27,309 --> 00:00:32,049
some of the research he's been doing

13
00:00:28,629 --> 00:00:33,460
into this it turns out that the that the

14
00:00:32,049 --> 00:00:35,738
answers are that there's a lot of

15
00:00:33,460 --> 00:00:37,689
different components involved in this so

16
00:00:35,738 --> 00:00:39,549
we'll learn about what that is and we

17
00:00:37,689 --> 00:00:40,869
will hopefully get some of your

18
00:00:39,549 --> 00:00:42,849
questions and comments throughout the

19
00:00:40,869 --> 00:00:44,738
Hangout as well but before I tell you

20
00:00:42,850 --> 00:00:47,018
how you can interact with this let me

21
00:00:44,738 --> 00:00:50,108
introduce my colleague dr. Carol

22
00:00:47,018 --> 00:00:52,088
Christian welcome back Carol oh you just

23
00:00:50,109 --> 00:00:53,769
got back from the IAU didn't you yes I

24
00:00:52,088 --> 00:00:59,170
did yeah you were telling me some of the

25
00:00:53,768 --> 00:01:05,920
fun that you had there yeah we avoided

26
00:00:59,170 --> 00:01:08,019
the storm you know dodged a bullet on

27
00:01:05,920 --> 00:01:09,310
that it sounds like but yeah it sounds

28
00:01:08,019 --> 00:01:10,629
like it was a big meeting a lot of a lot

29

00:01:09,310 --> 00:01:12,820
of astronomers showing up I don't think

30
00:01:10,629 --> 00:01:13,920
there was any Pluto catastrophes that

31
00:01:12,819 --> 00:01:18,489
came out of there as far as

32
00:01:13,920 --> 00:01:20,650
classifications or anything okay well

33
00:01:18,489 --> 00:01:22,269
cool and welcome back and I also have

34
00:01:20,650 --> 00:01:24,910
been just recently gotten back from

35
00:01:22,269 --> 00:01:27,310
vacation so I'm energized and ready to

36
00:01:24,909 --> 00:01:28,840
go and get started on this news is it a

37
00:01:27,310 --> 00:01:31,240
new season what is our season anyway to

38
00:01:28,840 --> 00:01:36,159
even have a season let's say this is the

39
00:01:31,239 --> 00:01:38,379
start of a new season of Hubble hangouts

40
00:01:36,159 --> 00:01:40,060
okay unfortunately Scott Lewis our

41
00:01:38,379 --> 00:01:41,619
internet driver extraordinary could not

42
00:01:40,060 --> 00:01:44,620
be with us this week but he will return

43
00:01:41,620 --> 00:01:46,540

next week and right now we're gonna have

44

00:01:44,620 --> 00:01:47,680

a lot of help from Kelly behind the

45

00:01:46,540 --> 00:01:50,470

scenes to show us a lot of different

46

00:01:47,680 --> 00:01:53,500

things so let's get started my guest

47

00:01:50,469 --> 00:01:54,780

today is dr. Ryan dr. Ryan Foley from

48

00:01:53,500 --> 00:01:56,500

the University of Illinois at

49

00:01:54,780 --> 00:01:58,659

champaign-urbana he's at the astronomy

50

00:01:56,500 --> 00:02:01,060

department there hi Ryan welcome what

51

00:01:58,659 --> 00:02:02,489

would our hangout I thanks for having me

52

00:02:01,060 --> 00:02:04,780

that's good of you to show up and we

53

00:02:02,489 --> 00:02:06,309

appreciated to hear about some of the

54

00:02:04,780 --> 00:02:09,519

things that you've been working on so

55

00:02:06,310 --> 00:02:11,199

there are oh I'm sorry I didn't go back

56

00:02:09,519 --> 00:02:12,760

to how to how to leave questions and

57

00:02:11,199 --> 00:02:13,839

comments like I should have so before I

58

00:02:12,759 --> 00:02:16,239

get going

59

00:02:13,840 --> 00:02:18,159

let me tell you how you can give us

60

00:02:16,239 --> 00:02:20,469

questions and comments we hope that you

61

00:02:18,159 --> 00:02:22,209

will use the Q&A app that's the easiest

62

00:02:20,469 --> 00:02:24,039

it's real there's a little button there

63

00:02:22,209 --> 00:02:25,780

but I didn't hang out window that you

64

00:02:24,039 --> 00:02:27,340

can press and ask a question and the

65

00:02:25,780 --> 00:02:29,919

advantage of doing that is I have a nice

66

00:02:27,340 --> 00:02:32,500

little pane right here that I can look

67

00:02:29,919 --> 00:02:33,939

at and see those those questions and

68

00:02:32,500 --> 00:02:36,250

comments real time and I can just click

69

00:02:33,939 --> 00:02:38,739

on one of them and then it will time it

70

00:02:36,250 --> 00:02:41,039

will timestamp when we actually address

71

00:02:38,739 --> 00:02:43,450

that comment in the YouTube video so

72
00:02:41,039 --> 00:02:46,150
that would be one way another way is to

73
00:02:43,449 --> 00:02:47,738
use the hashtag hub all hang out I'm

74
00:02:46,150 --> 00:02:49,180
using that I've got a whole column on my

75
00:02:47,739 --> 00:02:52,060
tweet deck set up to look at those

76
00:02:49,180 --> 00:02:54,340
tweets so we you can do that as well I'm

77
00:02:52,060 --> 00:02:57,069
also looking at the G+ event page in

78
00:02:54,340 --> 00:02:58,420
Google+ where you can leave comments and

79
00:02:57,068 --> 00:03:00,429
questions there as well so we hope that

80
00:02:58,419 --> 00:03:02,530
you will do it also and we should be

81
00:03:00,430 --> 00:03:03,969
doing this every week but if you want to

82
00:03:02,530 --> 00:03:06,098
learn more about our Hubbell hangouts

83
00:03:03,969 --> 00:03:08,348
please subscribe to our YouTube channel

84
00:03:06,098 --> 00:03:11,018
Hubbell site channel on YouTube as well

85
00:03:08,348 --> 00:03:13,750
as follow us at Hubbell telescope on

86

00:03:11,019 --> 00:03:17,829
Twitter we're also Hubble telescope on

87
00:03:13,750 --> 00:03:19,359
Facebook so like subscribe follow do all

88
00:03:17,829 --> 00:03:21,370
those things and you will learn more

89
00:03:19,359 --> 00:03:23,350
about when these when these hangouts

90
00:03:21,370 --> 00:03:25,000
occur as well as all the science and

91
00:03:23,349 --> 00:03:26,650
stuff that's fit to print from the

92
00:03:25,000 --> 00:03:29,560
hubble space telescope so please do that

93
00:03:26,650 --> 00:03:32,920
okay so back to Ryan dr. Ryan Foley so

94
00:03:29,560 --> 00:03:34,209
you were using Hubble archive data among

95
00:03:32,919 --> 00:03:35,559
other data sets and we're going to talk

96
00:03:34,209 --> 00:03:37,379
about what those are in just a little

97
00:03:35,560 --> 00:03:40,599
bit but you're interested in these

98
00:03:37,379 --> 00:03:42,818
supernovae that somehow we're exploding

99
00:03:40,599 --> 00:03:43,750
before they should have is that correct

100
00:03:42,818 --> 00:03:44,858

why don't you tell us a little bit of

101

00:03:43,750 --> 00:03:48,039

the background of what you were trying

102

00:03:44,859 --> 00:03:49,780

to do sure hopefully we'll be able to

103

00:03:48,039 --> 00:03:53,439

get it all done in the hour this is kind

104

00:03:49,780 --> 00:03:55,629

of a complex story but I'll take it slow

105

00:03:53,439 --> 00:03:57,818

and we'll do it as far as we can oh yeah

106

00:03:55,629 --> 00:04:00,459

and I'll try to hold your hand in this

107

00:03:57,818 --> 00:04:03,149

but if if you need additional

108

00:04:00,459 --> 00:04:06,280

explanation please stop me oh I will I

109

00:04:03,150 --> 00:04:09,459

can be a little long-winded sometimes so

110

00:04:06,280 --> 00:04:10,780

um so I guess I should I should start

111

00:04:09,459 --> 00:04:12,250

with just sort of the basic thing and

112

00:04:10,780 --> 00:04:16,750

say you know supernovae are exploding

113

00:04:12,250 --> 00:04:19,418

starts and that there's a variety of

114

00:04:16,750 --> 00:04:21,069

supernovae there are lots of ways that a

115
00:04:19,418 --> 00:04:24,609
star can explode and a lot of different

116
00:04:21,069 --> 00:04:26,159
kinds of stars that explode and so we

117
00:04:24,610 --> 00:04:28,889
probably have a

118
00:04:26,160 --> 00:04:30,510
you know at this point figured out about

119
00:04:28,889 --> 00:04:34,289
a dozen different classes of stellar

120
00:04:30,509 --> 00:04:37,399
explosions and and this is one of the

121
00:04:34,290 --> 00:04:41,310
more peculiar or rarer classes which

122
00:04:37,399 --> 00:04:43,199
we've called calcium-rich supernova and

123
00:04:41,310 --> 00:04:43,530
I'll get into why we call them that in a

124
00:04:43,199 --> 00:04:47,430
minute

125
00:04:43,529 --> 00:04:49,199
but the basic story is that there are

126
00:04:47,430 --> 00:04:52,740
only about a dozen of these that we know

127
00:04:49,199 --> 00:04:54,629
about right now compared to the several

128
00:04:52,740 --> 00:04:56,129
thousand total supernovae that we know

129
00:04:54,629 --> 00:04:57,719
now wait okay so we're not talking

130
00:04:56,129 --> 00:04:59,129
you're talking about all super novae

131
00:04:57,720 --> 00:05:03,150
that we can see from Earth or from

132
00:04:59,129 --> 00:05:04,829
Hubble and that we've necessarily in our

133
00:05:03,149 --> 00:05:07,409
galaxy they're just that's right they're

134
00:05:04,829 --> 00:05:09,659
all over in the universe in the visible

135
00:05:07,410 --> 00:05:13,920
universe there's about a supernova every

136
00:05:09,660 --> 00:05:15,840
second and you know so it stars

137
00:05:13,920 --> 00:05:17,580
exploding in the visible universe Wow a

138
00:05:15,839 --> 00:05:19,529
super Dover every second somewhere in

139
00:05:17,579 --> 00:05:21,240
Andres something like that first time

140
00:05:19,529 --> 00:05:23,969
I've heard that that's uh we're missing

141
00:05:21,240 --> 00:05:27,960
a lot of them aren't we yeah we're

142
00:05:23,970 --> 00:05:30,990
missing a lot and and so we've over over

143

00:05:27,959 --> 00:05:35,399
the the the entirety of humanity we've

144
00:05:30,990 --> 00:05:38,240
detected a few thousand of them and most

145
00:05:35,399 --> 00:05:42,239
of them fall into a few categories and

146
00:05:38,240 --> 00:05:45,480
only a handful of those few thousand are

147
00:05:42,240 --> 00:05:46,290
this peculiar class of calcium-rich

148
00:05:45,480 --> 00:05:48,540
supernovae

149
00:05:46,290 --> 00:05:50,340
yeah you said about a dozen okay so what

150
00:05:48,540 --> 00:05:52,379
all right so you you you singled these

151
00:05:50,339 --> 00:05:54,719
out for some reason or they they just

152
00:05:52,379 --> 00:05:56,850
happen to be catch your eye for because

153
00:05:54,720 --> 00:05:59,460
of the kind that they were well so a

154
00:05:56,850 --> 00:06:01,800
little more than a decade ago so the

155
00:05:59,459 --> 00:06:04,889
first supernova you know this class was

156
00:06:01,800 --> 00:06:07,439
actually detected in the year 2000 but

157
00:06:04,889 --> 00:06:08,939

when it was detected we didn't exactly

158

00:06:07,439 --> 00:06:12,269

know what it was it took a few years

159

00:06:08,939 --> 00:06:14,689

before we figured this out and we when

160

00:06:12,269 --> 00:06:18,810

we had about four of these objects in

161

00:06:14,689 --> 00:06:20,550

2003 it was first proposed that there

162

00:06:18,810 --> 00:06:21,990

was this class of calcium-rich

163

00:06:20,550 --> 00:06:23,579

supernovae the reason we call them

164

00:06:21,990 --> 00:06:25,110

calcium-rich is that when you take a

165

00:06:23,579 --> 00:06:27,180

spectrum when you take the light from

166

00:06:25,110 --> 00:06:28,919

the supernova you disperse it through

167

00:06:27,180 --> 00:06:31,319

something like a prism so you can see

168

00:06:28,918 --> 00:06:32,819

all the different wavelengths and doing

169

00:06:31,319 --> 00:06:35,879

that you can you can understand the

170

00:06:32,819 --> 00:06:38,759

composition of that of that object and

171

00:06:35,879 --> 00:06:39,959

when we do that for these calcium-rich

172
00:06:38,759 --> 00:06:42,899
supernovae they have very

173
00:06:39,959 --> 00:06:45,508
strong absorption and emission lines

174
00:06:42,899 --> 00:06:47,519
that are associated with calcium much

175
00:06:45,509 --> 00:06:51,840
stronger than what we see for other

176
00:06:47,519 --> 00:06:53,459
supernovae so we took a bit of a leap

177
00:06:51,839 --> 00:06:57,179
initially calling them from having

178
00:06:53,459 --> 00:06:59,430
strong calcium wines to say in calcium

179
00:06:57,180 --> 00:07:00,900
rich and which I was sort of like what

180
00:06:59,430 --> 00:07:02,610
the composition is that there's a lot of

181
00:07:00,899 --> 00:07:05,008
actually calcium created in the

182
00:07:02,610 --> 00:07:06,569
explosion but it turns out that when you

183
00:07:05,009 --> 00:07:08,009
do more detailed modeling that that

184
00:07:06,569 --> 00:07:10,348
works out so we got a little lucky there

185
00:07:08,009 --> 00:07:11,759
that's the opposite of what happened a

186
00:07:10,348 --> 00:07:14,129
little more than a hundred years ago

187
00:07:11,759 --> 00:07:16,169
where when people first started taking

188
00:07:14,129 --> 00:07:18,300
spectra of the Sun we saw a lot of iron

189
00:07:16,168 --> 00:07:20,758
lines and a lot of people initially who

190
00:07:18,300 --> 00:07:24,090
said that the Sun must be made of iron

191
00:07:20,759 --> 00:07:27,150
but then after understanding things like

192
00:07:24,089 --> 00:07:29,758
ionization it was then determined that

193
00:07:27,149 --> 00:07:31,859
those iron lines although very strong do

194
00:07:29,759 --> 00:07:33,870
not indicate that the Sun is mostly made

195
00:07:31,860 --> 00:07:35,280
out of iron it's mostly made out of

196
00:07:33,870 --> 00:07:38,098
hydrogen

197
00:07:35,279 --> 00:07:39,689
so in the in that same sense we can do

198
00:07:38,098 --> 00:07:41,189
the same thing with a with a supernova

199
00:07:39,689 --> 00:07:43,050
and determine what it's made out of and

200

00:07:41,189 --> 00:07:45,089
turns out that there is a lot of calcium

201
00:07:43,050 --> 00:07:48,030
in these calcium richer supernovae much

202
00:07:45,089 --> 00:07:50,098
more so per you know the total mass of

203
00:07:48,029 --> 00:07:52,559
the abundance the percentage of the

204
00:07:50,098 --> 00:07:55,199
material is much more calcium than other

205
00:07:52,560 --> 00:07:56,788
supernovae okay so that's not so in

206
00:07:55,199 --> 00:07:58,110
addition to being calcium rich though of

207
00:07:56,788 --> 00:08:00,029
these supernovae new of which there you

208
00:07:58,110 --> 00:08:02,400
said they were 13 that you analyzed in

209
00:08:00,029 --> 00:08:03,959
your study there that's not the only

210
00:08:02,399 --> 00:08:05,429
thing you noticed about them right they

211
00:08:03,959 --> 00:08:08,038
were actually moving in a characteristic

212
00:08:05,430 --> 00:08:10,530
way it's relevant my correct great so so

213
00:08:08,038 --> 00:08:14,848
the the next thing that happened was in

214
00:08:10,529 --> 00:08:18,239

about 2010 there were a hint there was

215

00:08:14,848 --> 00:08:19,829

the first really good study of one of

216

00:08:18,240 --> 00:08:23,250

these objects that was kind of out in

217

00:08:19,829 --> 00:08:26,008

the middle of nowhere it was close to a

218

00:08:23,250 --> 00:08:28,649

galaxy but it wasn't as close as as most

219

00:08:26,009 --> 00:08:29,879

of the stars in that galaxy so you

220

00:08:28,649 --> 00:08:31,948

wouldn't if you just looked at a picture

221

00:08:29,879 --> 00:08:34,528

of it you wouldn't necessarily say oh

222

00:08:31,949 --> 00:08:37,110

that's that's part of that galaxy but

223

00:08:34,528 --> 00:08:40,500

because galaxies are spread out enough

224

00:08:37,110 --> 00:08:42,599

it was the only nearby galaxy it had to

225

00:08:40,500 --> 00:08:44,610

have been sort of associated with it and

226

00:08:42,599 --> 00:08:46,470

then when we when we did more detailed

227

00:08:44,610 --> 00:08:47,820

analysis we we could say that it was at

228

00:08:46,470 --> 00:08:51,350

the same distance of that as like

229

00:08:47,820 --> 00:08:53,699

galaxies just kind of far away and so

230

00:08:51,350 --> 00:08:53,940

it's it's sort of like if you're in the

231

00:08:53,698 --> 00:08:56,819

middle

232

00:08:53,940 --> 00:08:58,560

Wyoming and you see somebody you know 20

233

00:08:56,820 --> 00:09:00,420

miles outside of a town but then the

234

00:08:58,559 --> 00:09:01,799

next town is a hundred miles away he was

235

00:09:00,419 --> 00:09:04,709

like well maybe they live in that town

236

00:09:01,799 --> 00:09:09,809

yeah so we we made so hit their mail

237

00:09:04,710 --> 00:09:13,019

there too yeah exactly so so that was a

238

00:09:09,809 --> 00:09:17,009

little odd but but we didn't think too

239

00:09:13,019 --> 00:09:18,750

much of it the but when we found a few

240

00:09:17,009 --> 00:09:21,480

more of these objects a lot of them were

241

00:09:18,750 --> 00:09:25,950

very far from their from their host

242

00:09:21,480 --> 00:09:27,810

galaxies and that was odd and we had to

243
00:09:25,950 --> 00:09:30,420
and we had to you know think about how

244
00:09:27,809 --> 00:09:31,889
they could possibly be that far away and

245
00:09:30,419 --> 00:09:33,929
there are a bunch of options just you

246
00:09:31,889 --> 00:09:37,590
know off the top of your head one of

247
00:09:33,929 --> 00:09:40,019
which is that there could just be a star

248
00:09:37,590 --> 00:09:41,940
that far out there that's kind of

249
00:09:40,019 --> 00:09:43,889
unlikely when you start getting a whole

250
00:09:41,940 --> 00:09:45,480
bunch of these objects because if you

251
00:09:43,889 --> 00:09:48,269
think that the stars that are exploding

252
00:09:45,480 --> 00:09:50,639
are like most stars in the galaxies then

253
00:09:48,269 --> 00:09:52,289
the supernova should kind of trace the

254
00:09:50,639 --> 00:09:54,149
light they should trace where the stars

255
00:09:52,289 --> 00:09:56,789
are if they're just I don't understand I

256
00:09:54,149 --> 00:09:59,459
don't understand that what trace them so

257

00:09:56,789 --> 00:10:01,679
you should have many more supernovae

258
00:09:59,460 --> 00:10:03,720
near the Centers of galaxies or you know

259
00:10:01,679 --> 00:10:05,489
that are spread out over the disk of the

260
00:10:03,720 --> 00:10:06,930
galaxy or anything like that because

261
00:10:05,490 --> 00:10:09,450
that's where the stars are in that

262
00:10:06,929 --> 00:10:11,219
galaxy and so if you found one thing

263
00:10:09,450 --> 00:10:12,720
that was really far away then you might

264
00:10:11,220 --> 00:10:14,790
say all right well you know that just

265
00:10:12,720 --> 00:10:16,800
happened be that one weird star that

266
00:10:14,789 --> 00:10:18,629
exploded but when you see a bunch of

267
00:10:16,799 --> 00:10:21,689
them that are very far away then that

268
00:10:18,629 --> 00:10:23,370
becomes very unlikely in the same sense

269
00:10:21,690 --> 00:10:25,560
that you know if you see one guy 10

270
00:10:23,370 --> 00:10:26,909
miles out of town and he's very well

271
00:10:25,559 --> 00:10:30,119

maybe he's just like going for a walk

272

00:10:26,909 --> 00:10:33,059

and he went for a really long walk but

273

00:10:30,120 --> 00:10:35,730

if you if you saw 50 people outside of

274

00:10:33,059 --> 00:10:37,679

town maybe even scatter all around then

275

00:10:35,730 --> 00:10:39,629

you start to think you know there might

276

00:10:37,679 --> 00:10:43,019

be a reason why people are out that far

277

00:10:39,629 --> 00:10:46,169

and it's not just sort of random and so

278

00:10:43,019 --> 00:10:47,939

so another possibility maybe I just want

279

00:10:46,169 --> 00:10:49,919

to start a communist out of town on well

280

00:10:47,940 --> 00:10:53,430

so exactly no that's not exactly the

281

00:10:49,919 --> 00:10:56,479

sort of thing is so it in galaxies there

282

00:10:53,429 --> 00:10:58,649

are very clumped populations of stars

283

00:10:56,480 --> 00:11:01,200

some of which we would call like a

284

00:10:58,649 --> 00:11:03,809

globular cluster which is a collection

285

00:11:01,200 --> 00:11:07,950

of stars in that galaxy but they are

286
00:11:03,809 --> 00:11:09,479
kind of self-gravitating they though

287
00:11:07,950 --> 00:11:12,960
we're gonna record those stars will

288
00:11:09,480 --> 00:11:15,269
orbit around some common center and and

289
00:11:12,960 --> 00:11:19,350
then that whole cluster will orbit the

290
00:11:15,269 --> 00:11:21,360
galaxies together and in that same sense

291
00:11:19,350 --> 00:11:23,610
you can have sort of a commune around

292
00:11:21,360 --> 00:11:25,500
some small town or maybe a suburb for a

293
00:11:23,610 --> 00:11:28,680
very large town that kind of thing um

294
00:11:25,500 --> 00:11:31,559
and so that was one real possibility

295
00:11:28,679 --> 00:11:34,620
because globular clusters tend to have a

296
00:11:31,559 --> 00:11:37,289
more extended distribution than just the

297
00:11:34,620 --> 00:11:40,620
normal stars and then similarly just

298
00:11:37,289 --> 00:11:42,089
like how there are satellite galaxies to

299
00:11:40,620 --> 00:11:44,190
the Milky Way like the Large Magellanic

300
00:11:42,090 --> 00:11:47,550
Cloud the small member I didn't even

301
00:11:44,190 --> 00:11:48,870
smaller dwarf galaxies it could be the

302
00:11:47,549 --> 00:11:52,250
case that there's something like that

303
00:11:48,870 --> 00:11:54,539
and that also has a very extended

304
00:11:52,250 --> 00:11:56,820
distribution in that there they can to

305
00:11:54,539 --> 00:11:59,399
be further out than this than the stars

306
00:11:56,820 --> 00:12:00,990
that compose the galaxies okay so these

307
00:11:59,399 --> 00:12:04,500
are these are things that are I was

308
00:12:00,990 --> 00:12:06,419
gonna comment here so so a fundamental

309
00:12:04,500 --> 00:12:10,200
to this is that we already know that

310
00:12:06,419 --> 00:12:14,789
supernovae are stars yes we don't expect

311
00:12:10,200 --> 00:12:16,830
that stars just form an ice in isolation

312
00:12:14,789 --> 00:12:19,079
there we don't have any evidence that

313
00:12:16,830 --> 00:12:21,570
there are these isolated clumps of not

314

00:12:19,080 --> 00:12:23,370
too often hydrogen gas and stuff that

315
00:12:21,570 --> 00:12:26,220
just collapsed this makes one star and

316
00:12:23,370 --> 00:12:28,379
it becomes a supernova wait so the idea

317
00:12:26,220 --> 00:12:30,420
is a supernova which is a star has to

318
00:12:28,379 --> 00:12:32,279
come from a population center where

319
00:12:30,419 --> 00:12:34,079
there are other stars because that's how

320
00:12:32,279 --> 00:12:35,939
stars form and we know this we have

321
00:12:34,080 --> 00:12:36,720
evidence across the universe that's how

322
00:12:35,940 --> 00:12:39,540
this that's right

323
00:12:36,720 --> 00:12:41,490
that's that's that's right all the other

324
00:12:39,539 --> 00:12:48,719
supernovae are associated and just as we

325
00:12:41,490 --> 00:12:51,450
expect exactly it's absolutely right

326
00:12:48,720 --> 00:12:54,750
that all other kinds of supernovae they

327
00:12:51,450 --> 00:12:57,270
they track where the stars should be and

328
00:12:54,750 --> 00:13:00,080

this one type they were out in the

329

00:12:57,269 --> 00:13:03,299

middle of nowhere we didn't know why and

330

00:13:00,080 --> 00:13:04,680

and so those those were those were some

331

00:13:03,299 --> 00:13:06,949

scenarios that I put out there but then

332

00:13:04,679 --> 00:13:09,419

there's another scenario and that's that

333

00:13:06,950 --> 00:13:11,850

you know like just like this guy who

334

00:13:09,419 --> 00:13:13,740

might be ten miles out of town walking

335

00:13:11,850 --> 00:13:16,379

on his own he doesn't live there

336

00:13:13,740 --> 00:13:17,519

necessarily maybe he does live in some

337

00:13:16,379 --> 00:13:19,259

little commune or something like that

338

00:13:17,519 --> 00:13:21,720

but another another possibility is that

339

00:13:19,259 --> 00:13:24,328

he lives in the town and he just walked

340

00:13:21,720 --> 00:13:27,600

miles that can happen with stars two

341

00:13:24,328 --> 00:13:31,049

stars can be born somewhere in a galaxy

342

00:13:27,600 --> 00:13:32,699

and then they can they can move very far

343
00:13:31,049 --> 00:13:34,969
from where they were born and under the

344
00:13:32,698 --> 00:13:37,769
certain conditions that we'll talk about

345
00:13:34,970 --> 00:13:39,000
you can have a star move very far away

346
00:13:37,769 --> 00:13:42,089
from the galaxy in fact you can have

347
00:13:39,000 --> 00:13:43,730
stars that that are kicked out of their

348
00:13:42,089 --> 00:13:46,110
galaxies they end up actually

349
00:13:43,730 --> 00:13:47,938
gravitationally unbound from their

350
00:13:46,110 --> 00:13:50,009
galaxies and so that's another

351
00:13:47,938 --> 00:13:51,750
possibility so were these I mean where

352
00:13:50,009 --> 00:13:56,970
they gravitationally unbound these

353
00:13:51,750 --> 00:14:01,740
supernovae well so I would say you know

354
00:13:56,970 --> 00:14:04,709
um so too we so a few years ago we had

355
00:14:01,740 --> 00:14:07,049
these handful of different possibilities

356
00:14:04,708 --> 00:14:09,119
and there was some clues that things

357
00:14:07,049 --> 00:14:11,149
weren't really making sense because

358
00:14:09,120 --> 00:14:14,339
using Hubble data and some other data

359
00:14:11,149 --> 00:14:16,078
other groups they looked at the

360
00:14:14,339 --> 00:14:19,680
positions of the supernovae and they

361
00:14:16,078 --> 00:14:21,659
took really really deep images of the

362
00:14:19,679 --> 00:14:24,568
spots where the supernova exploded and

363
00:14:21,659 --> 00:14:27,269
if if you expected there to be some

364
00:14:24,568 --> 00:14:28,948
little dwarf galaxies or globular

365
00:14:27,269 --> 00:14:31,318
clusters with like that you would have

366
00:14:28,948 --> 00:14:32,899
probably detected it in these these

367
00:14:31,318 --> 00:14:35,610
images and they didn't detect anything

368
00:14:32,899 --> 00:14:37,708
so there really was nothing there there

369
00:14:35,610 --> 00:14:39,539
are no stars there that's like literally

370
00:14:37,708 --> 00:14:41,489
a star out on its own now they're alone

371

00:14:39,539 --> 00:14:43,500
nowhere right so you know again if

372
00:14:41,490 --> 00:14:45,959
you're if we take this analogy of the

373
00:14:43,500 --> 00:14:47,399
guy walking ten miles out of town if you

374
00:14:45,958 --> 00:14:48,508
just saw him on the side of the road you

375
00:14:47,399 --> 00:14:50,549
wouldn't really know where he came from

376
00:14:48,509 --> 00:14:52,829
but then if you if you had an aerial

377
00:14:50,549 --> 00:14:54,628
image and you didn't see any other

378
00:14:52,828 --> 00:14:56,489
people around you didn't see any you

379
00:14:54,629 --> 00:14:58,379
know little buildings or something then

380
00:14:56,490 --> 00:14:59,850
you would say well he probably doesn't

381
00:14:58,379 --> 00:15:03,720
live out there he probably lives in town

382
00:14:59,850 --> 00:15:05,220
even he got there somehow so so that was

383
00:15:03,720 --> 00:15:07,230
the question is like so where were they

384
00:15:05,220 --> 00:15:10,860
born how did they get there

385
00:15:07,230 --> 00:15:13,528

and and so I this was something that I

386

00:15:10,860 --> 00:15:15,149

just like for a while it was stuck in my

387

00:15:13,528 --> 00:15:17,068

head I didn't know exactly what to do so

388

00:15:15,149 --> 00:15:19,828

I started looking at some of the

389

00:15:17,068 --> 00:15:21,328

archival data and there were a few

390

00:15:19,828 --> 00:15:26,878

things that that kind of popped out

391

00:15:21,328 --> 00:15:29,278

right away the first is is that there

392

00:15:26,879 --> 00:15:30,839

are some of these supernovae where we

393

00:15:29,278 --> 00:15:32,490

see them very very far from their

394

00:15:30,839 --> 00:15:34,019

galaxies and then there are others where

395

00:15:32,490 --> 00:15:35,310

they look like they're on top of the

396

00:15:34,019 --> 00:15:37,139

galaxy but

397

00:15:35,309 --> 00:15:40,138

of course we don't really know how close

398

00:15:37,139 --> 00:15:41,759

they are to that galaxy because we only

399

00:15:40,139 --> 00:15:46,409

have a two-dimensional picture of the

400
00:15:41,759 --> 00:15:47,730
sky right because because the distances

401
00:15:46,409 --> 00:15:49,828
are so large it just looks like

402
00:15:47,730 --> 00:15:52,920
everything's on top of each other and so

403
00:15:49,828 --> 00:15:55,979
you can have well those red ships I mean

404
00:15:52,919 --> 00:15:58,679
rupture exactly so so just from an image

405
00:15:55,980 --> 00:16:01,499
alone you can you can have a galaxy and

406
00:15:58,679 --> 00:16:03,628
a star this that's very close by or you

407
00:16:01,499 --> 00:16:05,639
can have a galaxy and a star that's very

408
00:16:03,629 --> 00:16:07,680
far away and they can still if I can't

409
00:16:05,639 --> 00:16:11,100
line them up they can be on top of each

410
00:16:07,679 --> 00:16:13,049
other and so so the images themselves

411
00:16:11,100 --> 00:16:14,999
are not enough information you need this

412
00:16:13,049 --> 00:16:17,008
third dimension and we get that through

413
00:16:14,999 --> 00:16:23,670
red chips oh sorry I didn't mean to

414
00:16:17,009 --> 00:16:26,789
steal your punchline oh you I just

415
00:16:23,669 --> 00:16:29,188
wanted to point out that in your analogy

416
00:16:26,789 --> 00:16:32,009
of the guy walking around away from town

417
00:16:29,188 --> 00:16:34,259
centre these objects are so far away we

418
00:16:32,009 --> 00:16:36,990
can't measure that transverse great

419
00:16:34,259 --> 00:16:39,539
motion so if Ryan could measure it going

420
00:16:36,990 --> 00:16:40,948
zoom that would have been a clue but you

421
00:16:39,539 --> 00:16:43,289
can't do that because it's too far away

422
00:16:40,948 --> 00:16:46,828
and you know it's a little tiny motion

423
00:16:43,289 --> 00:16:49,919
so right so so instead but we can

424
00:16:46,828 --> 00:16:54,539
measure the velocity along our line of

425
00:16:49,919 --> 00:16:56,838
sight and and and so I looked at those

426
00:16:54,539 --> 00:17:00,419
velocities for the different objects and

427
00:16:56,839 --> 00:17:02,459
what I found was was not expected for me

428

00:17:00,419 --> 00:17:05,668
so the objects that were really really

429
00:17:02,458 --> 00:17:08,519
far away from their galaxies it looked

430
00:17:05,669 --> 00:17:11,399
like they weren't moving at all in you

431
00:17:08,519 --> 00:17:12,869
know towards us or away from us but the

432
00:17:11,398 --> 00:17:15,208
ones that were on top of their galaxies

433
00:17:12,869 --> 00:17:16,918
they looked like they were mostly moving

434
00:17:15,209 --> 00:17:19,230
towards us some of them were moving away

435
00:17:16,919 --> 00:17:21,059
from us but mostly moving towards us and

436
00:17:19,230 --> 00:17:23,038
at very high speeds and we're still

437
00:17:21,058 --> 00:17:26,428
talking about these 13 right he's this

438
00:17:23,038 --> 00:17:30,599
group of 30 the 13 the 13 calcium-rich

439
00:17:26,429 --> 00:17:33,030
asleep unity okay and so so that that

440
00:17:30,599 --> 00:17:36,089
immediately tells you because there's

441
00:17:33,029 --> 00:17:39,269
this this relationship between how far

442
00:17:36,089 --> 00:17:42,058

away it appears this supernova appears

443

00:17:39,269 --> 00:17:43,980

to be from its galaxy and the velocity

444

00:17:42,058 --> 00:17:45,240

towards us or away from us that tells

445

00:17:43,980 --> 00:17:47,849

you immediately that it has something to

446

00:17:45,240 --> 00:17:48,960

do with their position it's not just

447

00:17:47,849 --> 00:17:51,089

something that had to do with

448

00:17:48,960 --> 00:17:52,679

the explosion or something like that if

449

00:17:51,089 --> 00:17:54,119

that were the case then you would expect

450

00:17:52,679 --> 00:17:55,830

some of the ones that are far away to

451

00:17:54,119 --> 00:17:58,500

look like they're coming very fast

452

00:17:55,829 --> 00:18:00,778

towards us or away from us and then some

453

00:17:58,500 --> 00:18:02,819

then the ones that are close in maybe

454

00:18:00,778 --> 00:18:04,440

just the same kind of distribution of

455

00:18:02,819 --> 00:18:09,960

velocities and we saw something very

456

00:18:04,440 --> 00:18:11,759

different and the the next step up that

457
00:18:09,960 --> 00:18:14,429
you would say is alright if we can

458
00:18:11,759 --> 00:18:16,079
measure these velocities and a lot of

459
00:18:14,429 --> 00:18:17,640
these objects that are right on top

460
00:18:16,079 --> 00:18:20,158
they're galaxies they're they're moving

461
00:18:17,640 --> 00:18:21,750
very quickly towards us and then we see

462
00:18:20,159 --> 00:18:23,880
these other objects that aren't moving

463
00:18:21,750 --> 00:18:27,000
towards us or away from us but they're

464
00:18:23,880 --> 00:18:28,830
really far away the the thing you you

465
00:18:27,000 --> 00:18:31,769
have to make in your head is here say

466
00:18:28,829 --> 00:18:33,359
alright I can move this velocity and

467
00:18:31,769 --> 00:18:35,190
think about it if they were moving in

468
00:18:33,359 --> 00:18:37,528
another direction if I just saw it from

469
00:18:35,190 --> 00:18:39,149
a different angle then the velocity

470
00:18:37,528 --> 00:18:40,849
would be going out in the plane of the

471
00:18:39,148 --> 00:18:43,319
sky but if it were moving very quickly

472
00:18:40,849 --> 00:18:46,079
for a long time then it would be very

473
00:18:43,319 --> 00:18:48,408
far away and so one of the keys is that

474
00:18:46,079 --> 00:18:50,699
the the velocities were incredibly high

475
00:18:48,409 --> 00:18:55,110
one to two thousand kilometers per

476
00:18:50,700 --> 00:18:57,569
second which is is sort of around 10

477
00:18:55,109 --> 00:19:00,839
times higher than the velocities for

478
00:18:57,569 --> 00:19:01,950
most stars in a galaxy I was gonna I was

479
00:19:00,839 --> 00:19:03,599
gonna ask you about that it's not

480
00:19:01,950 --> 00:19:05,700
characteristic of the Stars within that

481
00:19:03,599 --> 00:19:09,509
galaxy then yeah it's it's much higher

482
00:19:05,700 --> 00:19:12,230
and but it is it is similar to some

483
00:19:09,509 --> 00:19:15,599
stars very few stars that we've detected

484
00:19:12,230 --> 00:19:18,509
in the Milky Way and we call these

485

00:19:15,599 --> 00:19:21,389
hypervelocity stars that have velocities

486
00:19:18,509 --> 00:19:23,788
so high that they can escape the

487
00:19:21,390 --> 00:19:26,038
gravitational pull of the Milky Way in

488
00:19:23,788 --> 00:19:28,349
the same sense that when we shoot off

489
00:19:26,038 --> 00:19:31,079
rockets if you if you get the rocket

490
00:19:28,349 --> 00:19:32,759
moving fast enough then it can escape

491
00:19:31,079 --> 00:19:35,849
the gravitational pull of the earth and

492
00:19:32,759 --> 00:19:37,890
go off into deep space in the same sense

493
00:19:35,849 --> 00:19:39,599
if you can get a star moving fast enough

494
00:19:37,890 --> 00:19:41,970
it can escape the gravitational pull of

495
00:19:39,599 --> 00:19:45,599
its own galaxy and go off into deep

496
00:19:41,970 --> 00:19:48,120
space so so something was was

497
00:19:45,599 --> 00:19:50,278
accelerating these stars exactly so

498
00:19:48,119 --> 00:19:53,339
that's that's the story is that there is

499
00:19:50,278 --> 00:19:56,519

something that that from the the galaxy

500

00:19:53,339 --> 00:19:59,129

it was making some of these objects go

501

00:19:56,519 --> 00:20:02,829

very very quickly towards us and then we

502

00:19:59,130 --> 00:20:04,270

saw the velocity as being very high

503

00:20:02,829 --> 00:20:06,490

and then occasionally they'll go off

504

00:20:04,269 --> 00:20:09,579

just you know in a different direction

505

00:20:06,490 --> 00:20:12,819

it's just our art perspective and there

506

00:20:09,579 --> 00:20:14,259

it would go very very far away in the

507

00:20:12,819 --> 00:20:16,059

plane of the sky and when you take the

508

00:20:14,259 --> 00:20:17,440

snapshot when it finally explodes and

509

00:20:16,059 --> 00:20:19,569

you see where it is because it was

510

00:20:17,440 --> 00:20:21,730

moving so quickly for some amount of

511

00:20:19,569 --> 00:20:25,990

time then you would say all right it has

512

00:20:21,730 --> 00:20:28,960

to be very far away so so that that kind

513

00:20:25,990 --> 00:20:30,789

of explains this velocity effect and the

514
00:20:28,960 --> 00:20:32,950
distances but then you still have this

515
00:20:30,789 --> 00:20:37,359
question of well exactly how did you

516
00:20:32,950 --> 00:20:41,080
accelerate those stars and all I presume

517
00:20:37,359 --> 00:20:42,519
you're gonna tell us yes so to get back

518
00:20:41,079 --> 00:20:46,079
to the Milky Way where we have these

519
00:20:42,519 --> 00:20:48,970
hypervelocity stars there we have a very

520
00:20:46,079 --> 00:20:50,199
good theory for what's happening when we

521
00:20:48,970 --> 00:20:53,319
detect these stars that are moving in

522
00:20:50,200 --> 00:20:56,039
over a thousand kilometres per second we

523
00:20:53,319 --> 00:20:58,359
can we can trace their three-dimensional

524
00:20:56,039 --> 00:21:01,149
velocity vector because they're close

525
00:20:58,359 --> 00:21:02,889
enough where you can actually see the

526
00:21:01,150 --> 00:21:06,030
motion in the plane of the sky and

527
00:21:02,890 --> 00:21:08,500
measure the velocity with a redshift and

528
00:21:06,029 --> 00:21:09,430
when you do that you can you can say

529
00:21:08,500 --> 00:21:11,740
where did it come from

530
00:21:09,430 --> 00:21:16,539
and these stars come from the very very

531
00:21:11,740 --> 00:21:18,160
center of our galaxy and and what's at

532
00:21:16,539 --> 00:21:22,289
the very very center of our galaxy a

533
00:21:18,160 --> 00:21:25,180
supermassive black hole and and so

534
00:21:22,289 --> 00:21:27,430
there's there's a very clear theory of

535
00:21:25,180 --> 00:21:31,240
what what happens for these stars these

536
00:21:27,430 --> 00:21:33,549
stars start off in in a binary system so

537
00:21:31,240 --> 00:21:36,940
two stars that are orbiting each other

538
00:21:33,549 --> 00:21:39,669
and there's somewhere near this the

539
00:21:36,940 --> 00:21:41,080
supermassive black hole and some you

540
00:21:39,670 --> 00:21:43,240
know they most of the time they'll just

541
00:21:41,079 --> 00:21:44,379
be going in some normal orbit and even

542

00:21:43,240 --> 00:21:46,269
though they're close to that black hole

543
00:21:44,380 --> 00:21:48,370
they'll just continue in their orbit and

544
00:21:46,269 --> 00:21:49,720
nothing big ol now you're still talking

545
00:21:48,369 --> 00:21:51,399
about stars within our Milky Way right

546
00:21:49,720 --> 00:21:54,250
they die Milky Way very good we're still

547
00:21:51,400 --> 00:21:57,190
there but occasionally there will be

548
00:21:54,250 --> 00:21:58,509
some interaction with some other star or

549
00:21:57,190 --> 00:22:01,269
something like that that'll knock it

550
00:21:58,509 --> 00:22:04,779
slightly off of its orbit and it'll get

551
00:22:01,269 --> 00:22:07,690
so close to the to the black hole where

552
00:22:04,779 --> 00:22:11,139
what happens is the black hole will

553
00:22:07,690 --> 00:22:14,200
break up this pair one of them will be

554
00:22:11,140 --> 00:22:16,490
captured by the black hole and then the

555
00:22:14,200 --> 00:22:19,460
other one because it

556
00:22:16,490 --> 00:22:21,769

longer has this this companion plus its

557

00:22:19,460 --> 00:22:24,500

being you know whipped around this this

558

00:22:21,769 --> 00:22:26,869

black hole it gets slingshot it out its

559

00:22:24,500 --> 00:22:30,079

accelerated to one or two thousand

560

00:22:26,869 --> 00:22:32,899

kilometers per second and it just zooms

561

00:22:30,079 --> 00:22:35,059

away and it goes fast enough where you

562

00:22:32,900 --> 00:22:38,030

can escape the the pole of the entire

563

00:22:35,059 --> 00:22:39,740

galaxy and then this other star that

564

00:22:38,029 --> 00:22:43,160

what you know so there were the two

565

00:22:39,740 --> 00:22:45,230

stars in the pair one is zooming off you

566

00:22:43,160 --> 00:22:46,970

know incredibly high speeds and then the

567

00:22:45,230 --> 00:22:49,370

other one is captured by the black hole

568

00:22:46,970 --> 00:22:50,900

okay so these are star interactions with

569

00:22:49,369 --> 00:22:52,669

a single supermassive black hole within

570

00:22:50,900 --> 00:22:54,890

our within our Milky Way galaxy what's

571
00:22:52,670 --> 00:22:56,720
so special why you why are you careful

572
00:22:54,890 --> 00:22:59,360
to point out a binary star couldn't just

573
00:22:56,720 --> 00:23:02,450
any star happen to be on the wrong right

574
00:22:59,359 --> 00:23:05,809
so it's wrong time so it turns out that

575
00:23:02,450 --> 00:23:08,960
these super novae they we are pretty

576
00:23:05,809 --> 00:23:09,799
sure come from binary there's calcium

577
00:23:08,960 --> 00:23:11,240
rich ones

578
00:23:09,799 --> 00:23:13,549
the calcium richer supernova we are

579
00:23:11,240 --> 00:23:15,559
pretty sure come from a binary system

580
00:23:13,549 --> 00:23:18,849
and that's a binary system when they

581
00:23:15,559 --> 00:23:21,500
explode so you have to have two stars

582
00:23:18,849 --> 00:23:23,889
that that are in this system when they

583
00:23:21,500 --> 00:23:27,230
explode and the reason for that is that

584
00:23:23,890 --> 00:23:29,270
although single stars can explode a

585
00:23:27,230 --> 00:23:31,400
supernova then we think that they have

586
00:23:29,269 --> 00:23:35,930
to be very very massive stars right good

587
00:23:31,400 --> 00:23:38,630
okay and if you want it to a low-mass

588
00:23:35,930 --> 00:23:41,269
star to explode what you need is a white

589
00:23:38,630 --> 00:23:44,720
dwarf or something like that probably

590
00:23:41,269 --> 00:23:47,750
that it accretes material from a binary

591
00:23:44,720 --> 00:23:49,190
companion so material from from one

592
00:23:47,750 --> 00:23:52,420
other stars being dumped on to this

593
00:23:49,190 --> 00:23:55,100
white dwarf until something bad happens

594
00:23:52,420 --> 00:23:57,050
enough fuel and then it just it just

595
00:23:55,099 --> 00:23:58,159
will go through some explosion okay I

596
00:23:57,049 --> 00:23:59,569
want to stick with this idea for a

597
00:23:58,160 --> 00:24:00,830
minute because most supernova you

598
00:23:59,569 --> 00:24:03,169
already said and this is only most of us

599

00:24:00,829 --> 00:24:05,000
know about already occur with very very

600
00:24:03,170 --> 00:24:06,410
massive stars they're they're their

601
00:24:05,000 --> 00:24:08,180
course collapse there's different kinds

602
00:24:06,410 --> 00:24:09,980
of supernova like you point out but this

603
00:24:08,180 --> 00:24:12,500
one that you're addressing here these

604
00:24:09,980 --> 00:24:14,539
calcium-rich ones probably have because

605
00:24:12,500 --> 00:24:16,730
of the nature of the like because you

606
00:24:14,539 --> 00:24:18,740
can categorize these things yes are

607
00:24:16,730 --> 00:24:20,750
probably part of the binary and probably

608
00:24:18,740 --> 00:24:22,309
one of the companions is a white dwarf

609
00:24:20,750 --> 00:24:22,579
that somehow messing around with this

610
00:24:22,309 --> 00:24:26,240
one

611
00:24:22,579 --> 00:24:28,639
and so how low mass then cover star can

612
00:24:26,240 --> 00:24:30,700
you make exploding this way how how far

613
00:24:28,640 --> 00:24:32,560

down so we don't we

614

00:24:30,700 --> 00:24:35,019

no exactly but I would I would guess

615

00:24:32,559 --> 00:24:37,089

somewhere if you really wanted it to be

616

00:24:35,019 --> 00:24:39,579

the lowest it'd be about half the mass

617

00:24:37,089 --> 00:24:43,869

of the Sun really you can make a star

618

00:24:39,579 --> 00:24:45,970

half the mass of our Sun explode I would

619

00:24:43,869 --> 00:24:47,409

say you know alright so certainly things

620

00:24:45,970 --> 00:24:49,660

that are around the mass of our Sun we

621

00:24:47,410 --> 00:24:51,940

can make explode and I think if if you

622

00:24:49,660 --> 00:24:54,550

really wanted to in sort of the ways

623

00:24:51,940 --> 00:24:57,190

that we're talking about here it would

624

00:24:54,549 --> 00:24:59,109

explode at maybe about half of the mass

625

00:24:57,190 --> 00:25:00,640

this time wow that's amazing I learned

626

00:24:59,109 --> 00:25:02,799

to make two new things here today that's

627

00:25:00,640 --> 00:25:03,850

great okay so before we go to the next

628
00:25:02,799 --> 00:25:05,500
step which I know you're gonna talk

629
00:25:03,849 --> 00:25:07,480
about merging and anymore this is you've

630
00:25:05,500 --> 00:25:09,220
just described star interactions with a

631
00:25:07,480 --> 00:25:11,440
single black hole at the center of the

632
00:25:09,220 --> 00:25:12,850
or one like it I have I have a question

633
00:25:11,440 --> 00:25:14,559
here from Adams synergy which is a

634
00:25:12,849 --> 00:25:16,899
little relevant to what we just the

635
00:25:14,559 --> 00:25:18,549
topic we just left and he says if the

636
00:25:16,900 --> 00:25:20,440
stars travel at around five million

637
00:25:18,549 --> 00:25:21,970
miles an hour after ejection which was

638
00:25:20,440 --> 00:25:24,910
the high speed hyper stars you were

639
00:25:21,970 --> 00:25:26,860
talking about is the supernova ejecta

640
00:25:24,910 --> 00:25:28,450
traveling at even greater hyper velocity

641
00:25:26,859 --> 00:25:31,689
so you were you were looking at these

642
00:25:28,450 --> 00:25:33,100
these far-flung stars exploding what

643
00:25:31,690 --> 00:25:37,120
about is the ejecta now moving even

644
00:25:33,099 --> 00:25:40,029
faster yes so if if if we look at

645
00:25:37,119 --> 00:25:42,250
typical supernova they're there their

646
00:25:40,029 --> 00:25:44,940
velocities are definitely faster than

647
00:25:42,250 --> 00:25:48,519
typical velocities for supernovae or

648
00:25:44,940 --> 00:25:50,230
something like five to ten thousand

649
00:25:48,519 --> 00:25:52,420
kilometers per second so that that would

650
00:25:50,230 --> 00:25:55,750
be you know two to five times faster

651
00:25:52,420 --> 00:25:57,400
than the motion of these stars that's

652
00:25:55,750 --> 00:25:59,619
definitely true for these though they

653
00:25:57,400 --> 00:26:01,570
these calcium-rich supernovae are low

654
00:25:59,619 --> 00:26:03,189
energy supernovae their lower energy

655
00:26:01,569 --> 00:26:05,409
than the normal ones and their

656

00:26:03,190 --> 00:26:08,259
velocities tend to be lower but still

657
00:26:05,410 --> 00:26:10,990
higher than this one or two thousand

658
00:26:08,259 --> 00:26:15,460
kilometer per second a kick that it

659
00:26:10,990 --> 00:26:18,069
gets uncommon but we can still account

660
00:26:15,460 --> 00:26:21,190
for for the the difference here and the

661
00:26:18,069 --> 00:26:22,990
reason is eventually when when you have

662
00:26:21,190 --> 00:26:25,660
a supernova when it starts off it's very

663
00:26:22,990 --> 00:26:29,289
hot it's actually very similar to a star

664
00:26:25,660 --> 00:26:31,360
in that it has a photosphere and that

665
00:26:29,289 --> 00:26:34,059
just that just means that you can't see

666
00:26:31,359 --> 00:26:36,189
all the way through it that there's your

667
00:26:34,059 --> 00:26:37,569
son has a photosphere exactly a son has

668
00:26:36,190 --> 00:26:39,549
a photosphere and so that what that

669
00:26:37,569 --> 00:26:41,649
means is that when you look at the Sun

670
00:26:39,549 --> 00:26:44,289

you can't see the other side but

671

00:26:41,650 --> 00:26:46,120

eventually with a supernova because it's

672

00:26:44,289 --> 00:26:48,099

if the material is ejected in its

673

00:26:46,119 --> 00:26:50,739

expanding outward eventually that

674

00:26:48,099 --> 00:26:52,089

material becomes low enough density that

675

00:26:50,740 --> 00:26:54,490

you can see all the way through it and

676

00:26:52,089 --> 00:26:56,918

this is when we see a supernova remnant

677

00:26:54,490 --> 00:26:59,558

we can see all the way through it okay

678

00:26:56,919 --> 00:27:01,419

and in well before the the supernova

679

00:26:59,558 --> 00:27:03,759

remnant stage even you can see all the

680

00:27:01,419 --> 00:27:07,660

way through a supernova and so you can

681

00:27:03,759 --> 00:27:09,339

measure effectively the velocity of all

682

00:27:07,660 --> 00:27:13,360

of the material along your line of sight

683

00:27:09,339 --> 00:27:15,609

and so it doesn't necessarily matter how

684

00:27:13,359 --> 00:27:17,649

broad of a distribution you have a

685
00:27:15,609 --> 00:27:20,619
velocity is how fast the fastest

686
00:27:17,650 --> 00:27:23,230
material is moving because you can still

687
00:27:20,619 --> 00:27:25,529
as long as there is some sort of general

688
00:27:23,230 --> 00:27:28,539
peak you can measure what the average

689
00:27:25,529 --> 00:27:30,700
velocity is so you can measure the

690
00:27:28,539 --> 00:27:35,980
average velocity of all of the material

691
00:27:30,700 --> 00:27:38,230
and and that can be a fraction of the of

692
00:27:35,980 --> 00:27:40,599
the of the highest philosophies for the

693
00:27:38,230 --> 00:27:42,039
it occur the supernova explosion and you

694
00:27:40,599 --> 00:27:45,339
can still make a good measurement of

695
00:27:42,039 --> 00:27:47,579
that and that's what we did okay well so

696
00:27:45,339 --> 00:27:50,619
the the the you said that they were low

697
00:27:47,579 --> 00:27:52,689
intensity or low energy super these

698
00:27:50,619 --> 00:27:54,219
calcium-rich lenses is that due

699
00:27:52,690 --> 00:27:55,750
primarily the fact of these stars are

700
00:27:54,220 --> 00:27:59,169
pretty low mass as well there just isn't

701
00:27:55,750 --> 00:28:01,000
that much material to yes to really go

702
00:27:59,169 --> 00:28:03,820
so that's the theory

703
00:28:01,000 --> 00:28:07,660
I mean without getting into too much

704
00:28:03,819 --> 00:28:09,279
detail that when you when you burn a

705
00:28:07,660 --> 00:28:11,679
material if you if you're if you're

706
00:28:09,279 --> 00:28:14,230
undergoing nuclear fusion from light

707
00:28:11,679 --> 00:28:16,929
elements up to heavier elements you gain

708
00:28:14,230 --> 00:28:21,419
energy from those from those fusion

709
00:28:16,929 --> 00:28:25,480
reactions until you get to around iron

710
00:28:21,419 --> 00:28:28,360
and the reason for that is just a very

711
00:28:25,480 --> 00:28:32,079
stable nucleus that's relatively dense

712
00:28:28,359 --> 00:28:33,490
and when you go past the if you go to

713

00:28:32,079 --> 00:28:35,980
the elements that are much heavier than

714
00:28:33,490 --> 00:28:39,160
than iron if you go to things like gold

715
00:28:35,980 --> 00:28:43,058
or uranium or anything like that you

716
00:28:39,160 --> 00:28:47,169
have to add energy to to make those

717
00:28:43,058 --> 00:28:48,970
elements and so as a result because you

718
00:28:47,169 --> 00:28:51,040
don't want to necessarily steal that

719
00:28:48,970 --> 00:28:52,360
energy you just sort of go until you

720
00:28:51,039 --> 00:28:54,789
peter out of energy

721
00:28:52,359 --> 00:28:56,678
most supernova explosions or at least

722
00:28:54,789 --> 00:28:58,178
the ones that come from white dwarfs

723
00:28:56,679 --> 00:29:01,899
they produce a lot of

724
00:28:58,179 --> 00:29:06,190
a lot of elements near iron though iron

725
00:29:01,898 --> 00:29:09,788
cobalt nickel things like that and and

726
00:29:06,190 --> 00:29:12,220
and the these these calcium rich super

727
00:29:09,788 --> 00:29:14,908

novae however they have a lot of calcium

728

00:29:12,220 --> 00:29:19,179

and calcium is much lighter than iron

729

00:29:14,909 --> 00:29:21,820

and and so what that means is you know

730

00:29:19,179 --> 00:29:25,480

there was still the potential to to fuse

731

00:29:21,819 --> 00:29:28,450

to heavier elements and get some energy

732

00:29:25,480 --> 00:29:31,899

so something must have happened and the

733

00:29:28,450 --> 00:29:34,210

way that you you sort of stall this this

734

00:29:31,898 --> 00:29:35,939

process this fusion process this you

735

00:29:34,210 --> 00:29:39,429

have to just make it so that the overall

736

00:29:35,940 --> 00:29:42,220

explosion is very weak and very low

737

00:29:39,429 --> 00:29:44,710

energy and super effectively you can you

738

00:29:42,220 --> 00:29:47,558

can imagine doing this if you have if

739

00:29:44,710 --> 00:29:49,230

you have to just you know pure gasoline

740

00:29:47,558 --> 00:29:52,628

or something and you light it on fire

741

00:29:49,230 --> 00:29:54,159

then it'll all burn away but if you take

742
00:29:52,628 --> 00:29:56,079
gasoline and you throw a bunch of water

743
00:29:54,159 --> 00:29:57,429
in it you mix it up and then you and

744
00:29:56,079 --> 00:29:59,408
then you light it on fire maybe just the

745
00:29:57,429 --> 00:30:00,730
surface will burn and then everything

746
00:29:59,409 --> 00:30:02,769
that's mixed in with the water doesn't

747
00:30:00,730 --> 00:30:04,419
burn oh boy Ryan I just gonna say you're

748
00:30:02,769 --> 00:30:07,450
really good with analogies I really like

749
00:30:04,419 --> 00:30:08,799
your knowledge all right well good all

750
00:30:07,450 --> 00:30:10,090
right so thank you Adam that was a good

751
00:30:08,798 --> 00:30:12,460
question I appreciate your doing that

752
00:30:10,089 --> 00:30:16,209
you're asking us I want to get now to

753
00:30:12,460 --> 00:30:19,899
what the so so these these star

754
00:30:16,210 --> 00:30:21,220
interactions with normal normal a single

755
00:30:19,898 --> 00:30:23,518
supermassive black holes in the center

756
00:30:21,220 --> 00:30:25,509
of our galaxy is not what you think

757
00:30:23,519 --> 00:30:27,038
tributed to the motions of these

758
00:30:25,509 --> 00:30:28,808
supernovae why don't we get to that and

759
00:30:27,038 --> 00:30:30,940
while we do it let's go ahead and put up

760
00:30:28,808 --> 00:30:33,548
this schematic that we have in the press

761
00:30:30,940 --> 00:30:35,528
release called scenario for homeless

762
00:30:33,548 --> 00:30:38,378
supernova I think our analogy is getting

763
00:30:35,528 --> 00:30:40,388
away from us here but yeah here it is

764
00:30:38,378 --> 00:30:41,949
okay so why don't you explain what you

765
00:30:40,388 --> 00:30:42,819
think's going on with these with these

766
00:30:41,950 --> 00:30:45,429
speeds

767
00:30:42,819 --> 00:30:48,418
okay so just as a reminder career the

768
00:30:45,429 --> 00:30:50,769
Milky Way when you have these these two

769
00:30:48,419 --> 00:30:52,990
stars that come near a supermassive

770

00:30:50,769 --> 00:30:55,419
black hole then that that those two

771
00:30:52,990 --> 00:30:57,819
stars get ripped apart from each other

772
00:30:55,419 --> 00:31:00,129
one it stays behind with the black hole

773
00:30:57,819 --> 00:31:02,168
and the other one's ejected but what I

774
00:31:00,128 --> 00:31:03,908
said is for the supernova tap and you

775
00:31:02,169 --> 00:31:06,580
need two stars to begin and you need two

776
00:31:03,909 --> 00:31:08,499
stars at the time of the explosion which

777
00:31:06,579 --> 00:31:10,569
means if you're going to have another

778
00:31:08,499 --> 00:31:12,089
star ripped apart from that those other

779
00:31:10,569 --> 00:31:14,819
two stars then you need three star

780
00:31:12,089 --> 00:31:17,038
to begin with and that's just hard to do

781
00:31:14,819 --> 00:31:18,329
there aren't that many three-star

782
00:31:17,038 --> 00:31:19,890
systems that are in the right

783
00:31:18,329 --> 00:31:23,428
configuration and so if you only have a

784
00:31:19,890 --> 00:31:25,950

single black hole we don't think that

785

00:31:23,429 --> 00:31:28,650

there will be enough of these systems to

786

00:31:25,950 --> 00:31:31,288

make the super novae that we have so

787

00:31:28,650 --> 00:31:35,100

instead we come up with this we came up

788

00:31:31,288 --> 00:31:37,079

with this idea that it sounds crazier

789

00:31:35,099 --> 00:31:40,558

but it actually we think will will

790

00:31:37,079 --> 00:31:44,960

increase the the rate of these

791

00:31:40,558 --> 00:31:48,960

explosions so every once in a while a

792

00:31:44,960 --> 00:31:50,940

galaxy will be very close to another

793

00:31:48,960 --> 00:31:56,038

galaxy and gravitationally they'll come

794

00:31:50,940 --> 00:31:58,350

together and they'll merge and we have a

795

00:31:56,038 --> 00:32:00,000

video for this I think would you rather

796

00:31:58,349 --> 00:32:02,278

show that okay why don't we start with

797

00:32:00,000 --> 00:32:04,519

that and the launcher and what while I'm

798

00:32:02,278 --> 00:32:06,960

you know again in my long-winded

799

00:32:04,519 --> 00:32:10,139

explanation I'm sure we'll get to the

800

00:32:06,960 --> 00:32:13,649

details of this so if you have two if

801

00:32:10,140 --> 00:32:15,440

you have two galaxies that are that are

802

00:32:13,648 --> 00:32:17,069

close enough that they will

803

00:32:15,440 --> 00:32:19,470

gravitationally come together and this

804

00:32:17,069 --> 00:32:21,028

is something that will we will

805

00:32:19,470 --> 00:32:23,490

eventually happen to the Milky Way

806

00:32:21,028 --> 00:32:25,259

galaxy and the Andromeda galaxy they're

807

00:32:23,490 --> 00:32:26,849

on a collision course yeah this is one

808

00:32:25,259 --> 00:32:30,298

of our simulations or a frank simulation

809

00:32:26,849 --> 00:32:31,859

should show this collision and so when

810

00:32:30,298 --> 00:32:34,319

these two when these two galaxies

811

00:32:31,859 --> 00:32:37,288

combine what ends up happening

812

00:32:34,319 --> 00:32:39,509

importantly you know in addition to all

813
00:32:37,288 --> 00:32:42,808
the stars getting reconfigured and a

814
00:32:39,509 --> 00:32:44,278
bunch of gas getting spread around and

815
00:32:42,808 --> 00:32:46,109
there being these beautiful tidal tails

816
00:32:44,278 --> 00:32:49,048
and things like that

817
00:32:46,109 --> 00:32:52,379
additionally the supermassive black hole

818
00:32:49,048 --> 00:32:55,740
at at the center of each galaxy they

819
00:32:52,380 --> 00:32:57,809
come together to each each galaxy this

820
00:32:55,740 --> 00:33:01,048
is one of the highlights of what Hubble

821
00:32:57,808 --> 00:33:03,418
has done is is finding that essentially

822
00:33:01,048 --> 00:33:05,220
every single galaxy that we know of has

823
00:33:03,419 --> 00:33:08,460
a supermassive black hole at the center

824
00:33:05,220 --> 00:33:11,100
and Hubble has also shown that some

825
00:33:08,460 --> 00:33:12,390
supermassive black holes have two I'm

826
00:33:11,099 --> 00:33:13,798
sorry some galaxies have two

827

00:33:12,390 --> 00:33:17,159
supermassive black holes at their

828
00:33:13,798 --> 00:33:18,298
centers and what we think happens in

829
00:33:17,159 --> 00:33:20,490
those cases is that there were two

830
00:33:18,298 --> 00:33:22,859
galaxies that came together and merged

831
00:33:20,490 --> 00:33:25,859
and then these two supermassive black

832
00:33:22,859 --> 00:33:29,759
holes which are you

833
00:33:25,859 --> 00:33:31,918
very very massive they'll both sink to

834
00:33:29,759 --> 00:33:33,569
the center of this new galaxy and

835
00:33:31,919 --> 00:33:35,940
they'll be very close to each other and

836
00:33:33,569 --> 00:33:38,579
one day we expect them to actually merge

837
00:33:35,940 --> 00:33:41,429
together to make a single black hole but

838
00:33:38,579 --> 00:33:49,129
before that happens and now maybe we can

839
00:33:41,429 --> 00:33:49,130
go back to the schematic wait for it

840
00:33:50,898 --> 00:33:57,558
good so before that happens these black

841
00:33:55,140 --> 00:34:01,528

holes that are coming close together

842

00:33:57,558 --> 00:34:03,658
they'll go first of all bill each one

843

00:34:01,528 --> 00:34:06,329
has their own little star cluster around

844

00:34:03,659 --> 00:34:07,799
them these are the stars that just like

845

00:34:06,329 --> 00:34:09,989
in our Milky Way there's a big star

846

00:34:07,798 --> 00:34:12,960
cluster around it's at the Milky Way's

847

00:34:09,989 --> 00:34:14,699
supermassive black hole and these these

848

00:34:12,960 --> 00:34:16,199
stars normally they just they'll just

849

00:34:14,699 --> 00:34:18,289
orbit around and there won't be much of

850

00:34:16,199 --> 00:34:21,199
a problem but then as these two

851

00:34:18,289 --> 00:34:23,338
supermassive black holes come together

852

00:34:21,199 --> 00:34:26,819
then all of a sudden you're you're

853

00:34:23,338 --> 00:34:30,148
taking this this reservoir of stars you

854

00:34:26,820 --> 00:34:32,490
know this this entourage of millions of

855

00:34:30,148 --> 00:34:34,168
stars and all of a sudden you're you're

856
00:34:32,489 --> 00:34:38,338
effectively throwing them at another

857
00:34:34,168 --> 00:34:39,658
supermassive black hole and in the same

858
00:34:38,338 --> 00:34:42,148
is going in Reverse because each of

859
00:34:39,659 --> 00:34:44,579
these supermassive black holes has one

860
00:34:42,148 --> 00:34:46,559
of these big star clusters so as a

861
00:34:44,579 --> 00:34:49,529
result this this process that normally

862
00:34:46,559 --> 00:34:52,829
is very rare it happens like we think

863
00:34:49,530 --> 00:34:55,800
once every 100 or thousand years where

864
00:34:52,829 --> 00:34:58,469
one of these stars gets ejected from the

865
00:34:55,800 --> 00:35:01,950
Milky Way in the cases where you have

866
00:34:58,469 --> 00:35:05,189
two supermassive black holes you can you

867
00:35:01,949 --> 00:35:07,588
can increase that rate to not not one

868
00:35:05,190 --> 00:35:11,300
per hundred years but maybe something

869
00:35:07,588 --> 00:35:13,799
like a hundred per year so it's

870
00:35:11,300 --> 00:35:15,539
significantly more just because all of a

871
00:35:13,800 --> 00:35:20,030
sudden you have this other black hole by

872
00:35:15,539 --> 00:35:22,559
all of these millions of stars now um

873
00:35:20,030 --> 00:35:24,330
the other fun thing about this in

874
00:35:22,559 --> 00:35:25,829
addition to just like increasing the

875
00:35:24,329 --> 00:35:27,889
total number of stars that are going to

876
00:35:25,829 --> 00:35:31,500
interact gravitationally with these

877
00:35:27,889 --> 00:35:34,139
supermassive black holes is that if you

878
00:35:31,500 --> 00:35:36,179
have a binary system what you can do is

879
00:35:34,139 --> 00:35:39,150
you can essentially slingshot that

880
00:35:36,179 --> 00:35:39,480
binary system by one black hole and then

881
00:35:39,150 --> 00:35:42,210
by

882
00:35:39,480 --> 00:35:44,190
the second black hole and you can

883
00:35:42,210 --> 00:35:48,869
accelerate them to these hypervelocity

884

00:35:44,190 --> 00:35:51,630
speeds without breaking them up and and

885
00:35:48,869 --> 00:35:53,730
a lot of times they do break out those

886
00:35:51,630 --> 00:35:56,430
two stars that were orbiting around each

887
00:35:53,730 --> 00:35:58,559
other they'll completely separate but

888
00:35:56,429 --> 00:36:01,099
other times they won't and in fact when

889
00:35:58,559 --> 00:36:06,840
they don't what we think happens is

890
00:36:01,099 --> 00:36:08,880
they'll first get into these very very

891
00:36:06,840 --> 00:36:12,539
eccentric orbits where essentially

892
00:36:08,880 --> 00:36:14,849
they're the two stars instead of looking

893
00:36:12,539 --> 00:36:16,769
like a circle a circular orbit they'll

894
00:36:14,849 --> 00:36:18,449
look more like a really really stretched

895
00:36:16,769 --> 00:36:22,639
out ellipse and so they'll be going

896
00:36:18,449 --> 00:36:25,559
around very very elliptical orbits that

897
00:36:22,639 --> 00:36:28,379
that'll need to begin with but then very

898
00:36:25,559 --> 00:36:30,929

quickly because these these stars are

899

00:36:28,380 --> 00:36:32,910
already pretty close that'll that'll

900

00:36:30,929 --> 00:36:35,009
circularize the orbits will become more

901

00:36:32,909 --> 00:36:36,779
circular again but then they'll be

902

00:36:35,010 --> 00:36:38,550
tighter so when they started off they

903

00:36:36,780 --> 00:36:40,890
might be orbiting this far apart and

904

00:36:38,550 --> 00:36:43,440
then afterwards they do this really

905

00:36:40,889 --> 00:36:45,059
eccentric orbit and then eventually that

906

00:36:43,440 --> 00:36:46,829
becomes circular and then they're close

907

00:36:45,059 --> 00:36:48,449
together so the double black holes

908

00:36:46,829 --> 00:36:50,549
coming together really messes with their

909

00:36:48,449 --> 00:36:52,049
orbital dynamics and then one throw now

910

00:36:50,550 --> 00:36:53,880
they get they kind of stabilize a little

911

00:36:52,050 --> 00:36:55,470
bit better and we need that we still

912

00:36:53,880 --> 00:36:57,119
need the binary stars though to have an

913
00:36:55,469 --> 00:37:01,618
explosion at all right that's right and

914
00:36:57,119 --> 00:37:03,510
so and but but so this this process of

915
00:37:01,619 --> 00:37:06,750
having the two supermassive black holes

916
00:37:03,510 --> 00:37:08,609
does three really important things first

917
00:37:06,750 --> 00:37:11,340
it increases the number of stars that

918
00:37:08,608 --> 00:37:13,829
are going to get kicked out two it makes

919
00:37:11,340 --> 00:37:17,220
it so that these binary systems can

920
00:37:13,829 --> 00:37:19,559
survive and three when these binary

921
00:37:17,219 --> 00:37:23,569
systems do survive it brings the two

922
00:37:19,559 --> 00:37:26,429
stars much much closer together okay so

923
00:37:23,570 --> 00:37:27,900
we'll talk about this more but that last

924
00:37:26,429 --> 00:37:30,089
bit of the two stars getting closer

925
00:37:27,900 --> 00:37:32,849
together that's essentially shortening

926
00:37:30,090 --> 00:37:34,858
the fuse for the explosion which

927
00:37:32,849 --> 00:37:36,539
explains what which might be why they're

928
00:37:34,858 --> 00:37:39,179
exploding before their time why you

929
00:37:36,539 --> 00:37:41,759
would ordinarily expect I see so you've

930
00:37:39,179 --> 00:37:44,339
come together with a pretty elaborate

931
00:37:41,760 --> 00:37:46,200
scheme for for all of this to happen the

932
00:37:44,340 --> 00:37:48,210
way we're the to match the observations

933
00:37:46,199 --> 00:37:49,710
how confident are you that this is

934
00:37:48,210 --> 00:37:51,920
what's actually going on what have you

935
00:37:49,710 --> 00:37:51,920
Oh

936
00:37:53,070 --> 00:37:57,660
so I you know in with scientists we

937
00:37:56,340 --> 00:38:01,559
always have kind of have different

938
00:37:57,659 --> 00:38:03,989
levels of our confidence I'm I'm very

939
00:38:01,559 --> 00:38:06,329
confident that the the stars are coming

940
00:38:03,989 --> 00:38:09,029
from the Centers of their galaxies

941

00:38:06,329 --> 00:38:12,840
I'm very confident in that I'm also very

942
00:38:09,030 --> 00:38:14,100
confident that these these the galaxies

943
00:38:12,840 --> 00:38:15,390
that are hosting these objects and we

944
00:38:14,099 --> 00:38:20,429
haven't even really talked about this

945
00:38:15,389 --> 00:38:23,000
they seem to have had recent mergers and

946
00:38:20,429 --> 00:38:25,409
so the combination of those two things

947
00:38:23,000 --> 00:38:27,750
makes it so that it looks like they are

948
00:38:25,409 --> 00:38:29,879
getting ejected from the center the very

949
00:38:27,750 --> 00:38:31,530
centers of their galaxies and the

950
00:38:29,880 --> 00:38:35,760
mergers say that there's probably a

951
00:38:31,530 --> 00:38:37,350
binary supermassive black hole the the

952
00:38:35,760 --> 00:38:39,960
place where then things get more

953
00:38:37,349 --> 00:38:43,319
complicated is are there going to be

954
00:38:39,960 --> 00:38:45,329
enough of these events because we've

955
00:38:43,320 --> 00:38:49,530

found 13 which doesn't seem like that

956

00:38:45,329 --> 00:38:51,809

many but it's it actually you know it's

957

00:38:49,530 --> 00:38:53,700

a reasonable number and you might not

958

00:38:51,809 --> 00:38:56,369

have expected that many so together

959

00:38:53,699 --> 00:39:00,989

jives then with with galaxy merger rates

960

00:38:56,369 --> 00:39:03,329

and it's close enough where I'm not

961

00:39:00,989 --> 00:39:05,819

afraid to say that I think that this is

962

00:39:03,329 --> 00:39:08,190

possible but it's it's probably off by a

963

00:39:05,820 --> 00:39:10,260

factor of like 10 from what we think we

964

00:39:08,190 --> 00:39:12,119

know and of course you know every you

965

00:39:10,260 --> 00:39:13,800

know there there's a lot of uncertainty

966

00:39:12,119 --> 00:39:15,690

in in these numbers and so it's

967

00:39:13,800 --> 00:39:17,550

completely consistent but it's far

968

00:39:15,690 --> 00:39:19,019

enough away where where I'm not gonna

969

00:39:17,550 --> 00:39:22,380

you know I'm not gonna bet my house on

970
00:39:19,019 --> 00:39:24,900
it okay but but I bet a dinner on it I

971
00:39:22,380 --> 00:39:27,059
did it I so I have a question so you

972
00:39:24,900 --> 00:39:29,130
have these galaxies so you find these

973
00:39:27,059 --> 00:39:30,750
weird stars you try to figure it out you

974
00:39:29,130 --> 00:39:32,220
say okay it looks like some of them are

975
00:39:30,750 --> 00:39:34,260
wandering off we can't measure the

976
00:39:32,219 --> 00:39:35,939
velocity but they're a long way wait we

977
00:39:34,260 --> 00:39:37,620
think the analogous ones with ones

978
00:39:35,940 --> 00:39:40,010
coming towards us we can measure them

979
00:39:37,619 --> 00:39:43,799
they're all calcium-rich there is

980
00:39:40,010 --> 00:39:47,150
supernova trace back we have mergers is

981
00:39:43,800 --> 00:39:49,980
there are there any other symptoms of

982
00:39:47,150 --> 00:39:51,900
the I mean you see the mergers but are

983
00:39:49,980 --> 00:39:55,800
there any other symptoms of a binary

984
00:39:51,900 --> 00:39:59,070
black hole that would tell you oh also

985
00:39:55,800 --> 00:40:04,080
binary black holes produce this other

986
00:39:59,070 --> 00:40:07,079
thing we see that - whoa so yes so first

987
00:40:04,079 --> 00:40:08,429
of all let me step back in

988
00:40:07,079 --> 00:40:12,119
maybe maybe now is a good time to

989
00:40:08,429 --> 00:40:15,440
actually show the Hubble images now is

990
00:40:12,119 --> 00:40:21,479
always a good time to show Hubble that

991
00:40:15,440 --> 00:40:24,358
so in the in the little video that we

992
00:40:21,478 --> 00:40:27,328
saw when these two galaxies come

993
00:40:24,358 --> 00:40:30,028
together and merge in addition to kind

994
00:40:27,329 --> 00:40:31,528
of taking what were very pretty galaxies

995
00:40:30,028 --> 00:40:35,009
and then spreading out all the stars

996
00:40:31,528 --> 00:40:37,039
into this more spherical configuration

997
00:40:35,009 --> 00:40:40,769
one of the things that happens is that

998

00:40:37,039 --> 00:40:44,099
sort of the shredded galaxies there's

999
00:40:40,768 --> 00:40:46,889
still some remnant of it and one of the

1000
00:40:44,099 --> 00:40:51,209
things that we see are it are we see

1001
00:40:46,889 --> 00:40:54,808
that the dust and gas that was in one of

1002
00:40:51,208 --> 00:40:58,949
these galaxies it gets spread out in the

1003
00:40:54,809 --> 00:41:02,609
new galaxies and this is unlike what we

1004
00:40:58,949 --> 00:41:05,879
see in very old spherical galaxies if we

1005
00:41:02,608 --> 00:41:08,909
see if we see a relatively spherical

1006
00:41:05,880 --> 00:41:11,459
galaxy with a lot of dust then it's

1007
00:41:08,909 --> 00:41:14,098
likely that it had a recent merger and

1008
00:41:11,458 --> 00:41:16,978
so these beautiful Hubble images of

1009
00:41:14,099 --> 00:41:19,079
these galaxies you can see going kind of

1010
00:41:16,978 --> 00:41:23,399
from your top left to your bottom right

1011
00:41:19,079 --> 00:41:25,619
in both of these this this smudge that

1012
00:41:23,400 --> 00:41:29,849

goes straight through the beautiful

1013

00:41:25,619 --> 00:41:33,209

galaxy and that's thust that's we call

1014

00:41:29,849 --> 00:41:37,190

that a dust Blaine and what that really

1015

00:41:33,208 --> 00:41:41,368

is is the evidence of some recent merger

1016

00:41:37,190 --> 00:41:43,349

so so from these images and then from

1017

00:41:41,369 --> 00:41:45,479

some other lines of evidence it really

1018

00:41:43,349 --> 00:41:47,969

looks like these the galaxies that that

1019

00:41:45,478 --> 00:41:51,298

are near the supernovae had recent

1020

00:41:47,969 --> 00:41:52,679

mergers but that alone doesn't

1021

00:41:51,298 --> 00:41:54,768

necessarily say that there's a super

1022

00:41:52,679 --> 00:41:59,489

method of binary supermassive black hole

1023

00:41:54,768 --> 00:42:01,078

and and to confirm that there's a binary

1024

00:41:59,489 --> 00:42:03,358

supermassive black hole is actually a

1025

00:42:01,079 --> 00:42:06,690

very difficult observation to make it's

1026

00:42:03,358 --> 00:42:10,889

been done a handful of times sometimes

1027
00:42:06,690 --> 00:42:14,759
in in when you have very ideal

1028
00:42:10,889 --> 00:42:16,078
situations and we just don't have those

1029
00:42:14,759 --> 00:42:18,478
kinds of things it's sort of like you

1030
00:42:16,079 --> 00:42:20,670
know 1% of all galaxy mergers might be

1031
00:42:18,478 --> 00:42:21,269
in this configuration and then then it's

1032
00:42:20,670 --> 00:42:22,619
easier

1033
00:42:21,269 --> 00:42:25,289
to make that observation if you just

1034
00:42:22,619 --> 00:42:27,269
have normal binary supermassive black

1035
00:42:25,289 --> 00:42:28,829
holes it's hard but not impossible to do

1036
00:42:27,269 --> 00:42:32,579
and so one of the things that we're

1037
00:42:28,829 --> 00:42:36,119
looking into doing down the road is to

1038
00:42:32,579 --> 00:42:38,610
measure the velocities of the stars

1039
00:42:36,119 --> 00:42:42,000
right at the Centers of these galaxies

1040
00:42:38,610 --> 00:42:43,800
and so what you can find is if for a

1041
00:42:42,000 --> 00:42:46,889
normal single supermassive black hole

1042
00:42:43,800 --> 00:42:48,780
there's a certain way that the stars

1043
00:42:46,889 --> 00:42:51,329
will kind of orbit around that that

1044
00:42:48,780 --> 00:42:52,769
singled a supermassive black hole if

1045
00:42:51,329 --> 00:42:54,929
there are two supermassive black holes

1046
00:42:52,769 --> 00:42:57,719
that changes how those stars are

1047
00:42:54,929 --> 00:42:59,579
orbiting around the two of them and so

1048
00:42:57,719 --> 00:43:01,559
that's something that we're looking into

1049
00:42:59,579 --> 00:43:04,170
to confirm them how you gonna do that

1050
00:43:01,559 --> 00:43:07,619
how far away are these galaxies well so

1051
00:43:04,170 --> 00:43:11,460
the closest ones are not too far so that

1052
00:43:07,619 --> 00:43:15,809
the closest ones are are around 20 mega

1053
00:43:11,460 --> 00:43:19,429
parsecs or so which if so let me so yes

1054
00:43:15,809 --> 00:43:23,369
so the closest one is 23 mega parsecs

1055

00:43:19,429 --> 00:43:28,980
which is something like you know 75 60

1056
00:43:23,369 --> 00:43:31,589
75 million light-years away you know

1057
00:43:28,980 --> 00:43:34,170
it's their third depth that sounds large

1058
00:43:31,590 --> 00:43:36,690
those are actually pretty close by to

1059
00:43:34,170 --> 00:43:39,690
give some reference the the Virgo

1060
00:43:36,690 --> 00:43:41,760
cluster is it's like 15 to 20 min I'm

1061
00:43:39,690 --> 00:43:43,980
asked a group that our our galaxy is a

1062
00:43:41,760 --> 00:43:47,220
member of so well yeah yes so we're

1063
00:43:43,980 --> 00:43:50,429
we're on some of these are further but

1064
00:43:47,219 --> 00:43:53,579
but a lot of them are pretty close the

1065
00:43:50,429 --> 00:43:56,129
the key to to making the measurement

1066
00:43:53,579 --> 00:43:58,409
that I'm talking about is to is to

1067
00:43:56,130 --> 00:44:01,800
really resolve out the center of the

1068
00:43:58,409 --> 00:44:04,619
galaxy and you can do this two ways one

1069
00:44:01,800 --> 00:44:08,850

that's been done in this you know

1070

00:44:04,619 --> 00:44:13,880

incredibly well work from now two

1071

00:44:08,849 --> 00:44:18,029

decades ago with Hubble is to use the

1072

00:44:13,880 --> 00:44:20,640

really incredible resolution of Hubble

1073

00:44:18,030 --> 00:44:24,060

and take a spectrum of just the very

1074

00:44:20,639 --> 00:44:26,250

center of the galaxy and so this is

1075

00:44:24,059 --> 00:44:29,460

something that that was that's been done

1076

00:44:26,250 --> 00:44:32,099

many many times with Hubble and it's

1077

00:44:29,460 --> 00:44:33,720

it's it's been able to determine not

1078

00:44:32,099 --> 00:44:34,889

just that there are supermassive black

1079

00:44:33,719 --> 00:44:38,129

holes and

1080

00:44:34,889 --> 00:44:39,358

all these these galaxies but that we can

1081

00:44:38,130 --> 00:44:41,730

measure the the mass of those

1082

00:44:39,358 --> 00:44:43,828

supermassive black holes oh wow that's

1083

00:44:41,730 --> 00:44:45,690

great so I well I don't want to go back

1084
00:44:43,829 --> 00:44:47,789
to the idea that there was evidence of

1085
00:44:45,690 --> 00:44:49,798
these mergers have having these galaxies

1086
00:44:47,789 --> 00:44:52,410
haven't been in mergers when you said

1087
00:44:49,798 --> 00:44:54,179
that a telltale sign was the dust lanes

1088
00:44:52,409 --> 00:44:56,068
that you saw there but isn't it also

1089
00:44:54,179 --> 00:44:58,889
these were elliptical galaxies and these

1090
00:44:56,068 --> 00:45:00,449
are among the most oldest galaxies and

1091
00:44:58,889 --> 00:45:01,889
the largest galaxies in the universe so

1092
00:45:00,449 --> 00:45:05,250
wouldn't that by definition make them uh

1093
00:45:01,889 --> 00:45:10,018
I can't are a victim of lots of mergers

1094
00:45:05,250 --> 00:45:12,018
well yes so too the the there there are

1095
00:45:10,018 --> 00:45:14,879
there are a few theories on how

1096
00:45:12,018 --> 00:45:17,848
elliptical galaxies come to be but one

1097
00:45:14,880 --> 00:45:20,460
very prominent one is that you have

1098
00:45:17,849 --> 00:45:23,160
spiral galaxies that merge and then that

1099
00:45:20,460 --> 00:45:25,440
that will then reconfigure the orbits of

1100
00:45:23,159 --> 00:45:28,108
all the stars in the two galaxies and

1101
00:45:25,440 --> 00:45:31,769
then they become an elliptical galaxy uh

1102
00:45:28,108 --> 00:45:34,199
the the issue is that when when you have

1103
00:45:31,768 --> 00:45:37,259
a merger then there's some settling out

1104
00:45:34,199 --> 00:45:38,759
time early on you'll see you'll see two

1105
00:45:37,260 --> 00:45:40,470
galaxies where it's very clear that

1106
00:45:38,760 --> 00:45:41,819
there are two separate galaxies but

1107
00:45:40,469 --> 00:45:44,730
they're interacting with each other

1108
00:45:41,818 --> 00:45:47,250
later on you'll see us evidence of that

1109
00:45:44,730 --> 00:45:49,108
you might just see that the but there's

1110
00:45:47,250 --> 00:45:51,469
these dust lanes and then if you wait

1111
00:45:49,108 --> 00:45:53,838
even longer then the dust will dissipate

1112

00:45:51,469 --> 00:45:58,379
and you just see this beautiful

1113
00:45:53,838 --> 00:46:01,130
elliptical galaxy and so and so in those

1114
00:45:58,380 --> 00:46:03,500
cases it's just a matter of timing

1115
00:46:01,130 --> 00:46:06,150
there's also the you know the

1116
00:46:03,500 --> 00:46:08,068
possibility that you have an elliptical

1117
00:46:06,150 --> 00:46:09,930
galaxy and another elliptical galaxies

1118
00:46:08,068 --> 00:46:11,190
merge and then you wouldn't see any dust

1119
00:46:09,929 --> 00:46:14,460
but you would still have a binary

1120
00:46:11,190 --> 00:46:16,289
supermassive black hole so so there

1121
00:46:14,460 --> 00:46:19,588
there there are a lot of ways to think

1122
00:46:16,289 --> 00:46:21,089
about this and and and like I said you

1123
00:46:19,588 --> 00:46:23,190
know we we really do need to do the

1124
00:46:21,088 --> 00:46:25,739
follow-up observations and confirm that

1125
00:46:23,190 --> 00:46:28,798
at least a subset of these have binary

1126
00:46:25,739 --> 00:46:30,479

supermassive black holes but all the all

1127

00:46:28,798 --> 00:46:32,548

the evidence that we have so far is

1128

00:46:30,480 --> 00:46:34,108

pointing that way cool alright great

1129

00:46:32,548 --> 00:46:36,268

well good running out of time now I have

1130

00:46:34,108 --> 00:46:37,920

some questions piling up on the QA app

1131

00:46:36,268 --> 00:46:41,608

so let me get to a couple of them Ronald

1132

00:46:37,920 --> 00:46:43,950

Minch is is asking does a black hole

1133

00:46:41,608 --> 00:46:46,048

ejecting debris in this case the star I

1134

00:46:43,949 --> 00:46:48,210

would imagine indicate that they aren't

1135

00:46:46,048 --> 00:46:48,719

as powerful and stable as once thought

1136

00:46:48,210 --> 00:46:50,519

is there

1137

00:46:48,719 --> 00:46:53,789

correlation between these do they lose

1138

00:46:50,519 --> 00:46:55,170

energy when they eject things well so

1139

00:46:53,789 --> 00:46:58,230

this is this is an interesting question

1140

00:46:55,170 --> 00:47:02,700

there's actually a way to steal energy

1141
00:46:58,230 --> 00:47:04,199
from a black hole we probably don't have

1142
00:47:02,699 --> 00:47:06,000
enough time to get into this but there's

1143
00:47:04,199 --> 00:47:09,598
there's a region near the black hole

1144
00:47:06,000 --> 00:47:13,349
called the Virgo sphere and if you can

1145
00:47:09,599 --> 00:47:16,289
dip something into that region and come

1146
00:47:13,349 --> 00:47:18,840
out of it you can steal some energy from

1147
00:47:16,289 --> 00:47:21,659
the black hole and similarly you know

1148
00:47:18,840 --> 00:47:23,700
energy is always conserved and so when

1149
00:47:21,659 --> 00:47:25,108
you when you slingshot these stars the

1150
00:47:23,699 --> 00:47:26,789
energy has to come from somewhere and it

1151
00:47:25,108 --> 00:47:30,000
does come from these orbits it's the

1152
00:47:26,789 --> 00:47:31,440
same process basically as when we send

1153
00:47:30,000 --> 00:47:33,659
out satellites to the outer solar system

1154
00:47:31,440 --> 00:47:36,358
and we have a gravitational assist or a

1155
00:47:33,659 --> 00:47:37,920
slingshot by Mars or Jupiter it's the

1156
00:47:36,358 --> 00:47:39,299
same idea the energy has to come from

1157
00:47:37,920 --> 00:47:43,500
somewhere it comes from the orbit of

1158
00:47:39,300 --> 00:47:47,550
those ergo sphere the ergosphere the

1159
00:47:43,500 --> 00:47:51,630
other means energy Oh sphere so ergo I

1160
00:47:47,550 --> 00:47:53,670
think means work in Greek yeah yeah so I

1161
00:47:51,630 --> 00:47:54,960
did not know that I want to find out

1162
00:47:53,670 --> 00:47:56,849
more about that unfortunately right we

1163
00:47:54,960 --> 00:47:58,019
won't have a lot of time that is cool

1164
00:47:56,849 --> 00:47:59,640
thank you very much Ron well that was a

1165
00:47:58,019 --> 00:48:02,759
good question

1166
00:47:59,639 --> 00:48:04,679
let's see Craig Landon is asking on the

1167
00:48:02,760 --> 00:48:07,320
Q&A app similar to dr. Christians

1168
00:48:04,679 --> 00:48:09,419
question do these need to be binary

1169

00:48:07,320 --> 00:48:11,039
supermassive black holes or could

1170
00:48:09,420 --> 00:48:13,710
something like an intermediate mass

1171
00:48:11,039 --> 00:48:16,858
black hole binary or not produce the

1172
00:48:13,710 --> 00:48:17,670
same energy necessary yeah so that's an

1173
00:48:16,858 --> 00:48:19,650
excellent question

1174
00:48:17,670 --> 00:48:23,329
and the short answer is we don't know

1175
00:48:19,650 --> 00:48:25,800
because there's there's only been some

1176
00:48:23,329 --> 00:48:28,289
theoretical modeling you know computer

1177
00:48:25,800 --> 00:48:31,230
modeling of these systems and people

1178
00:48:28,289 --> 00:48:33,239
haven't looked at how low of a mass you

1179
00:48:31,230 --> 00:48:35,190
could have her the companion I guess is

1180
00:48:33,239 --> 00:48:37,829
that having a intermediate-mass black

1181
00:48:35,190 --> 00:48:41,010
holes or something that's a thousand or

1182
00:48:37,829 --> 00:48:42,539
a few thousand solar masses and a

1183
00:48:41,010 --> 00:48:44,250

supermassive black hole say something

1184

00:48:42,539 --> 00:48:46,529
that's a million to a billion solar

1185

00:48:44,250 --> 00:48:50,159
masses if you had that pair you probably

1186

00:48:46,530 --> 00:48:51,599
would do okay and and then you could do

1187

00:48:50,159 --> 00:48:54,299
there is still this scenario where you

1188

00:48:51,599 --> 00:48:56,789
could do it with a single black hole to

1189

00:48:54,300 --> 00:48:58,769
do that you need you need to start off

1190

00:48:56,789 --> 00:49:01,679
with three stars the triple star system

1191

00:48:58,769 --> 00:49:02,610
and those are those are just rare it's

1192

00:49:01,679 --> 00:49:04,379
not impossible

1193

00:49:02,610 --> 00:49:08,400
talking about 13 that we've seen all

1194

00:49:04,380 --> 00:49:11,309
that you know more rare than that uh no

1195

00:49:08,400 --> 00:49:12,720
so sooo that I it doesn't necessarily

1196

00:49:11,309 --> 00:49:15,630
have to be more rare than that I think

1197

00:49:12,719 --> 00:49:18,389
the the reason why the one reason why we

1198
00:49:15,630 --> 00:49:20,730
go to the binaries that really helps is

1199
00:49:18,389 --> 00:49:23,489
that we have all this evidence for

1200
00:49:20,730 --> 00:49:25,920
mergers and we know that when you have

1201
00:49:23,489 --> 00:49:27,899
binary you know you know that the two

1202
00:49:25,920 --> 00:49:30,300
versus three stars that's not as

1203
00:49:27,900 --> 00:49:32,369
important as just elevating the overall

1204
00:49:30,300 --> 00:49:35,010
rate of ejection and that happens when

1205
00:49:32,369 --> 00:49:36,750
you just have these two black holes yeah

1206
00:49:35,010 --> 00:49:38,700
and I think the rate was again you say a

1207
00:49:36,750 --> 00:49:41,190
hundred per year versus one per year

1208
00:49:38,699 --> 00:49:43,649
well one per hundred years in the Milky

1209
00:49:41,190 --> 00:49:45,059
Way or even if you could even stretch it

1210
00:49:43,650 --> 00:49:47,130
further depending on you know it could

1211
00:49:45,059 --> 00:49:48,900
be one per thousand years and then up to

1212
00:49:47,130 --> 00:49:51,570
a thousand per year so it's really like

1213
00:49:48,900 --> 00:49:53,099
it's significantly different right right

1214
00:49:51,570 --> 00:49:55,820
okay well very good question Craig thank

1215
00:49:53,099 --> 00:49:58,529
you okay so Adams energy is asking again

1216
00:49:55,820 --> 00:50:00,539
another question normally we would

1217
00:49:58,530 --> 00:50:03,390
expect binary stars to take a long time

1218
00:50:00,539 --> 00:50:06,179
to merge but these stars must merge much

1219
00:50:03,389 --> 00:50:08,670
much quicker can Ryan estimate how long

1220
00:50:06,179 --> 00:50:13,069
it takes for these a ejected by an Aries

1221
00:50:08,670 --> 00:50:16,980
to go bang this is a beautiful question

1222
00:50:13,070 --> 00:50:21,240
so for these cases we we can determine

1223
00:50:16,980 --> 00:50:23,309
this at least on average so we know for

1224
00:50:21,239 --> 00:50:25,709
the objects that are coming right at us

1225
00:50:23,309 --> 00:50:28,710
we know how fast they're moving and then

1226

00:50:25,710 --> 00:50:31,230
the ones that that are very far away we

1227
00:50:28,710 --> 00:50:33,269
have a rough estimate of how far away

1228
00:50:31,230 --> 00:50:35,190
they are from their galaxies now of

1229
00:50:33,269 --> 00:50:37,829
course they could be you know out in

1230
00:50:35,190 --> 00:50:39,240
front of us and then in projection they

1231
00:50:37,829 --> 00:50:41,099
look like they're they're closer than

1232
00:50:39,239 --> 00:50:42,809
what they really are but if you take

1233
00:50:41,099 --> 00:50:44,909
those two things we have a velocity in a

1234
00:50:42,809 --> 00:50:49,829
distance then you can measure a time

1235
00:50:44,909 --> 00:50:51,779
right so it must have gone some speed

1236
00:50:49,829 --> 00:50:54,420
for some amount of time to get to that

1237
00:50:51,780 --> 00:50:57,380
distance if you do that you end up

1238
00:50:54,420 --> 00:51:00,960
getting a time of about 50 million years

1239
00:50:57,380 --> 00:51:03,960
so that sounds like a long time it's

1240
00:51:00,960 --> 00:51:07,670

actually a very short time in terms of

1241

00:51:03,960 --> 00:51:11,490

the the life of a star or in terms of

1242

00:51:07,670 --> 00:51:14,030

the age of the universe and so this is

1243

00:51:11,489 --> 00:51:16,559

one of the important things is that if

1244

00:51:14,030 --> 00:51:18,690

if you have some few

1245

00:51:16,559 --> 00:51:21,659

between say when the stars were born and

1246

00:51:18,690 --> 00:51:24,360

when they explode and and it's

1247

00:51:21,659 --> 00:51:26,460

sufficiently short then you'll see them

1248

00:51:24,360 --> 00:51:28,769

all over the place and you should see

1249

00:51:26,460 --> 00:51:30,960

them close to where they're born and we

1250

00:51:28,769 --> 00:51:33,420

don't see that in this case so it has to

1251

00:51:30,960 --> 00:51:36,240

have a very long fuse normally say

1252

00:51:33,420 --> 00:51:39,119

longer than the age of the universe so

1253

00:51:36,239 --> 00:51:41,069

the typical objects that explode as

1254

00:51:39,119 --> 00:51:43,679

these thousand richer supernovae they

1255
00:51:41,070 --> 00:51:45,900
typically won't explode for say you know

1256
00:51:43,679 --> 00:51:48,359
twenty or fifty or a hundred billion

1257
00:51:45,900 --> 00:51:51,059
years much longer than the age of the

1258
00:51:48,360 --> 00:51:53,700
universe but through this interaction we

1259
00:51:51,059 --> 00:51:55,590
were able to shorten that fuse and so

1260
00:51:53,699 --> 00:51:57,839
then we're you know it who knows how

1261
00:51:55,590 --> 00:51:59,730
long it took maybe five billion years or

1262
00:51:57,840 --> 00:52:02,100
ten billion years before the star

1263
00:51:59,730 --> 00:52:03,750
actually gets kicked out but then after

1264
00:52:02,099 --> 00:52:06,110
that it's only about fifty million years

1265
00:52:03,750 --> 00:52:08,280
before it explodes Wow so that rapidly

1266
00:52:06,110 --> 00:52:10,079
accelerates the time that would take

1267
00:52:08,280 --> 00:52:12,300
direct to make a blow-up that's amazing

1268
00:52:10,079 --> 00:52:13,739
okay well two-toed it's sort of so to go

1269
00:52:12,300 --> 00:52:16,019
back to our analogy with the homeless

1270
00:52:13,739 --> 00:52:18,329
and knowing that where that guy is on

1271
00:52:16,019 --> 00:52:19,949
the outside of town and how we got there

1272
00:52:18,329 --> 00:52:22,319
you're saying you got kicked out of town

1273
00:52:19,949 --> 00:52:24,929
is that what it is yeah it's somebody

1274
00:52:22,320 --> 00:52:26,190
somebody drove him out of town yeah he

1275
00:52:24,929 --> 00:52:27,989
got drove out it that's what he's doing

1276
00:52:26,190 --> 00:52:29,880
there great question I'd appreciate that

1277
00:52:27,989 --> 00:52:32,639
okay one more question for model men

1278
00:52:29,880 --> 00:52:36,059
cheer he's asking I think this was to

1279
00:52:32,639 --> 00:52:38,849
you Carol it's like doctor see what PhD

1280
00:52:36,059 --> 00:52:40,559
are you I know someone who will just end

1281
00:52:38,849 --> 00:52:42,179
of someone who is just beginning to

1282
00:52:40,559 --> 00:52:45,199
venture into the physicists field so

1283

00:52:42,179 --> 00:52:48,029
what's your PhD astronomy physics

1284
00:52:45,199 --> 00:52:50,879
physics and astronomy and any advice to

1285
00:52:48,030 --> 00:52:52,560
those just starting out if that's what

1286
00:52:50,880 --> 00:52:54,720
you love to do go for it there's no

1287
00:52:52,559 --> 00:52:56,159
reason not to it's fabulous there's all

1288
00:52:54,719 --> 00:53:00,269
kinds of opportunities

1289
00:52:56,159 --> 00:53:03,659
I mean besides hangouts there's no and

1290
00:53:00,269 --> 00:53:06,420
research on supernovae there there are

1291
00:53:03,659 --> 00:53:08,129
lots of things to do in astronomy in

1292
00:53:06,420 --> 00:53:11,700
space science so that's what you know

1293
00:53:08,130 --> 00:53:14,640
okay yeah good question on thank you

1294
00:53:11,699 --> 00:53:16,049
thanks for asking so okay so Ryan before

1295
00:53:14,639 --> 00:53:17,909
we leave I just want to real quickly

1296
00:53:16,050 --> 00:53:19,500
delve into some of the datasets you use

1297
00:53:17,909 --> 00:53:22,170

you said you use the Hubble archival

1298

00:53:19,500 --> 00:53:24,860

data with this this is data that's open

1299

00:53:22,170 --> 00:53:27,360

up to everyone you go to them at the the

1300

00:53:24,860 --> 00:53:29,590

master archive or the Hubble legacy

1301

00:53:27,360 --> 00:53:31,390

archive and you can get these data

1302

00:53:29,590 --> 00:53:33,789

what else did you use besides Hubble

1303

00:53:31,389 --> 00:53:37,269

data for your analysis yeah so first

1304

00:53:33,789 --> 00:53:39,009

before before I go on I mean I should

1305

00:53:37,269 --> 00:53:41,110

just say that the Hubble archive is one

1306

00:53:39,010 --> 00:53:43,540

of the best things in all of science and

1307

00:53:41,110 --> 00:53:44,769

I encourage people even if they're not

1308

00:53:43,539 --> 00:53:47,110

interested in doing some sort of

1309

00:53:44,769 --> 00:53:49,420

research you can just look up your

1310

00:53:47,110 --> 00:53:51,880

favorite part of the sky choose your

1311

00:53:49,420 --> 00:53:54,119

favorite object and look at beautiful

1312
00:53:51,880 --> 00:53:56,800
images that are not you know nobody else

1313
00:53:54,119 --> 00:53:58,690
has necessarily looked at exactly what

1314
00:53:56,800 --> 00:53:59,980
you're seeing and they have this there's

1315
00:53:58,690 --> 00:54:02,230
something called the Hubble legacy

1316
00:53:59,980 --> 00:54:04,510
archive where they they have a webpage

1317
00:54:02,230 --> 00:54:06,730
it's it's like Google Maps you can you

1318
00:54:04,510 --> 00:54:08,470
know you can zoom in and zoom out and

1319
00:54:06,730 --> 00:54:10,420
move things around it's really really

1320
00:54:08,469 --> 00:54:13,719
nice so I encourage everybody to look at

1321
00:54:10,420 --> 00:54:15,550
that you hear a leak well we'll just as

1322
00:54:13,719 --> 00:54:18,129
easy to say its archive that is TS CI

1323
00:54:15,550 --> 00:54:22,710
dot edu and you can go right from there

1324
00:54:18,130 --> 00:54:28,450
also I think hla dot stsci that the

1325
00:54:22,710 --> 00:54:32,470
legacy archive so in addition to Hubble

1326
00:54:28,449 --> 00:54:35,079
data I mainly used spectra that came

1327
00:54:32,469 --> 00:54:38,589
from the Lick Observatory the Keck

1328
00:54:35,079 --> 00:54:42,730
Observatory and Subaru which is another

1329
00:54:38,590 --> 00:54:45,370
telescope in in Hawaii and and then I

1330
00:54:42,730 --> 00:54:48,429
used a handful of other data sets that

1331
00:54:45,369 --> 00:54:49,960
for little bits and pieces so for a

1332
00:54:48,429 --> 00:54:51,609
handful of the galaxies there were

1333
00:54:49,960 --> 00:54:54,909
spectra in the Sloan Digital Sky Survey

1334
00:54:51,610 --> 00:54:58,120
things like that it really was pulling

1335
00:54:54,909 --> 00:55:00,909
whatever I could to try to understand

1336
00:54:58,119 --> 00:55:02,529
this whole topic so are you going to you

1337
00:55:00,909 --> 00:55:04,089
said that the further observations that

1338
00:55:02,530 --> 00:55:05,500
we're gonna be needed to kind of you

1339
00:55:04,090 --> 00:55:06,760
know make you feel a little bit more

1340

00:55:05,500 --> 00:55:09,250
confident about these would be to try

1341
00:55:06,760 --> 00:55:10,540
and resolve these in these binary

1342
00:55:09,250 --> 00:55:12,730
supermassive black holes in these

1343
00:55:10,539 --> 00:55:14,230
particular galaxies is using spectra any

1344
00:55:12,730 --> 00:55:18,909
plans to do that or are you writing on

1345
00:55:14,230 --> 00:55:20,500
two proposals now or yes so so the the

1346
00:55:18,909 --> 00:55:22,539
the great thing is at the University of

1347
00:55:20,500 --> 00:55:25,090
Illinois we just hired a new faculty

1348
00:55:22,539 --> 00:55:28,110
member a new professor whose specialty

1349
00:55:25,090 --> 00:55:30,519
is binary supermassive black holes oh

1350
00:55:28,110 --> 00:55:32,769
we're looking into doing something about

1351
00:55:30,519 --> 00:55:35,949
this and then I should also point out

1352
00:55:32,769 --> 00:55:39,250
that in the schedule for the for the

1353
00:55:35,949 --> 00:55:42,069
Hubble Space Telescope is to image some

1354
00:55:39,250 --> 00:55:43,230

of these other supernovae where they

1355

00:55:42,070 --> 00:55:45,510

where they happened

1356

00:55:43,230 --> 00:55:47,730

and so while we have images of a handful

1357

00:55:45,510 --> 00:55:49,500

of them pretty soon we're gonna we're

1358

00:55:47,730 --> 00:55:52,260

going to have almost all of them will

1359

00:55:49,500 --> 00:55:54,900

have Hubble images of them so I mean all

1360

00:55:52,260 --> 00:55:57,630

of them all of the 13 or 13 I think and

1361

00:55:54,900 --> 00:56:00,170

I think out of the 13 will will end up

1362

00:55:57,630 --> 00:56:03,329

with something like seven or eight

1363

00:56:00,170 --> 00:56:07,320

Hubble images whereas right now we we

1364

00:56:03,329 --> 00:56:09,569

don't have nearly that many and so so

1365

00:56:07,320 --> 00:56:10,950

that's that's going to be great and so

1366

00:56:09,570 --> 00:56:13,590

that'll be another way with the high

1367

00:56:10,949 --> 00:56:15,000

resolution images of Hubble they have a

1368

00:56:13,590 --> 00:56:16,680

better idea of what's going on at the

1369
00:56:15,000 --> 00:56:17,909
Centers of their galaxies well that's

1370
00:56:16,679 --> 00:56:19,618
grad sounds standing what hope do we

1371
00:56:17,909 --> 00:56:20,759
hope you'll come back and share with us

1372
00:56:19,619 --> 00:56:23,039
what you find out once you get those

1373
00:56:20,760 --> 00:56:25,500
images as well as if you do manage to

1374
00:56:23,039 --> 00:56:26,969
get some more of the of the evidence of

1375
00:56:25,500 --> 00:56:29,219
the super of the binary black holes that

1376
00:56:26,969 --> 00:56:30,569
would be awesome as well so thank you

1377
00:56:29,219 --> 00:56:31,980
very much Ryan this has been a great

1378
00:56:30,570 --> 00:56:33,809
hangout we appreciate you joining us

1379
00:56:31,980 --> 00:56:37,199
where it's always fun yeah we're running

1380
00:56:33,809 --> 00:56:38,340
out of time but I guess I Carol I guess

1381
00:56:37,199 --> 00:56:40,409
we've got another one in the books that

1382
00:56:38,340 --> 00:56:42,809
I we hope you guys will join us next

1383
00:56:40,409 --> 00:56:44,309
week we are still working on the title

1384
00:56:42,809 --> 00:56:45,630
and what the subject will be because

1385
00:56:44,309 --> 00:56:48,590
Carol and I are still scrambling to get

1386
00:56:45,630 --> 00:56:52,050
a prize mode now that's right

1387
00:56:48,590 --> 00:56:54,809
and I really appreciate Brian coming on

1388
00:56:52,050 --> 00:56:58,920
at the last minute I do - Thank You Ryan

1389
00:56:54,809 --> 00:57:00,329
there's been a last-minute yeah thank

1390
00:56:58,920 --> 00:57:01,349
you so much this has been great I want

1391
00:57:00,329 --> 00:57:03,210
to thank all of you for asking questions

1392
00:57:01,349 --> 00:57:05,009
and even your comments this has been

1393
00:57:03,210 --> 00:57:07,199
really fun until next week we'll see you

1394
00:57:05,010 --> 00:57:09,930
or another Hubble hangout thank you all

1395
00:57:07,199 --> 00:57:12,289
for watching and as always keep looking

1396
00:57:09,929 --> 00:57:12,289
up