

HUBBLE
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HUBBLE

hangouts

Hubble Observes Supermassive Black Holes
Ejecting Dying Stars from Host Galaxies

Thursday August 27, 2015 3pm EDT

1
00:00:09,629 --> 00:00:07,469
hello everybody and welcome to this

2
00:00:11,640 --> 00:00:09,639
week's Hubbell hangout we are back from

3
00:00:13,320 --> 00:00:11,650
summer hiatus and this week we have

4
00:00:15,959 --> 00:00:13,330
another great hangout plan for you today

5
00:00:17,970 --> 00:00:15,969
astronomers using Hubble's archived data

6
00:00:21,120 --> 00:00:17,980
among other data sets have been looking

7
00:00:23,100 --> 00:00:21,130
into a mystery of how certain supernovae

8
00:00:24,540 --> 00:00:23,110
are exploding sooner than they should

9
00:00:26,100 --> 00:00:24,550
have our least than they were believed

10
00:00:27,300 --> 00:00:26,110
to and we've got an astronomer here from

11
00:00:28,620 --> 00:00:27,310
the University of Illinois to show us

12
00:00:32,040 --> 00:00:28,630
some of the research he's been doing

13
00:00:33,450 --> 00:00:32,050

into this it turns out that the that the

14

00:00:35,729 --> 00:00:33,460

answers are that there's a lot of

15

00:00:37,680 --> 00:00:35,739

different components involved in this so

16

00:00:39,540 --> 00:00:37,690

we'll learn about what that is and we

17

00:00:40,860 --> 00:00:39,550

will hopefully get some of your

18

00:00:42,840 --> 00:00:40,870

questions and comments throughout the

19

00:00:44,729 --> 00:00:42,850

Hangout as well but before I tell you

20

00:00:47,009 --> 00:00:44,739

how you can interact with this let me

21

00:00:50,099 --> 00:00:47,019

introduce my colleague dr. Carol

22

00:00:52,079 --> 00:00:50,109

Christian welcome back Carol oh you just

23

00:00:53,759 --> 00:00:52,089

got back from the IAU didn't you yes I

24

00:00:59,160 --> 00:00:53,769

did yeah you were telling me some of the

25

00:01:05,910 --> 00:00:59,170

fun that you had there yeah we avoided

26
00:01:08,010 --> 00:01:05,920
the storm you know dodged a bullet on

27
00:01:09,300 --> 00:01:08,020
that it sounds like but yeah it sounds

28
00:01:10,620 --> 00:01:09,310
like it was a big meeting a lot of a lot

29
00:01:12,810 --> 00:01:10,630
of astronomers showing up I don't think

30
00:01:13,910 --> 00:01:12,820
there was any Pluto catastrophes that

31
00:01:18,480 --> 00:01:13,920
came out of there as far as

32
00:01:20,640 --> 00:01:18,490
classifications or anything okay well

33
00:01:22,260 --> 00:01:20,650
cool and welcome back and I also have

34
00:01:24,900 --> 00:01:22,270
been just recently gotten back from

35
00:01:27,300 --> 00:01:24,910
vacation so I'm energized and ready to

36
00:01:28,830 --> 00:01:27,310
go and get started on this news is it a

37
00:01:31,230 --> 00:01:28,840
new season what is our season anyway to

38
00:01:36,150 --> 00:01:31,240

even have a season let's say this is the

39

00:01:38,370 --> 00:01:36,160

start of a new season of Hubble hangouts

40

00:01:40,050 --> 00:01:38,380

okay unfortunately Scott Lewis our

41

00:01:41,610 --> 00:01:40,060

internet driver extraordinary could not

42

00:01:44,610 --> 00:01:41,620

be with us this week but he will return

43

00:01:46,530 --> 00:01:44,620

next week and right now we're gonna have

44

00:01:47,670 --> 00:01:46,540

a lot of help from Kelly behind the

45

00:01:50,460 --> 00:01:47,680

scenes to show us a lot of different

46

00:01:53,490 --> 00:01:50,470

things so let's get started my guest

47

00:01:54,770 --> 00:01:53,500

today is dr. Ryan dr. Ryan Foley from

48

00:01:56,490 --> 00:01:54,780

the University of Illinois at

49

00:01:58,650 --> 00:01:56,500

champaign-urbana he's at the astronomy

50

00:02:01,050 --> 00:01:58,660

department there hi Ryan welcome what

51
00:02:02,480 --> 00:02:01,060
would our hangout I thanks for having me

52
00:02:04,770 --> 00:02:02,490
that's good of you to show up and we

53
00:02:06,300 --> 00:02:04,780
appreciated to hear about some of the

54
00:02:09,509 --> 00:02:06,310
things that you've been working on so

55
00:02:11,190 --> 00:02:09,519
there are oh I'm sorry I didn't go back

56
00:02:12,750 --> 00:02:11,200
to how to how to leave questions and

57
00:02:13,830 --> 00:02:12,760
comments like I should have so before I

58
00:02:16,229 --> 00:02:13,840
get going

59
00:02:18,150 --> 00:02:16,239
let me tell you how you can give us

60
00:02:20,460 --> 00:02:18,160
questions and comments we hope that you

61
00:02:22,199 --> 00:02:20,470
will use the Q&A app that's the easiest

62
00:02:24,030 --> 00:02:22,209
it's real there's a little button there

63
00:02:25,770 --> 00:02:24,040

but I didn't hang out window that you

64

00:02:27,330 --> 00:02:25,780

can press and ask a question and the

65

00:02:29,910 --> 00:02:27,340

advantage of doing that is I have a nice

66

00:02:32,490 --> 00:02:29,920

little pane right here that I can look

67

00:02:33,930 --> 00:02:32,500

at and see those those questions and

68

00:02:36,240 --> 00:02:33,940

comments real time and I can just click

69

00:02:38,729 --> 00:02:36,250

on one of them and then it will time it

70

00:02:41,030 --> 00:02:38,739

will timestamp when we actually address

71

00:02:43,440 --> 00:02:41,040

that comment in the YouTube video so

72

00:02:46,140 --> 00:02:43,450

that would be one way another way is to

73

00:02:47,729 --> 00:02:46,150

use the hashtag hub all hang out I'm

74

00:02:49,170 --> 00:02:47,739

using that I've got a whole column on my

75

00:02:52,050 --> 00:02:49,180

tweet deck set up to look at those

76
00:02:54,330 --> 00:02:52,060
tweets so we you can do that as well I'm

77
00:02:57,059 --> 00:02:54,340
also looking at the G+ event page in

78
00:02:58,410 --> 00:02:57,069
Google+ where you can leave comments and

79
00:03:00,420 --> 00:02:58,420
questions there as well so we hope that

80
00:03:02,520 --> 00:03:00,430
you will do it also and we should be

81
00:03:03,960 --> 00:03:02,530
doing this every week but if you want to

82
00:03:06,089 --> 00:03:03,970
learn more about our Hubbell hangouts

83
00:03:08,339 --> 00:03:06,099
please subscribe to our YouTube channel

84
00:03:11,009 --> 00:03:08,349
Hubbell site channel on YouTube as well

85
00:03:13,740 --> 00:03:11,019
as follow us at Hubbell telescope on

86
00:03:17,819 --> 00:03:13,750
Twitter we're also Hubble telescope on

87
00:03:19,349 --> 00:03:17,829
Facebook so like subscribe follow do all

88
00:03:21,360 --> 00:03:19,359

those things and you will learn more

89

00:03:23,340 --> 00:03:21,370

about when these when these hangouts

90

00:03:24,990 --> 00:03:23,350

occur as well as all the science and

91

00:03:26,640 --> 00:03:25,000

stuff that's fit to print from the

92

00:03:29,550 --> 00:03:26,650

hubble space telescope so please do that

93

00:03:32,910 --> 00:03:29,560

okay so back to Ryan dr. Ryan Foley so

94

00:03:34,199 --> 00:03:32,920

you were using Hubble archive data among

95

00:03:35,550 --> 00:03:34,209

other data sets and we're going to talk

96

00:03:37,370 --> 00:03:35,560

about what those are in just a little

97

00:03:40,590 --> 00:03:37,380

bit but you're interested in these

98

00:03:42,809 --> 00:03:40,600

supernovae that somehow we're exploding

99

00:03:43,740 --> 00:03:42,819

before they should have is that correct

100

00:03:44,849 --> 00:03:43,750

why don't you tell us a little bit of

101
00:03:48,030 --> 00:03:44,859
the background of what you were trying

102
00:03:49,770 --> 00:03:48,040
to do sure hopefully we'll be able to

103
00:03:53,430 --> 00:03:49,780
get it all done in the hour this is kind

104
00:03:55,620 --> 00:03:53,440
of a complex story but I'll take it slow

105
00:03:57,809 --> 00:03:55,630
and we'll do it as far as we can oh yeah

106
00:04:00,449 --> 00:03:57,819
and I'll try to hold your hand in this

107
00:04:03,140 --> 00:04:00,459
but if if you need additional

108
00:04:06,270 --> 00:04:03,150
explanation please stop me oh I will I

109
00:04:09,449 --> 00:04:06,280
can be a little long-winded sometimes so

110
00:04:10,770 --> 00:04:09,459
um so I guess I should I should start

111
00:04:12,240 --> 00:04:10,780
with just sort of the basic thing and

112
00:04:16,740 --> 00:04:12,250
say you know supernovae are exploding

113
00:04:19,409 --> 00:04:16,750

starts and that there's a variety of

114

00:04:21,060 --> 00:04:19,419

supernovae there are lots of ways that a

115

00:04:24,600 --> 00:04:21,070

star can explode and a lot of different

116

00:04:26,150 --> 00:04:24,610

kinds of stars that explode and so we

117

00:04:28,880 --> 00:04:26,160

probably have a

118

00:04:30,500 --> 00:04:28,890

you know at this point figured out about

119

00:04:34,280 --> 00:04:30,510

a dozen different classes of stellar

120

00:04:37,390 --> 00:04:34,290

explosions and and this is one of the

121

00:04:41,300 --> 00:04:37,400

more peculiar or rarer classes which

122

00:04:43,190 --> 00:04:41,310

we've called calcium-rich supernova and

123

00:04:43,520 --> 00:04:43,200

I'll get into why we call them that in a

124

00:04:47,420 --> 00:04:43,530

minute

125

00:04:49,190 --> 00:04:47,430

but the basic story is that there are

126
00:04:52,730 --> 00:04:49,200
only about a dozen of these that we know

127
00:04:54,620 --> 00:04:52,740
about right now compared to the several

128
00:04:56,120 --> 00:04:54,630
thousand total supernovae that we know

129
00:04:57,710 --> 00:04:56,130
now wait okay so we're not talking

130
00:04:59,120 --> 00:04:57,720
you're talking about all super novae

131
00:05:03,140 --> 00:04:59,130
that we can see from Earth or from

132
00:05:04,820 --> 00:05:03,150
Hubble and that we've necessarily in our

133
00:05:07,400 --> 00:05:04,830
galaxy they're just that's right they're

134
00:05:09,650 --> 00:05:07,410
all over in the universe in the visible

135
00:05:13,910 --> 00:05:09,660
universe there's about a supernova every

136
00:05:15,830 --> 00:05:13,920
second and you know so it stars

137
00:05:17,570 --> 00:05:15,840
exploding in the visible universe Wow a

138
00:05:19,520 --> 00:05:17,580

super Dover every second somewhere in

139

00:05:21,230 --> 00:05:19,530

Andres something like that first time

140

00:05:23,960 --> 00:05:21,240

I've heard that that's uh we're missing

141

00:05:27,950 --> 00:05:23,970

a lot of them aren't we yeah we're

142

00:05:30,980 --> 00:05:27,960

missing a lot and and so we've over over

143

00:05:35,390 --> 00:05:30,990

the the the entirety of humanity we've

144

00:05:38,230 --> 00:05:35,400

detected a few thousand of them and most

145

00:05:42,230 --> 00:05:38,240

of them fall into a few categories and

146

00:05:45,470 --> 00:05:42,240

only a handful of those few thousand are

147

00:05:46,280 --> 00:05:45,480

this peculiar class of calcium-rich

148

00:05:48,530 --> 00:05:46,290

supernovae

149

00:05:50,330 --> 00:05:48,540

yeah you said about a dozen okay so what

150

00:05:52,370 --> 00:05:50,340

all right so you you you singled these

151
00:05:54,710 --> 00:05:52,380
out for some reason or they they just

152
00:05:56,840 --> 00:05:54,720
happen to be catch your eye for because

153
00:05:59,450 --> 00:05:56,850
of the kind that they were well so a

154
00:06:01,790 --> 00:05:59,460
little more than a decade ago so the

155
00:06:04,880 --> 00:06:01,800
first supernova you know this class was

156
00:06:07,430 --> 00:06:04,890
actually detected in the year 2000 but

157
00:06:08,930 --> 00:06:07,440
when it was detected we didn't exactly

158
00:06:12,260 --> 00:06:08,940
know what it was it took a few years

159
00:06:14,680 --> 00:06:12,270
before we figured this out and we when

160
00:06:18,800 --> 00:06:14,690
we had about four of these objects in

161
00:06:20,540 --> 00:06:18,810
2003 it was first proposed that there

162
00:06:21,980 --> 00:06:20,550
was this class of calcium-rich

163
00:06:23,570 --> 00:06:21,990

supernovae the reason we call them

164

00:06:25,100 --> 00:06:23,580

calcium-rich is that when you take a

165

00:06:27,170 --> 00:06:25,110

spectrum when you take the light from

166

00:06:28,909 --> 00:06:27,180

the supernova you disperse it through

167

00:06:31,310 --> 00:06:28,919

something like a prism so you can see

168

00:06:32,810 --> 00:06:31,320

all the different wavelengths and doing

169

00:06:35,870 --> 00:06:32,820

that you can you can understand the

170

00:06:38,750 --> 00:06:35,880

composition of that of that object and

171

00:06:39,950 --> 00:06:38,760

when we do that for these calcium-rich

172

00:06:42,890 --> 00:06:39,960

supernovae they have very

173

00:06:45,499 --> 00:06:42,900

strong absorption and emission lines

174

00:06:47,510 --> 00:06:45,509

that are associated with calcium much

175

00:06:51,830 --> 00:06:47,520

stronger than what we see for other

176

00:06:53,450 --> 00:06:51,840

supernovae so we took a bit of a leap

177

00:06:57,170 --> 00:06:53,460

initially calling them from having

178

00:06:59,420 --> 00:06:57,180

strong calcium wines to say in calcium

179

00:07:00,890 --> 00:06:59,430

rich and which I was sort of like what

180

00:07:02,600 --> 00:07:00,900

the composition is that there's a lot of

181

00:07:04,999 --> 00:07:02,610

actually calcium created in the

182

00:07:06,559 --> 00:07:05,009

explosion but it turns out that when you

183

00:07:07,999 --> 00:07:06,569

do more detailed modeling that that

184

00:07:10,339 --> 00:07:08,009

works out so we got a little lucky there

185

00:07:11,749 --> 00:07:10,349

that's the opposite of what happened a

186

00:07:14,120 --> 00:07:11,759

little more than a hundred years ago

187

00:07:16,159 --> 00:07:14,130

where when people first started taking

188

00:07:18,290 --> 00:07:16,169

spectra of the Sun we saw a lot of iron

189

00:07:20,749 --> 00:07:18,300

lines and a lot of people initially who

190

00:07:24,080 --> 00:07:20,759

said that the Sun must be made of iron

191

00:07:27,140 --> 00:07:24,090

but then after understanding things like

192

00:07:29,749 --> 00:07:27,150

ionization it was then determined that

193

00:07:31,850 --> 00:07:29,759

those iron lines although very strong do

194

00:07:33,860 --> 00:07:31,860

not indicate that the Sun is mostly made

195

00:07:35,270 --> 00:07:33,870

out of iron it's mostly made out of

196

00:07:38,089 --> 00:07:35,280

hydrogen

197

00:07:39,680 --> 00:07:38,099

so in the in that same sense we can do

198

00:07:41,180 --> 00:07:39,690

the same thing with a with a supernova

199

00:07:43,040 --> 00:07:41,190

and determine what it's made out of and

200

00:07:45,080 --> 00:07:43,050

turns out that there is a lot of calcium

201
00:07:48,020 --> 00:07:45,090
in these calcium richer supernovae much

202
00:07:50,089 --> 00:07:48,030
more so per you know the total mass of

203
00:07:52,550 --> 00:07:50,099
the abundance the percentage of the

204
00:07:55,189 --> 00:07:52,560
material is much more calcium than other

205
00:07:56,779 --> 00:07:55,199
supernovae okay so that's not so in

206
00:07:58,100 --> 00:07:56,789
addition to being calcium rich though of

207
00:08:00,020 --> 00:07:58,110
these supernovae new of which there you

208
00:08:02,390 --> 00:08:00,030
said they were 13 that you analyzed in

209
00:08:03,950 --> 00:08:02,400
your study there that's not the only

210
00:08:05,420 --> 00:08:03,960
thing you noticed about them right they

211
00:08:08,029 --> 00:08:05,430
were actually moving in a characteristic

212
00:08:10,520 --> 00:08:08,039
way it's relevant my correct great so so

213
00:08:14,839 --> 00:08:10,530

the the next thing that happened was in

214

00:08:18,230 --> 00:08:14,849

about 2010 there were a hint there was

215

00:08:19,820 --> 00:08:18,240

the first really good study of one of

216

00:08:23,240 --> 00:08:19,830

these objects that was kind of out in

217

00:08:25,999 --> 00:08:23,250

the middle of nowhere it was close to a

218

00:08:28,640 --> 00:08:26,009

galaxy but it wasn't as close as as most

219

00:08:29,870 --> 00:08:28,650

of the stars in that galaxy so you

220

00:08:31,939 --> 00:08:29,880

wouldn't if you just looked at a picture

221

00:08:34,519 --> 00:08:31,949

of it you wouldn't necessarily say oh

222

00:08:37,100 --> 00:08:34,529

that's that's part of that galaxy but

223

00:08:40,490 --> 00:08:37,110

because galaxies are spread out enough

224

00:08:42,589 --> 00:08:40,500

it was the only nearby galaxy it had to

225

00:08:44,600 --> 00:08:42,599

have been sort of associated with it and

226
00:08:46,460 --> 00:08:44,610
then when we when we did more detailed

227
00:08:47,810 --> 00:08:46,470
analysis we we could say that it was at

228
00:08:51,340 --> 00:08:47,820
the same distance of that as like

229
00:08:53,689 --> 00:08:51,350
galaxies just kind of far away and so

230
00:08:53,930 --> 00:08:53,699
it's it's sort of like if you're in the

231
00:08:56,810 --> 00:08:53,940
middle

232
00:08:58,550 --> 00:08:56,820
Wyoming and you see somebody you know 20

233
00:09:00,410 --> 00:08:58,560
miles outside of a town but then the

234
00:09:01,790 --> 00:09:00,420
next town is a hundred miles away he was

235
00:09:04,700 --> 00:09:01,800
like well maybe they live in that town

236
00:09:09,800 --> 00:09:04,710
yeah so we we made so hit their mail

237
00:09:13,010 --> 00:09:09,810
there too yeah exactly so so that was a

238
00:09:17,000 --> 00:09:13,020

little odd but but we didn't think too

239

00:09:18,740 --> 00:09:17,010

much of it the but when we found a few

240

00:09:21,470 --> 00:09:18,750

more of these objects a lot of them were

241

00:09:25,940 --> 00:09:21,480

very far from their from their host

242

00:09:27,800 --> 00:09:25,950

galaxies and that was odd and we had to

243

00:09:30,410 --> 00:09:27,810

and we had to you know think about how

244

00:09:31,880 --> 00:09:30,420

they could possibly be that far away and

245

00:09:33,920 --> 00:09:31,890

there are a bunch of options just you

246

00:09:37,580 --> 00:09:33,930

know off the top of your head one of

247

00:09:40,010 --> 00:09:37,590

which is that there could just be a star

248

00:09:41,930 --> 00:09:40,020

that far out there that's kind of

249

00:09:43,880 --> 00:09:41,940

unlikely when you start getting a whole

250

00:09:45,470 --> 00:09:43,890

bunch of these objects because if you

251

00:09:48,260 --> 00:09:45,480

think that the stars that are exploding

252

00:09:50,630 --> 00:09:48,270

are like most stars in the galaxies then

253

00:09:52,280 --> 00:09:50,640

the supernova should kind of trace the

254

00:09:54,140 --> 00:09:52,290

light they should trace where the stars

255

00:09:56,780 --> 00:09:54,150

are if they're just I don't understand I

256

00:09:59,450 --> 00:09:56,790

don't understand that what trace them so

257

00:10:01,670 --> 00:09:59,460

you should have many more supernovae

258

00:10:03,710 --> 00:10:01,680

near the Centers of galaxies or you know

259

00:10:05,480 --> 00:10:03,720

that are spread out over the disk of the

260

00:10:06,920 --> 00:10:05,490

galaxy or anything like that because

261

00:10:09,440 --> 00:10:06,930

that's where the stars are in that

262

00:10:11,210 --> 00:10:09,450

galaxy and so if you found one thing

263

00:10:12,710 --> 00:10:11,220

that was really far away then you might

264

00:10:14,780 --> 00:10:12,720

say all right well you know that just

265

00:10:16,790 --> 00:10:14,790

happened be that one weird star that

266

00:10:18,620 --> 00:10:16,800

exploded but when you see a bunch of

267

00:10:21,680 --> 00:10:18,630

them that are very far away then that

268

00:10:23,360 --> 00:10:21,690

becomes very unlikely in the same sense

269

00:10:25,550 --> 00:10:23,370

that you know if you see one guy 10

270

00:10:26,900 --> 00:10:25,560

miles out of town and he's very well

271

00:10:30,110 --> 00:10:26,910

maybe he's just like going for a walk

272

00:10:33,050 --> 00:10:30,120

and he went for a really long walk but

273

00:10:35,720 --> 00:10:33,060

if you if you saw 50 people outside of

274

00:10:37,670 --> 00:10:35,730

town maybe even scatter all around then

275

00:10:39,620 --> 00:10:37,680

you start to think you know there might

276

00:10:43,010 --> 00:10:39,630

be a reason why people are out that far

277

00:10:46,160 --> 00:10:43,020

and it's not just sort of random and so

278

00:10:47,930 --> 00:10:46,170

so another possibility maybe I just want

279

00:10:49,910 --> 00:10:47,940

to start a communist out of town on well

280

00:10:53,420 --> 00:10:49,920

so exactly no that's not exactly the

281

00:10:56,470 --> 00:10:53,430

sort of thing is so it in galaxies there

282

00:10:58,640 --> 00:10:56,480

are very clumped populations of stars

283

00:11:01,190 --> 00:10:58,650

some of which we would call like a

284

00:11:03,800 --> 00:11:01,200

globular cluster which is a collection

285

00:11:07,940 --> 00:11:03,810

of stars in that galaxy but they are

286

00:11:09,470 --> 00:11:07,950

kind of self-gravitating they though

287

00:11:12,950 --> 00:11:09,480

we're gonna record those stars will

288

00:11:15,260 --> 00:11:12,960

orbit around some common center and and

289

00:11:19,340 --> 00:11:15,270

then that whole cluster will orbit the

290

00:11:21,350 --> 00:11:19,350

galaxies together and in that same sense

291

00:11:23,600 --> 00:11:21,360

you can have sort of a commune around

292

00:11:25,490 --> 00:11:23,610

some small town or maybe a suburb for a

293

00:11:28,670 --> 00:11:25,500

very large town that kind of thing um

294

00:11:31,550 --> 00:11:28,680

and so that was one real possibility

295

00:11:34,610 --> 00:11:31,560

because globular clusters tend to have a

296

00:11:37,280 --> 00:11:34,620

more extended distribution than just the

297

00:11:40,610 --> 00:11:37,290

normal stars and then similarly just

298

00:11:42,080 --> 00:11:40,620

like how there are satellite galaxies to

299

00:11:44,180 --> 00:11:42,090

the Milky Way like the Large Magellanic

300

00:11:47,540 --> 00:11:44,190

Cloud the small member I didn't even

301
00:11:48,860 --> 00:11:47,550
smaller dwarf galaxies it could be the

302
00:11:52,240 --> 00:11:48,870
case that there's something like that

303
00:11:54,530 --> 00:11:52,250
and that also has a very extended

304
00:11:56,810 --> 00:11:54,540
distribution in that there they can to

305
00:11:59,390 --> 00:11:56,820
be further out than this than the stars

306
00:12:00,980 --> 00:11:59,400
that compose the galaxies okay so these

307
00:12:04,490 --> 00:12:00,990
are these are things that are I was

308
00:12:06,410 --> 00:12:04,500
gonna comment here so so a fundamental

309
00:12:10,190 --> 00:12:06,420
to this is that we already know that

310
00:12:14,780 --> 00:12:10,200
supernovae are stars yes we don't expect

311
00:12:16,820 --> 00:12:14,790
that stars just form an ice in isolation

312
00:12:19,070 --> 00:12:16,830
there we don't have any evidence that

313
00:12:21,560 --> 00:12:19,080

there are these isolated clumps of not

314

00:12:23,360 --> 00:12:21,570

too often hydrogen gas and stuff that

315

00:12:26,210 --> 00:12:23,370

just collapsed this makes one star and

316

00:12:28,370 --> 00:12:26,220

it becomes a supernova wait so the idea

317

00:12:30,410 --> 00:12:28,380

is a supernova which is a star has to

318

00:12:32,270 --> 00:12:30,420

come from a population center where

319

00:12:34,070 --> 00:12:32,280

there are other stars because that's how

320

00:12:35,930 --> 00:12:34,080

stars form and we know this we have

321

00:12:36,710 --> 00:12:35,940

evidence across the universe that's how

322

00:12:39,530 --> 00:12:36,720

this that's right

323

00:12:41,480 --> 00:12:39,540

that's that's that's right all the other

324

00:12:48,710 --> 00:12:41,490

supernovae are associated and just as we

325

00:12:51,440 --> 00:12:48,720

expect exactly it's absolutely right

326

00:12:54,740 --> 00:12:51,450

that all other kinds of supernovae they

327

00:12:57,260 --> 00:12:54,750

they track where the stars should be and

328

00:13:00,070 --> 00:12:57,270

this one type they were out in the

329

00:13:03,290 --> 00:13:00,080

middle of nowhere we didn't know why and

330

00:13:04,670 --> 00:13:03,300

and so those those were those were some

331

00:13:06,940 --> 00:13:04,680

scenarios that I put out there but then

332

00:13:09,410 --> 00:13:06,950

there's another scenario and that's that

333

00:13:11,840 --> 00:13:09,420

you know like just like this guy who

334

00:13:13,730 --> 00:13:11,850

might be ten miles out of town walking

335

00:13:16,370 --> 00:13:13,740

on his own he doesn't live there

336

00:13:17,510 --> 00:13:16,380

necessarily maybe he does live in some

337

00:13:19,250 --> 00:13:17,520

little commune or something like that

338

00:13:21,710 --> 00:13:19,260

but another another possibility is that

339

00:13:24,319 --> 00:13:21,720

he lives in the town and he just walked

340

00:13:27,590 --> 00:13:24,329

miles that can happen with stars two

341

00:13:31,040 --> 00:13:27,600

stars can be born somewhere in a galaxy

342

00:13:32,689 --> 00:13:31,050

and then they can they can move very far

343

00:13:34,960 --> 00:13:32,699

from where they were born and under the

344

00:13:37,759 --> 00:13:34,970

certain conditions that we'll talk about

345

00:13:38,990 --> 00:13:37,769

you can have a star move very far away

346

00:13:42,079 --> 00:13:39,000

from the galaxy in fact you can have

347

00:13:43,720 --> 00:13:42,089

stars that that are kicked out of their

348

00:13:46,100 --> 00:13:43,730

galaxies they end up actually

349

00:13:47,929 --> 00:13:46,110

gravitationally unbound from their

350

00:13:49,999 --> 00:13:47,939

galaxies and so that's another

351
00:13:51,740 --> 00:13:50,009
possibility so were these I mean where

352
00:13:56,960 --> 00:13:51,750
they gravitationally unbound these

353
00:14:01,730 --> 00:13:56,970
supernovae well so I would say you know

354
00:14:04,699 --> 00:14:01,740
um so too we so a few years ago we had

355
00:14:07,040 --> 00:14:04,709
these handful of different possibilities

356
00:14:09,110 --> 00:14:07,050
and there was some clues that things

357
00:14:11,139 --> 00:14:09,120
weren't really making sense because

358
00:14:14,329 --> 00:14:11,149
using Hubble data and some other data

359
00:14:16,069 --> 00:14:14,339
other groups they looked at the

360
00:14:19,670 --> 00:14:16,079
positions of the supernovae and they

361
00:14:21,650 --> 00:14:19,680
took really really deep images of the

362
00:14:24,559 --> 00:14:21,660
spots where the supernova exploded and

363
00:14:27,259 --> 00:14:24,569

if if you expected there to be some

364

00:14:28,939 --> 00:14:27,269

little dwarf galaxies or globular

365

00:14:31,309 --> 00:14:28,949

clusters with like that you would have

366

00:14:32,889 --> 00:14:31,319

probably detected it in these these

367

00:14:35,600 --> 00:14:32,899

images and they didn't detect anything

368

00:14:37,699 --> 00:14:35,610

so there really was nothing there there

369

00:14:39,530 --> 00:14:37,709

are no stars there that's like literally

370

00:14:41,480 --> 00:14:39,540

a star out on its own now they're alone

371

00:14:43,490 --> 00:14:41,490

nowhere right so you know again if

372

00:14:45,949 --> 00:14:43,500

you're if we take this analogy of the

373

00:14:47,389 --> 00:14:45,959

guy walking ten miles out of town if you

374

00:14:48,499 --> 00:14:47,399

just saw him on the side of the road you

375

00:14:50,540 --> 00:14:48,509

wouldn't really know where he came from

376

00:14:52,819 --> 00:14:50,550

but then if you if you had an aerial

377

00:14:54,619 --> 00:14:52,829

image and you didn't see any other

378

00:14:56,480 --> 00:14:54,629

people around you didn't see any you

379

00:14:58,369 --> 00:14:56,490

know little buildings or something then

380

00:14:59,840 --> 00:14:58,379

you would say well he probably doesn't

381

00:15:03,710 --> 00:14:59,850

live out there he probably lives in town

382

00:15:05,210 --> 00:15:03,720

even he got there somehow so so that was

383

00:15:07,220 --> 00:15:05,220

the question is like so where were they

384

00:15:10,850 --> 00:15:07,230

born how did they get there

385

00:15:13,519 --> 00:15:10,860

and and so I this was something that I

386

00:15:15,139 --> 00:15:13,529

just like for a while it was stuck in my

387

00:15:17,059 --> 00:15:15,149

head I didn't know exactly what to do so

388

00:15:19,819 --> 00:15:17,069

I started looking at some of the

389

00:15:21,319 --> 00:15:19,829

archival data and there were a few

390

00:15:26,869 --> 00:15:21,329

things that that kind of popped out

391

00:15:29,269 --> 00:15:26,879

right away the first is is that there

392

00:15:30,829 --> 00:15:29,279

are some of these supernovae where we

393

00:15:32,480 --> 00:15:30,839

see them very very far from their

394

00:15:34,009 --> 00:15:32,490

galaxies and then there are others where

395

00:15:35,300 --> 00:15:34,019

they look like they're on top of the

396

00:15:37,129 --> 00:15:35,310

galaxy but

397

00:15:40,129 --> 00:15:37,139

of course we don't really know how close

398

00:15:41,749 --> 00:15:40,139

they are to that galaxy because we only

399

00:15:46,400 --> 00:15:41,759

have a two-dimensional picture of the

400

00:15:47,720 --> 00:15:46,410

sky right because because the distances

401
00:15:49,819 --> 00:15:47,730
are so large it just looks like

402
00:15:52,910 --> 00:15:49,829
everything's on top of each other and so

403
00:15:55,970 --> 00:15:52,920
you can have well those red ships I mean

404
00:15:58,670 --> 00:15:55,980
rupture exactly so so just from an image

405
00:16:01,489 --> 00:15:58,680
alone you can you can have a galaxy and

406
00:16:03,619 --> 00:16:01,499
a star this that's very close by or you

407
00:16:05,629 --> 00:16:03,629
can have a galaxy and a star that's very

408
00:16:07,670 --> 00:16:05,639
far away and they can still if I can't

409
00:16:11,090 --> 00:16:07,680
line them up they can be on top of each

410
00:16:13,040 --> 00:16:11,100
other and so so the images themselves

411
00:16:14,989 --> 00:16:13,050
are not enough information you need this

412
00:16:16,999 --> 00:16:14,999
third dimension and we get that through

413
00:16:23,660 --> 00:16:17,009

red chips oh sorry I didn't mean to

414

00:16:26,780 --> 00:16:23,670

steal your punchline oh you I just

415

00:16:29,179 --> 00:16:26,790

wanted to point out that in your analogy

416

00:16:31,999 --> 00:16:29,189

of the guy walking around away from town

417

00:16:34,249 --> 00:16:32,009

centre these objects are so far away we

418

00:16:36,980 --> 00:16:34,259

can't measure that transverse great

419

00:16:39,530 --> 00:16:36,990

motion so if Ryan could measure it going

420

00:16:40,939 --> 00:16:39,540

zoom that would have been a clue but you

421

00:16:43,280 --> 00:16:40,949

can't do that because it's too far away

422

00:16:46,819 --> 00:16:43,290

and you know it's a little tiny motion

423

00:16:49,910 --> 00:16:46,829

so right so so instead but we can

424

00:16:54,530 --> 00:16:49,920

measure the velocity along our line of

425

00:16:56,829 --> 00:16:54,540

sight and and and so I looked at those

426
00:17:00,410 --> 00:16:56,839
velocities for the different objects and

427
00:17:02,449 --> 00:17:00,420
what I found was was not expected for me

428
00:17:05,659 --> 00:17:02,459
so the objects that were really really

429
00:17:08,510 --> 00:17:05,669
far away from their galaxies it looked

430
00:17:11,389 --> 00:17:08,520
like they weren't moving at all in you

431
00:17:12,860 --> 00:17:11,399
know towards us or away from us but the

432
00:17:15,199 --> 00:17:12,870
ones that were on top of their galaxies

433
00:17:16,909 --> 00:17:15,209
they looked like they were mostly moving

434
00:17:19,220 --> 00:17:16,919
towards us some of them were moving away

435
00:17:21,049 --> 00:17:19,230
from us but mostly moving towards us and

436
00:17:23,029 --> 00:17:21,059
at very high speeds and we're still

437
00:17:26,419 --> 00:17:23,039
talking about these 13 right he's this

438
00:17:30,590 --> 00:17:26,429

group of 30 the 13 the 13 calcium-rich

439

00:17:33,020 --> 00:17:30,600

asleep unity okay and so so that that

440

00:17:36,080 --> 00:17:33,030

immediately tells you because there's

441

00:17:39,260 --> 00:17:36,090

this this relationship between how far

442

00:17:42,049 --> 00:17:39,270

away it appears this supernova appears

443

00:17:43,970 --> 00:17:42,059

to be from its galaxy and the velocity

444

00:17:45,230 --> 00:17:43,980

towards us or away from us that tells

445

00:17:47,840 --> 00:17:45,240

you immediately that it has something to

446

00:17:48,950 --> 00:17:47,850

do with their position it's not just

447

00:17:51,080 --> 00:17:48,960

something that had to do with

448

00:17:52,669 --> 00:17:51,090

the explosion or something like that if

449

00:17:54,110 --> 00:17:52,679

that were the case then you would expect

450

00:17:55,820 --> 00:17:54,120

some of the ones that are far away to

451
00:17:58,490 --> 00:17:55,830
look like they're coming very fast

452
00:18:00,769 --> 00:17:58,500
towards us or away from us and then some

453
00:18:02,810 --> 00:18:00,779
then the ones that are close in maybe

454
00:18:04,430 --> 00:18:02,820
just the same kind of distribution of

455
00:18:09,950 --> 00:18:04,440
velocities and we saw something very

456
00:18:11,750 --> 00:18:09,960
different and the the next step up that

457
00:18:14,419 --> 00:18:11,760
you would say is alright if we can

458
00:18:16,070 --> 00:18:14,429
measure these velocities and a lot of

459
00:18:17,630 --> 00:18:16,080
these objects that are right on top

460
00:18:20,149 --> 00:18:17,640
they're galaxies they're they're moving

461
00:18:21,740 --> 00:18:20,159
very quickly towards us and then we see

462
00:18:23,870 --> 00:18:21,750
these other objects that aren't moving

463
00:18:26,990 --> 00:18:23,880

towards us or away from us but they're

464

00:18:28,820 --> 00:18:27,000

really far away the the thing you you

465

00:18:31,760 --> 00:18:28,830

have to make in your head is here say

466

00:18:33,350 --> 00:18:31,770

alright I can move this velocity and

467

00:18:35,180 --> 00:18:33,360

think about it if they were moving in

468

00:18:37,519 --> 00:18:35,190

another direction if I just saw it from

469

00:18:39,139 --> 00:18:37,529

a different angle then the velocity

470

00:18:40,840 --> 00:18:39,149

would be going out in the plane of the

471

00:18:43,310 --> 00:18:40,850

sky but if it were moving very quickly

472

00:18:46,070 --> 00:18:43,320

for a long time then it would be very

473

00:18:48,399 --> 00:18:46,080

far away and so one of the keys is that

474

00:18:50,690 --> 00:18:48,409

the the velocities were incredibly high

475

00:18:55,100 --> 00:18:50,700

one to two thousand kilometers per

476

00:18:57,560 --> 00:18:55,110

second which is is sort of around 10

477

00:19:00,830 --> 00:18:57,570

times higher than the velocities for

478

00:19:01,940 --> 00:19:00,840

most stars in a galaxy I was gonna I was

479

00:19:03,590 --> 00:19:01,950

gonna ask you about that it's not

480

00:19:05,690 --> 00:19:03,600

characteristic of the Stars within that

481

00:19:09,500 --> 00:19:05,700

galaxy then yeah it's it's much higher

482

00:19:12,220 --> 00:19:09,510

and but it is it is similar to some

483

00:19:15,590 --> 00:19:12,230

stars very few stars that we've detected

484

00:19:18,500 --> 00:19:15,600

in the Milky Way and we call these

485

00:19:21,380 --> 00:19:18,510

hypervelocity stars that have velocities

486

00:19:23,779 --> 00:19:21,390

so high that they can escape the

487

00:19:26,029 --> 00:19:23,789

gravitational pull of the Milky Way in

488

00:19:28,340 --> 00:19:26,039

the same sense that when we shoot off

489

00:19:31,070 --> 00:19:28,350

rockets if you if you get the rocket

490

00:19:32,750 --> 00:19:31,080

moving fast enough then it can escape

491

00:19:35,840 --> 00:19:32,760

the gravitational pull of the earth and

492

00:19:37,880 --> 00:19:35,850

go off into deep space in the same sense

493

00:19:39,590 --> 00:19:37,890

if you can get a star moving fast enough

494

00:19:41,960 --> 00:19:39,600

it can escape the gravitational pull of

495

00:19:45,590 --> 00:19:41,970

its own galaxy and go off into deep

496

00:19:48,110 --> 00:19:45,600

space so so something was was

497

00:19:50,269 --> 00:19:48,120

accelerating these stars exactly so

498

00:19:53,330 --> 00:19:50,279

that's that's the story is that there is

499

00:19:56,510 --> 00:19:53,340

something that that from the the galaxy

500

00:19:59,120 --> 00:19:56,520

it was making some of these objects go

501
00:20:02,820 --> 00:19:59,130
very very quickly towards us and then we

502
00:20:04,260 --> 00:20:02,830
saw the velocity as being very high

503
00:20:06,480 --> 00:20:04,270
and then occasionally they'll go off

504
00:20:09,570 --> 00:20:06,490
just you know in a different direction

505
00:20:12,810 --> 00:20:09,580
it's just our art perspective and there

506
00:20:14,250 --> 00:20:12,820
it would go very very far away in the

507
00:20:16,050 --> 00:20:14,260
plane of the sky and when you take the

508
00:20:17,430 --> 00:20:16,060
snapshot when it finally explodes and

509
00:20:19,560 --> 00:20:17,440
you see where it is because it was

510
00:20:21,720 --> 00:20:19,570
moving so quickly for some amount of

511
00:20:25,980 --> 00:20:21,730
time then you would say all right it has

512
00:20:28,950 --> 00:20:25,990
to be very far away so so that that kind

513
00:20:30,780 --> 00:20:28,960

of explains this velocity effect and the

514

00:20:32,940 --> 00:20:30,790

distances but then you still have this

515

00:20:37,350 --> 00:20:32,950

question of well exactly how did you

516

00:20:41,070 --> 00:20:37,360

accelerate those stars and all I presume

517

00:20:42,510 --> 00:20:41,080

you're gonna tell us yes so to get back

518

00:20:46,070 --> 00:20:42,520

to the Milky Way where we have these

519

00:20:48,960 --> 00:20:46,080

hypervelocity stars there we have a very

520

00:20:50,190 --> 00:20:48,970

good theory for what's happening when we

521

00:20:53,310 --> 00:20:50,200

detect these stars that are moving in

522

00:20:56,030 --> 00:20:53,320

over a thousand kilometres per second we

523

00:20:58,350 --> 00:20:56,040

can we can trace their three-dimensional

524

00:21:01,140 --> 00:20:58,360

velocity vector because they're close

525

00:21:02,880 --> 00:21:01,150

enough where you can actually see the

526

00:21:06,020 --> 00:21:02,890

motion in the plane of the sky and

527

00:21:08,490 --> 00:21:06,030

measure the velocity with a redshift and

528

00:21:09,420 --> 00:21:08,500

when you do that you can you can say

529

00:21:11,730 --> 00:21:09,430

where did it come from

530

00:21:16,530 --> 00:21:11,740

and these stars come from the very very

531

00:21:18,150 --> 00:21:16,540

center of our galaxy and and what's at

532

00:21:22,280 --> 00:21:18,160

the very very center of our galaxy a

533

00:21:25,170 --> 00:21:22,290

supermassive black hole and and so

534

00:21:27,420 --> 00:21:25,180

there's there's a very clear theory of

535

00:21:31,230 --> 00:21:27,430

what what happens for these stars these

536

00:21:33,540 --> 00:21:31,240

stars start off in in a binary system so

537

00:21:36,930 --> 00:21:33,550

two stars that are orbiting each other

538

00:21:39,660 --> 00:21:36,940

and there's somewhere near this the

539

00:21:41,070 --> 00:21:39,670

supermassive black hole and some you

540

00:21:43,230 --> 00:21:41,080

know they most of the time they'll just

541

00:21:44,370 --> 00:21:43,240

be going in some normal orbit and even

542

00:21:46,260 --> 00:21:44,380

though they're close to that black hole

543

00:21:48,360 --> 00:21:46,270

they'll just continue in their orbit and

544

00:21:49,710 --> 00:21:48,370

nothing big ol now you're still talking

545

00:21:51,390 --> 00:21:49,720

about stars within our Milky Way right

546

00:21:54,240 --> 00:21:51,400

they die Milky Way very good we're still

547

00:21:57,180 --> 00:21:54,250

there but occasionally there will be

548

00:21:58,500 --> 00:21:57,190

some interaction with some other star or

549

00:22:01,260 --> 00:21:58,510

something like that that'll knock it

550

00:22:04,770 --> 00:22:01,270

slightly off of its orbit and it'll get

551
00:22:07,680 --> 00:22:04,780
so close to the to the black hole where

552
00:22:11,130 --> 00:22:07,690
what happens is the black hole will

553
00:22:14,190 --> 00:22:11,140
break up this pair one of them will be

554
00:22:16,480 --> 00:22:14,200
captured by the black hole and then the

555
00:22:19,450 --> 00:22:16,490
other one because it

556
00:22:21,760 --> 00:22:19,460
longer has this this companion plus its

557
00:22:24,490 --> 00:22:21,770
being you know whipped around this this

558
00:22:26,860 --> 00:22:24,500
black hole it gets slingshot it out its

559
00:22:30,070 --> 00:22:26,870
accelerated to one or two thousand

560
00:22:32,890 --> 00:22:30,080
kilometers per second and it just zooms

561
00:22:35,050 --> 00:22:32,900
away and it goes fast enough where you

562
00:22:38,020 --> 00:22:35,060
can escape the the pole of the entire

563
00:22:39,730 --> 00:22:38,030

galaxy and then this other star that

564

00:22:43,150 --> 00:22:39,740

what you know so there were the two

565

00:22:45,220 --> 00:22:43,160

stars in the pair one is zooming off you

566

00:22:46,960 --> 00:22:45,230

know incredibly high speeds and then the

567

00:22:49,360 --> 00:22:46,970

other one is captured by the black hole

568

00:22:50,890 --> 00:22:49,370

okay so these are star interactions with

569

00:22:52,660 --> 00:22:50,900

a single supermassive black hole within

570

00:22:54,880 --> 00:22:52,670

our within our Milky Way galaxy what's

571

00:22:56,710 --> 00:22:54,890

so special why you why are you careful

572

00:22:59,350 --> 00:22:56,720

to point out a binary star couldn't just

573

00:23:02,440 --> 00:22:59,360

any star happen to be on the wrong right

574

00:23:05,800 --> 00:23:02,450

so it's wrong time so it turns out that

575

00:23:08,950 --> 00:23:05,810

these super novae they we are pretty

576
00:23:09,790 --> 00:23:08,960
sure come from binary there's calcium

577
00:23:11,230 --> 00:23:09,800
rich ones

578
00:23:13,540 --> 00:23:11,240
the calcium richer supernova we are

579
00:23:15,550 --> 00:23:13,550
pretty sure come from a binary system

580
00:23:18,840 --> 00:23:15,560
and that's a binary system when they

581
00:23:21,490 --> 00:23:18,850
explode so you have to have two stars

582
00:23:23,880 --> 00:23:21,500
that that are in this system when they

583
00:23:27,220 --> 00:23:23,890
explode and the reason for that is that

584
00:23:29,260 --> 00:23:27,230
although single stars can explode a

585
00:23:31,390 --> 00:23:29,270
supernova then we think that they have

586
00:23:35,920 --> 00:23:31,400
to be very very massive stars right good

587
00:23:38,620 --> 00:23:35,930
okay and if you want it to a low-mass

588
00:23:41,260 --> 00:23:38,630

star to explode what you need is a white

589

00:23:44,710 --> 00:23:41,270

dwarf or something like that probably

590

00:23:47,740 --> 00:23:44,720

that it accretes material from a binary

591

00:23:49,180 --> 00:23:47,750

companion so material from from one

592

00:23:52,410 --> 00:23:49,190

other stars being dumped on to this

593

00:23:55,090 --> 00:23:52,420

white dwarf until something bad happens

594

00:23:57,040 --> 00:23:55,100

enough fuel and then it just it just

595

00:23:58,150 --> 00:23:57,050

will go through some explosion okay I

596

00:23:59,560 --> 00:23:58,160

want to stick with this idea for a

597

00:24:00,820 --> 00:23:59,570

minute because most supernova you

598

00:24:03,160 --> 00:24:00,830

already said and this is only most of us

599

00:24:04,990 --> 00:24:03,170

know about already occur with very very

600

00:24:06,400 --> 00:24:05,000

massive stars they're they're their

601
00:24:08,170 --> 00:24:06,410
course collapse there's different kinds

602
00:24:09,970 --> 00:24:08,180
of supernova like you point out but this

603
00:24:12,490 --> 00:24:09,980
one that you're addressing here these

604
00:24:14,530 --> 00:24:12,500
calcium-rich ones probably have because

605
00:24:16,720 --> 00:24:14,540
of the nature of the like because you

606
00:24:18,730 --> 00:24:16,730
can categorize these things yes are

607
00:24:20,740 --> 00:24:18,740
probably part of the binary and probably

608
00:24:22,300 --> 00:24:20,750
one of the companions is a white dwarf

609
00:24:22,570 --> 00:24:22,310
that somehow messing around with this

610
00:24:26,230 --> 00:24:22,580
one

611
00:24:28,630 --> 00:24:26,240
and so how low mass then cover star can

612
00:24:30,690 --> 00:24:28,640
you make exploding this way how how far

613
00:24:32,550 --> 00:24:30,700

down so we don't we

614

00:24:35,010 --> 00:24:32,560

no exactly but I would I would guess

615

00:24:37,080 --> 00:24:35,020

somewhere if you really wanted it to be

616

00:24:39,570 --> 00:24:37,090

the lowest it'd be about half the mass

617

00:24:43,860 --> 00:24:39,580

of the Sun really you can make a star

618

00:24:45,960 --> 00:24:43,870

half the mass of our Sun explode I would

619

00:24:47,400 --> 00:24:45,970

say you know alright so certainly things

620

00:24:49,650 --> 00:24:47,410

that are around the mass of our Sun we

621

00:24:51,930 --> 00:24:49,660

can make explode and I think if if you

622

00:24:54,540 --> 00:24:51,940

really wanted to in sort of the ways

623

00:24:57,180 --> 00:24:54,550

that we're talking about here it would

624

00:24:59,100 --> 00:24:57,190

explode at maybe about half of the mass

625

00:25:00,630 --> 00:24:59,110

this time wow that's amazing I learned

626
00:25:02,790 --> 00:25:00,640
to make two new things here today that's

627
00:25:03,840 --> 00:25:02,800
great okay so before we go to the next

628
00:25:05,490 --> 00:25:03,850
step which I know you're gonna talk

629
00:25:07,470 --> 00:25:05,500
about merging and anymore this is you've

630
00:25:09,210 --> 00:25:07,480
just described star interactions with a

631
00:25:11,430 --> 00:25:09,220
single black hole at the center of the

632
00:25:12,840 --> 00:25:11,440
or one like it I have I have a question

633
00:25:14,550 --> 00:25:12,850
here from Adams synergy which is a

634
00:25:16,890 --> 00:25:14,560
little relevant to what we just the

635
00:25:18,540 --> 00:25:16,900
topic we just left and he says if the

636
00:25:20,430 --> 00:25:18,550
stars travel at around five million

637
00:25:21,960 --> 00:25:20,440
miles an hour after ejection which was

638
00:25:24,900 --> 00:25:21,970

the high speed hyper stars you were

639

00:25:26,850 --> 00:25:24,910

talking about is the supernova ejecta

640

00:25:28,440 --> 00:25:26,860

traveling at even greater hyper velocity

641

00:25:31,680 --> 00:25:28,450

so you were you were looking at these

642

00:25:33,090 --> 00:25:31,690

these far-flung stars exploding what

643

00:25:37,110 --> 00:25:33,100

about is the ejecta now moving even

644

00:25:40,020 --> 00:25:37,120

faster yes so if if if we look at

645

00:25:42,240 --> 00:25:40,030

typical supernova they're there their

646

00:25:44,930 --> 00:25:42,250

velocities are definitely faster than

647

00:25:48,510 --> 00:25:44,940

typical velocities for supernovae or

648

00:25:50,220 --> 00:25:48,520

something like five to ten thousand

649

00:25:52,410 --> 00:25:50,230

kilometers per second so that that would

650

00:25:55,740 --> 00:25:52,420

be you know two to five times faster

651
00:25:57,390 --> 00:25:55,750
than the motion of these stars that's

652
00:25:59,610 --> 00:25:57,400
definitely true for these though they

653
00:26:01,560 --> 00:25:59,620
these calcium-rich supernovae are low

654
00:26:03,180 --> 00:26:01,570
energy supernovae their lower energy

655
00:26:05,400 --> 00:26:03,190
than the normal ones and their

656
00:26:08,250 --> 00:26:05,410
velocities tend to be lower but still

657
00:26:10,980 --> 00:26:08,260
higher than this one or two thousand

658
00:26:15,450 --> 00:26:10,990
kilometer per second a kick that it

659
00:26:18,060 --> 00:26:15,460
gets uncommon but we can still account

660
00:26:21,180 --> 00:26:18,070
for for the the difference here and the

661
00:26:22,980 --> 00:26:21,190
reason is eventually when when you have

662
00:26:25,650 --> 00:26:22,990
a supernova when it starts off it's very

663
00:26:29,280 --> 00:26:25,660

hot it's actually very similar to a star

664

00:26:31,350 --> 00:26:29,290

in that it has a photosphere and that

665

00:26:34,050 --> 00:26:31,360

just that just means that you can't see

666

00:26:36,180 --> 00:26:34,060

all the way through it that there's your

667

00:26:37,560 --> 00:26:36,190

son has a photosphere exactly a son has

668

00:26:39,540 --> 00:26:37,570

a photosphere and so that what that

669

00:26:41,640 --> 00:26:39,550

means is that when you look at the Sun

670

00:26:44,280 --> 00:26:41,650

you can't see the other side but

671

00:26:46,110 --> 00:26:44,290

eventually with a supernova because it's

672

00:26:48,090 --> 00:26:46,120

if the material is ejected in its

673

00:26:50,730 --> 00:26:48,100

expanding outward eventually that

674

00:26:52,080 --> 00:26:50,740

material becomes low enough density that

675

00:26:54,480 --> 00:26:52,090

you can see all the way through it and

676
00:26:56,909 --> 00:26:54,490
this is when we see a supernova remnant

677
00:26:59,549 --> 00:26:56,919
we can see all the way through it okay

678
00:27:01,409 --> 00:26:59,559
and in well before the the supernova

679
00:27:03,750 --> 00:27:01,419
remnant stage even you can see all the

680
00:27:07,650 --> 00:27:03,760
way through a supernova and so you can

681
00:27:09,330 --> 00:27:07,660
measure effectively the velocity of all

682
00:27:13,350 --> 00:27:09,340
of the material along your line of sight

683
00:27:15,600 --> 00:27:13,360
and so it doesn't necessarily matter how

684
00:27:17,640 --> 00:27:15,610
broad of a distribution you have a

685
00:27:20,610 --> 00:27:17,650
velocity is how fast the fastest

686
00:27:23,220 --> 00:27:20,620
material is moving because you can still

687
00:27:25,520 --> 00:27:23,230
as long as there is some sort of general

688
00:27:28,530 --> 00:27:25,530

peak you can measure what the average

689

00:27:30,690 --> 00:27:28,540

velocity is so you can measure the

690

00:27:35,970 --> 00:27:30,700

average velocity of all of the material

691

00:27:38,220 --> 00:27:35,980

and and that can be a fraction of the of

692

00:27:40,590 --> 00:27:38,230

the of the highest philosophies for the

693

00:27:42,030 --> 00:27:40,600

it occur the supernova explosion and you

694

00:27:45,330 --> 00:27:42,040

can still make a good measurement of

695

00:27:47,570 --> 00:27:45,340

that and that's what we did okay well so

696

00:27:50,610 --> 00:27:47,580

the the the you said that they were low

697

00:27:52,680 --> 00:27:50,620

intensity or low energy super these

698

00:27:54,210 --> 00:27:52,690

calcium-rich lenses is that due

699

00:27:55,740 --> 00:27:54,220

primarily the fact of these stars are

700

00:27:59,159 --> 00:27:55,750

pretty low mass as well there just isn't

701
00:28:00,990 --> 00:27:59,169
that much material to yes to really go

702
00:28:03,810 --> 00:28:01,000
so that's the theory

703
00:28:07,650 --> 00:28:03,820
I mean without getting into too much

704
00:28:09,270 --> 00:28:07,660
detail that when you when you burn a

705
00:28:11,669 --> 00:28:09,280
material if you if you're if you're

706
00:28:14,220 --> 00:28:11,679
undergoing nuclear fusion from light

707
00:28:16,919 --> 00:28:14,230
elements up to heavier elements you gain

708
00:28:21,409 --> 00:28:16,929
energy from those from those fusion

709
00:28:25,470 --> 00:28:21,419
reactions until you get to around iron

710
00:28:28,350 --> 00:28:25,480
and the reason for that is just a very

711
00:28:32,070 --> 00:28:28,360
stable nucleus that's relatively dense

712
00:28:33,480 --> 00:28:32,080
and when you go past the if you go to

713
00:28:35,970 --> 00:28:33,490

the elements that are much heavier than

714

00:28:39,150 --> 00:28:35,980

than iron if you go to things like gold

715

00:28:43,049 --> 00:28:39,160

or uranium or anything like that you

716

00:28:47,159 --> 00:28:43,059

have to add energy to to make those

717

00:28:48,960 --> 00:28:47,169

elements and so as a result because you

718

00:28:51,030 --> 00:28:48,970

don't want to necessarily steal that

719

00:28:52,350 --> 00:28:51,040

energy you just sort of go until you

720

00:28:54,780 --> 00:28:52,360

run out of energy

721

00:28:56,669 --> 00:28:54,790

most supernova explosions or at least

722

00:28:58,169 --> 00:28:56,679

the ones that come from white dwarfs

723

00:29:01,889 --> 00:28:58,179

they produce a lot of

724

00:29:06,180 --> 00:29:01,899

a lot of elements near iron though iron

725

00:29:09,779 --> 00:29:06,190

cobalt nickel things like that and and

726

00:29:12,210 --> 00:29:09,789

and the these these calcium rich super

727

00:29:14,899 --> 00:29:12,220

novae however they have a lot of calcium

728

00:29:19,169 --> 00:29:14,909

and calcium is much lighter than iron

729

00:29:21,810 --> 00:29:19,179

and and so what that means is you know

730

00:29:25,470 --> 00:29:21,820

there was still the potential to to fuse

731

00:29:28,440 --> 00:29:25,480

to heavier elements and get some energy

732

00:29:31,889 --> 00:29:28,450

so something must have happened and the

733

00:29:34,200 --> 00:29:31,899

way that you you sort of stall this this

734

00:29:35,930 --> 00:29:34,210

process this fusion process this you

735

00:29:39,419 --> 00:29:35,940

have to just make it so that the overall

736

00:29:42,210 --> 00:29:39,429

explosion is very weak and very low

737

00:29:44,700 --> 00:29:42,220

energy and super effectively you can you

738

00:29:47,549 --> 00:29:44,710

can imagine doing this if you have if

739

00:29:49,220 --> 00:29:47,559

you have to just you know pure gasoline

740

00:29:52,619 --> 00:29:49,230

or something and you light it on fire

741

00:29:54,149 --> 00:29:52,629

then it'll all burn away but if you take

742

00:29:56,070 --> 00:29:54,159

gasoline and you throw a bunch of water

743

00:29:57,419 --> 00:29:56,080

in it you mix it up and then you and

744

00:29:59,399 --> 00:29:57,429

then you light it on fire maybe just the

745

00:30:00,720 --> 00:29:59,409

surface will burn and then everything

746

00:30:02,759 --> 00:30:00,730

that's mixed in with the water doesn't

747

00:30:04,409 --> 00:30:02,769

burn oh boy Ryan I just gonna say you're

748

00:30:07,440 --> 00:30:04,419

really good with analogies I really like

749

00:30:08,789 --> 00:30:07,450

your knowledge all right well good all

750

00:30:10,080 --> 00:30:08,799

right so thank you Adam that was a good

751
00:30:12,450 --> 00:30:10,090
question I appreciate your doing that

752
00:30:16,200 --> 00:30:12,460
you're asking us I want to get now to

753
00:30:19,889 --> 00:30:16,210
what the so so these these star

754
00:30:21,210 --> 00:30:19,899
interactions with normal normal a single

755
00:30:23,509 --> 00:30:21,220
supermassive black holes in the center

756
00:30:25,499 --> 00:30:23,519
of our galaxy is not what you think

757
00:30:27,029 --> 00:30:25,509
tributed to the motions of these

758
00:30:28,799 --> 00:30:27,039
supernovae why don't we get to that and

759
00:30:30,930 --> 00:30:28,809
while we do it let's go ahead and put up

760
00:30:33,539 --> 00:30:30,940
this schematic that we have in the press

761
00:30:35,519 --> 00:30:33,549
release called scenario for homeless

762
00:30:38,369 --> 00:30:35,529
supernova I think our analogy is getting

763
00:30:40,379 --> 00:30:38,379

away from us here but yeah here it is

764

00:30:41,940 --> 00:30:40,389

okay so why don't you explain what you

765

00:30:42,810 --> 00:30:41,950

think's going on with these with these

766

00:30:45,419 --> 00:30:42,820

speeds

767

00:30:48,409 --> 00:30:45,429

okay so just as a reminder career the

768

00:30:50,759 --> 00:30:48,419

Milky Way when you have these these two

769

00:30:52,980 --> 00:30:50,769

stars that come near a supermassive

770

00:30:55,409 --> 00:30:52,990

black hole then that that those two

771

00:30:57,810 --> 00:30:55,419

stars get ripped apart from each other

772

00:31:00,119 --> 00:30:57,820

one it stays behind with the black hole

773

00:31:02,159 --> 00:31:00,129

and the other one's ejected but what I

774

00:31:03,899 --> 00:31:02,169

said is for the supernova tap and you

775

00:31:06,570 --> 00:31:03,909

need two stars to begin and you need two

776

00:31:08,489 --> 00:31:06,580

stars at the time of the explosion which

777

00:31:10,560 --> 00:31:08,499

means if you're going to have another

778

00:31:12,080 --> 00:31:10,570

star ripped apart from that those other

779

00:31:14,810 --> 00:31:12,090

two stars then you need three star

780

00:31:17,029 --> 00:31:14,820

to begin with and that's just hard to do

781

00:31:18,320 --> 00:31:17,039

there aren't that many three-star

782

00:31:19,880 --> 00:31:18,330

systems that are in the right

783

00:31:23,419 --> 00:31:19,890

configuration and so if you only have a

784

00:31:25,940 --> 00:31:23,429

single black hole we don't think that

785

00:31:28,640 --> 00:31:25,950

there will be enough of these systems to

786

00:31:31,279 --> 00:31:28,650

make the super novae that we have so

787

00:31:35,090 --> 00:31:31,289

instead we come up with this we came up

788

00:31:37,070 --> 00:31:35,100

with this idea that it sounds crazier

789

00:31:40,549 --> 00:31:37,080

but it actually we think will will

790

00:31:44,950 --> 00:31:40,559

increase the the rate of these

791

00:31:48,950 --> 00:31:44,960

explosions so every once in a while a

792

00:31:50,930 --> 00:31:48,960

galaxy will be very close to another

793

00:31:56,029 --> 00:31:50,940

galaxy and gravitationally they'll come

794

00:31:58,340 --> 00:31:56,039

together and they'll merge and we have a

795

00:31:59,990 --> 00:31:58,350

video for this I think would you rather

796

00:32:02,269 --> 00:32:00,000

show that okay why don't we start with

797

00:32:04,510 --> 00:32:02,279

that and the launcher and what while I'm

798

00:32:06,950 --> 00:32:04,520

you know again in my long-winded

799

00:32:10,130 --> 00:32:06,960

explanation I'm sure we'll get to the

800

00:32:13,639 --> 00:32:10,140

details of this so if you have two if

801
00:32:15,430 --> 00:32:13,649
you have two galaxies that are that are

802
00:32:17,060 --> 00:32:15,440
close enough that they will

803
00:32:19,460 --> 00:32:17,070
gravitationally come together and this

804
00:32:21,019 --> 00:32:19,470
is something that will we will

805
00:32:23,480 --> 00:32:21,029
eventually happen to the Milky Way

806
00:32:25,250 --> 00:32:23,490
galaxy and the Andromeda galaxy they're

807
00:32:26,840 --> 00:32:25,260
on a collision course yeah this is one

808
00:32:30,289 --> 00:32:26,850
of our simulations or a frank simulation

809
00:32:31,850 --> 00:32:30,299
should show this collision and so when

810
00:32:34,310 --> 00:32:31,860
these two when these two galaxies

811
00:32:37,279 --> 00:32:34,320
combine what ends up happening

812
00:32:39,500 --> 00:32:37,289
importantly you know in addition to all

813
00:32:42,799 --> 00:32:39,510

the stars getting reconfigured and a

814

00:32:44,269 --> 00:32:42,809

bunch of gas getting spread around and

815

00:32:46,100 --> 00:32:44,279

there being these beautiful tidal tails

816

00:32:49,039 --> 00:32:46,110

and things like that

817

00:32:52,370 --> 00:32:49,049

additionally the supermassive black hole

818

00:32:55,730 --> 00:32:52,380

at at the center of each galaxy they

819

00:32:57,799 --> 00:32:55,740

come together to each each galaxy this

820

00:33:01,039 --> 00:32:57,809

is one of the highlights of what Hubble

821

00:33:03,409 --> 00:33:01,049

has done is is finding that essentially

822

00:33:05,210 --> 00:33:03,419

every single galaxy that we know of has

823

00:33:08,450 --> 00:33:05,220

a supermassive black hole at the center

824

00:33:11,090 --> 00:33:08,460

and Hubble has also shown that some

825

00:33:12,380 --> 00:33:11,100

supermassive black holes have two I'm

826

00:33:13,789 --> 00:33:12,390

sorry some galaxies have two

827

00:33:17,149 --> 00:33:13,799

supermassive black holes at their

828

00:33:18,289 --> 00:33:17,159

centers and what we think happens in

829

00:33:20,480 --> 00:33:18,299

those cases is that there were two

830

00:33:22,850 --> 00:33:20,490

galaxies that came together and merged

831

00:33:25,850 --> 00:33:22,860

and then these two supermassive black

832

00:33:29,750 --> 00:33:25,860

holes which are you

833

00:33:31,909 --> 00:33:29,760

very very massive they'll both sink to

834

00:33:33,560 --> 00:33:31,919

the center of this new galaxy and

835

00:33:35,930 --> 00:33:33,570

they'll be very close to each other and

836

00:33:38,570 --> 00:33:35,940

one day we expect them to actually merge

837

00:33:41,419 --> 00:33:38,580

together to make a single backflip but

838

00:33:50,889 --> 00:33:41,429

before that happens and now maybe we can

839

00:33:57,549 --> 00:33:55,130

good so before that happens these black

840

00:34:01,519 --> 00:33:57,559

holes that are coming close together

841

00:34:03,649 --> 00:34:01,529

they'll go first of all bill each one

842

00:34:06,320 --> 00:34:03,659

has their own little star cluster around

843

00:34:07,789 --> 00:34:06,330

them these are the stars that just like

844

00:34:09,980 --> 00:34:07,799

in our Milky Way there's a big star

845

00:34:12,950 --> 00:34:09,990

cluster around it's at the Milky Way's

846

00:34:14,690 --> 00:34:12,960

supermassive black hole and these these

847

00:34:16,190 --> 00:34:14,700

stars normally they just they'll just

848

00:34:18,280 --> 00:34:16,200

orbit around and there won't be much of

849

00:34:21,190 --> 00:34:18,290

a problem but then as these two

850

00:34:23,329 --> 00:34:21,200

supermassive black holes come together

851
00:34:26,810 --> 00:34:23,339
then all of a sudden you're you're

852
00:34:30,139 --> 00:34:26,820
taking this this reservoir of stars you

853
00:34:32,480 --> 00:34:30,149
know this this entourage of millions of

854
00:34:34,159 --> 00:34:32,490
stars and all of a sudden you're you're

855
00:34:38,329 --> 00:34:34,169
effectively throwing them at another

856
00:34:39,649 --> 00:34:38,339
supermassive black hole and in the same

857
00:34:42,139 --> 00:34:39,659
is going in Reverse because each of

858
00:34:44,570 --> 00:34:42,149
these supermassive black holes has one

859
00:34:46,550 --> 00:34:44,580
of these big star clusters so as a

860
00:34:49,520 --> 00:34:46,560
result this this process that normally

861
00:34:52,820 --> 00:34:49,530
is very rare it happens like we think

862
00:34:55,790 --> 00:34:52,830
once every 100 or thousand years where

863
00:34:58,460 --> 00:34:55,800

one of these stars gets ejected from the

864

00:35:01,940 --> 00:34:58,470

Milky Way in the cases where you have

865

00:35:05,180 --> 00:35:01,950

two supermassive black holes you can you

866

00:35:07,579 --> 00:35:05,190

can increase that rate to not not one

867

00:35:11,290 --> 00:35:07,589

per hundred years but maybe something

868

00:35:13,790 --> 00:35:11,300

like a hundred per year so it's

869

00:35:15,530 --> 00:35:13,800

significantly more just because all of a

870

00:35:20,020 --> 00:35:15,540

sudden you have this other black hole by

871

00:35:22,550 --> 00:35:20,030

all of these millions of stars now um

872

00:35:24,320 --> 00:35:22,560

the other fun thing about this in

873

00:35:25,820 --> 00:35:24,330

addition to just like increasing the

874

00:35:27,880 --> 00:35:25,830

total number of stars that are going to

875

00:35:31,490 --> 00:35:27,890

interact gravitationally with these

876

00:35:34,130 --> 00:35:31,500

supermassive black holes is that if you

877

00:35:36,170 --> 00:35:34,140

have a binary system what you can do is

878

00:35:39,140 --> 00:35:36,180

you can essentially slingshot that

879

00:35:39,470 --> 00:35:39,150

binary system by one black hole and then

880

00:35:42,200 --> 00:35:39,480

by

881

00:35:44,180 --> 00:35:42,210

the second black hole and you can

882

00:35:48,859 --> 00:35:44,190

accelerate them to these hypervelocity

883

00:35:51,620 --> 00:35:48,869

speeds without breaking them up and and

884

00:35:53,720 --> 00:35:51,630

a lot of times they do break out those

885

00:35:56,420 --> 00:35:53,730

two stars that were orbiting around each

886

00:35:58,550 --> 00:35:56,430

other they'll completely separate but

887

00:36:01,090 --> 00:35:58,560

other times they won't and in fact when

888

00:36:06,830 --> 00:36:01,100

they don't what we think happens is

889

00:36:08,870 --> 00:36:06,840

they'll first get into these very very

890

00:36:12,530 --> 00:36:08,880

eccentric orbits where essentially

891

00:36:14,840 --> 00:36:12,540

they're the two stars instead of looking

892

00:36:16,760 --> 00:36:14,850

like a circle a circular orbit they'll

893

00:36:18,440 --> 00:36:16,770

look more like a really really stretched

894

00:36:22,630 --> 00:36:18,450

out ellipse and so they'll be going

895

00:36:25,550 --> 00:36:22,640

around very very elliptical orbits that

896

00:36:28,370 --> 00:36:25,560

that'll need to begin with but then very

897

00:36:30,920 --> 00:36:28,380

quickly because these these stars are

898

00:36:32,900 --> 00:36:30,930

already pretty close that'll that'll

899

00:36:35,000 --> 00:36:32,910

circularize the orbits will become more

900

00:36:36,770 --> 00:36:35,010

circular again but then they'll be

901
00:36:38,540 --> 00:36:36,780
tighter so when they started off they

902
00:36:40,880 --> 00:36:38,550
might be orbiting this far apart and

903
00:36:43,430 --> 00:36:40,890
then afterwards they do this really

904
00:36:45,050 --> 00:36:43,440
eccentric orbit and then eventually that

905
00:36:46,820 --> 00:36:45,060
becomes circular and then they're close

906
00:36:48,440 --> 00:36:46,830
together so the double black holes

907
00:36:50,540 --> 00:36:48,450
coming together really messes with their

908
00:36:52,040 --> 00:36:50,550
orbital dynamics and then one throw now

909
00:36:53,870 --> 00:36:52,050
they get they kind of stabilize a little

910
00:36:55,460 --> 00:36:53,880
bit better and we need that we still

911
00:36:57,109 --> 00:36:55,470
need the binary stars though to have an

912
00:37:01,609 --> 00:36:57,119
explosion at all right that's right and

913
00:37:03,500 --> 00:37:01,619

so and but but so this this process of

914

00:37:06,740 --> 00:37:03,510

having the two supermassive black holes

915

00:37:08,599 --> 00:37:06,750

does three really important things first

916

00:37:11,330 --> 00:37:08,609

it increases the number of stars that

917

00:37:13,820 --> 00:37:11,340

are going to get kicked out two it makes

918

00:37:17,210 --> 00:37:13,830

it so that these binary systems can

919

00:37:19,550 --> 00:37:17,220

survive and three when these binary

920

00:37:23,560 --> 00:37:19,560

systems do survive it brings the two

921

00:37:26,420 --> 00:37:23,570

stars much much closer together okay so

922

00:37:27,890 --> 00:37:26,430

we'll talk about this more but that last

923

00:37:30,080 --> 00:37:27,900

bit of the two stars getting closer

924

00:37:32,840 --> 00:37:30,090

together that's essentially shortening

925

00:37:34,849 --> 00:37:32,850

the fuse for the explosion which

926
00:37:36,530 --> 00:37:34,859
explains what which might be why they're

927
00:37:39,170 --> 00:37:36,540
exploding before their time why you

928
00:37:41,750 --> 00:37:39,180
would ordinarily expect I see so you've

929
00:37:44,330 --> 00:37:41,760
come together with a pretty elaborate

930
00:37:46,190 --> 00:37:44,340
scheme for for all of this to happen the

931
00:37:48,200 --> 00:37:46,200
way we're the to match the observations

932
00:37:49,700 --> 00:37:48,210
how confident are you that this is

933
00:37:53,060 --> 00:37:49,710
what's actually going on what have you

934
00:37:57,650 --> 00:37:56,330
so I you know in with scientists we

935
00:38:01,550 --> 00:37:57,660
always have kind of have different

936
00:38:03,980 --> 00:38:01,560
levels of our confidence I'm I'm very

937
00:38:06,320 --> 00:38:03,990
confident that the the stars are coming

938
00:38:09,020 --> 00:38:06,330

from the Centers of their galaxies

939

00:38:12,830 --> 00:38:09,030

I'm very confident in that I'm also very

940

00:38:14,090 --> 00:38:12,840

confident that these these the galaxies

941

00:38:15,380 --> 00:38:14,100

that are hosting these objects and we

942

00:38:20,420 --> 00:38:15,390

haven't even really talked about this

943

00:38:22,990 --> 00:38:20,430

they seem to have had recent mergers and

944

00:38:25,400 --> 00:38:23,000

so the combination of those two things

945

00:38:27,740 --> 00:38:25,410

makes it so that it looks like they are

946

00:38:29,870 --> 00:38:27,750

getting ejected from the center the very

947

00:38:31,520 --> 00:38:29,880

centers of their galaxies and the

948

00:38:35,750 --> 00:38:31,530

mergers say that there's probably a

949

00:38:37,340 --> 00:38:35,760

binary supermassive black hole the the

950

00:38:39,950 --> 00:38:37,350

place where then things get more

951
00:38:43,310 --> 00:38:39,960
complicated is are there going to be

952
00:38:45,320 --> 00:38:43,320
enough of these events because we've

953
00:38:49,520 --> 00:38:45,330
found 13 which doesn't seem like that

954
00:38:51,800 --> 00:38:49,530
many but it's it actually you know it's

955
00:38:53,690 --> 00:38:51,810
a reasonable number and you might not

956
00:38:56,360 --> 00:38:53,700
have expected that many so together

957
00:39:00,980 --> 00:38:56,370
jives then with with galaxy merger rates

958
00:39:03,320 --> 00:39:00,990
and it's close enough where I'm not

959
00:39:05,810 --> 00:39:03,330
afraid to say that I think that this is

960
00:39:08,180 --> 00:39:05,820
possible but it's it's probably off by a

961
00:39:10,250 --> 00:39:08,190
factor of like 10 from what we think we

962
00:39:12,110 --> 00:39:10,260
know and of course you know every you

963
00:39:13,790 --> 00:39:12,120

know there there's a lot of uncertainty

964

00:39:15,680 --> 00:39:13,800

in in these numbers and so it's

965

00:39:17,540 --> 00:39:15,690

completely consistent but it's far

966

00:39:19,010 --> 00:39:17,550

enough away where where I'm not gonna

967

00:39:22,370 --> 00:39:19,020

you know I'm not gonna bet my house on

968

00:39:24,890 --> 00:39:22,380

it okay but but I bet a dinner on it I

969

00:39:27,050 --> 00:39:24,900

did it I so I have a question so you

970

00:39:29,120 --> 00:39:27,060

have these galaxies so you find these

971

00:39:30,740 --> 00:39:29,130

weird stars you try to figure it out you

972

00:39:32,210 --> 00:39:30,750

say okay it looks like some of them are

973

00:39:34,250 --> 00:39:32,220

wandering off we can't measure the

974

00:39:35,930 --> 00:39:34,260

velocity but they're a long way wait we

975

00:39:37,610 --> 00:39:35,940

think the analogous ones with ones

976
00:39:40,000 --> 00:39:37,620
coming towards us we can measure them

977
00:39:43,790 --> 00:39:40,010
they're all calcium-rich there is

978
00:39:47,140 --> 00:39:43,800
supernova trace back we have mergers is

979
00:39:49,970 --> 00:39:47,150
there are there any other symptoms of

980
00:39:51,890 --> 00:39:49,980
the I mean you see the mergers but are

981
00:39:55,790 --> 00:39:51,900
there any other symptoms of a binary

982
00:39:59,060 --> 00:39:55,800
black hole that would tell you oh also

983
00:40:04,070 --> 00:39:59,070
binary black holes produce this other

984
00:40:07,069 --> 00:40:04,080
thing we see that - whoa so yes so first

985
00:40:08,420 --> 00:40:07,079
of all let me step back in

986
00:40:12,109 --> 00:40:08,430
maybe maybe now is a good time to

987
00:40:15,430 --> 00:40:12,119
actually show the Hubble images now is

988
00:40:21,469 --> 00:40:15,440

always a good time to show Hubble that

989

00:40:24,349 --> 00:40:21,479

so in the in the little video that we

990

00:40:27,319 --> 00:40:24,359

saw when these two galaxies come

991

00:40:30,019 --> 00:40:27,329

together and merge in addition to kind

992

00:40:31,519 --> 00:40:30,029

of taking what were very pretty galaxies

993

00:40:34,999 --> 00:40:31,529

and then spreading out all the stars

994

00:40:37,029 --> 00:40:35,009

into this more spherical configuration

995

00:40:40,759 --> 00:40:37,039

one of the things that happens is that

996

00:40:44,089 --> 00:40:40,769

sort of the shredded galaxies there's

997

00:40:46,880 --> 00:40:44,099

still some remnant of it and one of the

998

00:40:51,199 --> 00:40:46,890

things that we see are it are we see

999

00:40:54,799 --> 00:40:51,209

that the dust and gas that was in one of

1000

00:40:58,940 --> 00:40:54,809

these galaxies it gets spread out in the

1001
00:41:02,599 --> 00:40:58,950
new galaxies and this is unlike what we

1002
00:41:05,870 --> 00:41:02,609
see in very old spherical galaxies if we

1003
00:41:08,900 --> 00:41:05,880
see if we see a relatively spherical

1004
00:41:11,449 --> 00:41:08,910
galaxy with a lot of dust then it's

1005
00:41:14,089 --> 00:41:11,459
likely that it had a recent merger and

1006
00:41:16,969 --> 00:41:14,099
so these beautiful Hubble images of

1007
00:41:19,069 --> 00:41:16,979
these galaxies you can see going kind of

1008
00:41:23,390 --> 00:41:19,079
from your top left to your bottom right

1009
00:41:25,609 --> 00:41:23,400
in both of these this this smudge that

1010
00:41:29,839 --> 00:41:25,619
goes straight through the beautiful

1011
00:41:33,199 --> 00:41:29,849
galaxy and that's that's that's we call

1012
00:41:37,180 --> 00:41:33,209
that a dust Blaine and what that really

1013
00:41:41,359 --> 00:41:37,190

is is the evidence of some recent merger

1014

00:41:43,339 --> 00:41:41,369

so so from these images and then from

1015

00:41:45,469 --> 00:41:43,349

some other lines of evidence it really

1016

00:41:47,959 --> 00:41:45,479

looks like these the galaxies that that

1017

00:41:51,289 --> 00:41:47,969

are near the supernovae had recent

1018

00:41:52,670 --> 00:41:51,299

mergers but that alone doesn't

1019

00:41:54,759 --> 00:41:52,680

necessarily say that there's a super

1020

00:41:59,479 --> 00:41:54,769

method of binary supermassive black hole

1021

00:42:01,069 --> 00:41:59,489

and and to confirm that there's a binary

1022

00:42:03,349 --> 00:42:01,079

supermassive black hole is actually a

1023

00:42:06,680 --> 00:42:03,359

very difficult observation to make it's

1024

00:42:10,880 --> 00:42:06,690

been done a handful of times sometimes

1025

00:42:14,749 --> 00:42:10,890

in in when you have very ideal

1026
00:42:16,069 --> 00:42:14,759
situations and we just don't have those

1027
00:42:18,469 --> 00:42:16,079
kinds of things it's sort of like you

1028
00:42:20,660 --> 00:42:18,479
know 1% of all galaxy mergers might be

1029
00:42:21,260 --> 00:42:20,670
in this configuration and then then it's

1030
00:42:22,610 --> 00:42:21,270
easier

1031
00:42:25,280 --> 00:42:22,620
to make that observation if you just

1032
00:42:27,260 --> 00:42:25,290
have normal binary supermassive black

1033
00:42:28,820 --> 00:42:27,270
holes it's hard but not impossible to do

1034
00:42:32,570 --> 00:42:28,830
and so one of the things that we're

1035
00:42:36,110 --> 00:42:32,580
looking into doing down the road is to

1036
00:42:38,600 --> 00:42:36,120
measure the velocities of the stars

1037
00:42:41,990 --> 00:42:38,610
right at the Centers of these galaxies

1038
00:42:43,790 --> 00:42:42,000

and so what you can find is if for a

1039

00:42:46,880 --> 00:42:43,800

normal single supermassive black hole

1040

00:42:48,770 --> 00:42:46,890

there's a certain way that the stars

1041

00:42:51,320 --> 00:42:48,780

will kind of orbit around that that

1042

00:42:52,760 --> 00:42:51,330

singled a supermassive black hole if

1043

00:42:54,920 --> 00:42:52,770

there are two supermassive black holes

1044

00:42:57,710 --> 00:42:54,930

that changes how those stars are

1045

00:42:59,570 --> 00:42:57,720

orbiting around the two of them and so

1046

00:43:01,550 --> 00:42:59,580

that's something that we're looking into

1047

00:43:04,160 --> 00:43:01,560

to confirm them how you gonna do that

1048

00:43:07,610 --> 00:43:04,170

how far away are these galaxies well so

1049

00:43:11,450 --> 00:43:07,620

the closest ones are not too far so that

1050

00:43:15,800 --> 00:43:11,460

the closest ones are are around 20 mega

1051
00:43:19,420 --> 00:43:15,810
parsecs or so which if so let me so yes

1052
00:43:23,360 --> 00:43:19,430
so the closest one is 23 mega parsecs

1053
00:43:28,970 --> 00:43:23,370
which is something like you know 75 60

1054
00:43:31,580 --> 00:43:28,980
75 million light-years away you know

1055
00:43:34,160 --> 00:43:31,590
it's their third depth that sounds large

1056
00:43:36,680 --> 00:43:34,170
those are actually pretty close by to

1057
00:43:39,680 --> 00:43:36,690
give some reference the the Virgo

1058
00:43:41,750 --> 00:43:39,690
cluster is it's like 15 to 20 min I'm

1059
00:43:43,970 --> 00:43:41,760
asked a group that our our galaxy is a

1060
00:43:47,210 --> 00:43:43,980
member of so well yeah yes so we're

1061
00:43:50,420 --> 00:43:47,220
we're on some of these are further but

1062
00:43:53,570 --> 00:43:50,430
but a lot of them are pretty close the

1063
00:43:56,120 --> 00:43:53,580

the key to to making the measurement

1064

00:43:58,400 --> 00:43:56,130

that I'm talking about is to is to

1065

00:44:01,790 --> 00:43:58,410

really resolve out the center of the

1066

00:44:04,610 --> 00:44:01,800

galaxy and you can do this two ways one

1067

00:44:08,840 --> 00:44:04,620

that's been done in this you know

1068

00:44:13,870 --> 00:44:08,850

incredibly well work from now two

1069

00:44:18,020 --> 00:44:13,880

decades ago with Hubble is to use the

1070

00:44:20,630 --> 00:44:18,030

really incredible resolution of Hubble

1071

00:44:24,050 --> 00:44:20,640

and take a spectrum of just the very

1072

00:44:26,240 --> 00:44:24,060

center of the galaxy and so this is

1073

00:44:29,450 --> 00:44:26,250

something that that was that's been done

1074

00:44:32,090 --> 00:44:29,460

many many times with Hubble and it's

1075

00:44:33,710 --> 00:44:32,100

it's it's been able to determine not

1076
00:44:34,880 --> 00:44:33,720
just that there are supermassive black

1077
00:44:38,120 --> 00:44:34,890
holes and

1078
00:44:39,349 --> 00:44:38,130
all these these galaxies but that we can

1079
00:44:41,720 --> 00:44:39,359
measure the the mass of those

1080
00:44:43,819 --> 00:44:41,730
supermassive black holes oh wow that's

1081
00:44:45,680 --> 00:44:43,829
great so I well I don't want to go back

1082
00:44:47,779 --> 00:44:45,690
to the idea that there was evidence of

1083
00:44:49,789 --> 00:44:47,789
these mergers have having these galaxies

1084
00:44:52,400 --> 00:44:49,799
haven't been in mergers when you said

1085
00:44:54,170 --> 00:44:52,410
that a telltale sign was the dust lanes

1086
00:44:56,059 --> 00:44:54,180
that you saw there but isn't it also

1087
00:44:58,880 --> 00:44:56,069
these were elliptical galaxies and these

1088
00:45:00,440 --> 00:44:58,890

are among the most oldest galaxies and

1089

00:45:01,880 --> 00:45:00,450

the largest galaxies in the universe so

1090

00:45:05,240 --> 00:45:01,890

wouldn't that by definition make them uh

1091

00:45:10,009 --> 00:45:05,250

I can't are a victim of lots of mergers

1092

00:45:12,009 --> 00:45:10,019

well yes so too the the there there are

1093

00:45:14,870 --> 00:45:12,019

there are a few theories on how

1094

00:45:17,839 --> 00:45:14,880

elliptical galaxies come to be but one

1095

00:45:20,450 --> 00:45:17,849

very prominent one is that you have

1096

00:45:23,150 --> 00:45:20,460

spiral galaxies that merge and then that

1097

00:45:25,430 --> 00:45:23,160

that will then reconfigure the orbits of

1098

00:45:28,099 --> 00:45:25,440

all the stars in the two galaxies and

1099

00:45:31,759 --> 00:45:28,109

then they become an elliptical galaxy uh

1100

00:45:34,190 --> 00:45:31,769

the the issue is that when when you have

1101
00:45:37,250 --> 00:45:34,200
a merger then there's some settling out

1102
00:45:38,750 --> 00:45:37,260
time early on you'll see you'll see two

1103
00:45:40,460 --> 00:45:38,760
galaxies where it's very clear that

1104
00:45:41,809 --> 00:45:40,470
there are two separate galaxies but

1105
00:45:44,720 --> 00:45:41,819
they're interacting with each other

1106
00:45:47,240 --> 00:45:44,730
later on you'll see us evidence of that

1107
00:45:49,099 --> 00:45:47,250
you might just see that the but there's

1108
00:45:51,460 --> 00:45:49,109
these dust lanes and then if you wait

1109
00:45:53,829 --> 00:45:51,470
even longer then the dust will dissipate

1110
00:45:58,370 --> 00:45:53,839
and you just see this beautiful

1111
00:46:01,120 --> 00:45:58,380
elliptical galaxy and so and so in those

1112
00:46:03,490 --> 00:46:01,130
cases it's just a matter of timing

1113
00:46:06,140 --> 00:46:03,500

there's also the you know the

1114

00:46:08,059 --> 00:46:06,150

possibility that you have an elliptical

1115

00:46:09,920 --> 00:46:08,069

galaxy and another elliptical galaxies

1116

00:46:11,180 --> 00:46:09,930

merge and then you wouldn't see any dust

1117

00:46:14,450 --> 00:46:11,190

but you would still have a binary

1118

00:46:16,279 --> 00:46:14,460

supermassive black hole so so there

1119

00:46:19,579 --> 00:46:16,289

there there are a lot of ways to think

1120

00:46:21,079 --> 00:46:19,589

about this and and and like I said you

1121

00:46:23,180 --> 00:46:21,089

know we we really do need to do the

1122

00:46:25,730 --> 00:46:23,190

follow-up observations and confirm that

1123

00:46:28,789 --> 00:46:25,740

at least a subset of these have binary

1124

00:46:30,470 --> 00:46:28,799

supermassive black holes but all the all

1125

00:46:32,539 --> 00:46:30,480

the evidence that we have so far is

1126

00:46:34,099 --> 00:46:32,549

pointing that way cool alright great

1127

00:46:36,259 --> 00:46:34,109

well good running out of time now I have

1128

00:46:37,910 --> 00:46:36,269

some questions piling up on the QA app

1129

00:46:41,599 --> 00:46:37,920

so let me get to a couple of them Ronald

1130

00:46:43,940 --> 00:46:41,609

Minch is is asking does a black hole

1131

00:46:46,039 --> 00:46:43,950

ejecting debris in this case the star I

1132

00:46:48,200 --> 00:46:46,049

would imagine indicate that they aren't

1133

00:46:48,710 --> 00:46:48,210

as powerful and stable as once thought

1134

00:46:50,510 --> 00:46:48,720

is there

1135

00:46:53,780 --> 00:46:50,520

correlation between these do they lose

1136

00:46:55,160 --> 00:46:53,790

energy when they eject things well so

1137

00:46:58,220 --> 00:46:55,170

this is this is an interesting question

1138

00:47:02,690 --> 00:46:58,230

there's actually a way to steal energy

1139

00:47:04,190 --> 00:47:02,700

from a black hole we probably don't have

1140

00:47:05,990 --> 00:47:04,200

enough time to get into this but there's

1141

00:47:09,589 --> 00:47:06,000

there's a region near the black hole

1142

00:47:13,339 --> 00:47:09,599

called the Virgo sphere and if you can

1143

00:47:16,280 --> 00:47:13,349

dip something into that region and come

1144

00:47:18,830 --> 00:47:16,290

out of it you can steal some energy from

1145

00:47:21,650 --> 00:47:18,840

the black hole and similarly you know

1146

00:47:23,690 --> 00:47:21,660

energy is always conserved and so when

1147

00:47:25,099 --> 00:47:23,700

you when you slingshot these stars the

1148

00:47:26,780 --> 00:47:25,109

energy has to come from somewhere and it

1149

00:47:29,990 --> 00:47:26,790

does come from these orbits it's the

1150

00:47:31,430 --> 00:47:30,000

same process basically as when we send

1151
00:47:33,650 --> 00:47:31,440
out satellites to the outer solar system

1152
00:47:36,349 --> 00:47:33,660
and we have a gravitational assist or a

1153
00:47:37,910 --> 00:47:36,359
slingshot by Mars or Jupiter it's the

1154
00:47:39,290 --> 00:47:37,920
same idea the energy has to come from

1155
00:47:43,490 --> 00:47:39,300
somewhere it comes from the orbit of

1156
00:47:47,540 --> 00:47:43,500
those ergo sphere the ergosphere the

1157
00:47:51,620 --> 00:47:47,550
other means energy Oh sphere so ergo I

1158
00:47:53,660 --> 00:47:51,630
think means work in Greek yeah yeah so I

1159
00:47:54,950 --> 00:47:53,670
did not know that I want to find out

1160
00:47:56,839 --> 00:47:54,960
more about that unfortunately right we

1161
00:47:58,010 --> 00:47:56,849
won't have a lot of time that is cool

1162
00:47:59,630 --> 00:47:58,020
thank you very much Ron well that was a

1163
00:48:02,750 --> 00:47:59,640

good question

1164

00:48:04,670 --> 00:48:02,760

let's see Craig Landon is asking on the

1165

00:48:07,310 --> 00:48:04,680

Q&A app similar to dr. Christians

1166

00:48:09,410 --> 00:48:07,320

question do these need to be binary

1167

00:48:11,030 --> 00:48:09,420

supermassive black holes or could

1168

00:48:13,700 --> 00:48:11,040

something like an intermediate mass

1169

00:48:16,849 --> 00:48:13,710

black hole binary or not produce the

1170

00:48:17,660 --> 00:48:16,859

same energy necessary yeah so that's an

1171

00:48:19,640 --> 00:48:17,670

excellent question

1172

00:48:23,320 --> 00:48:19,650

and the short answer is we don't know

1173

00:48:25,790 --> 00:48:23,330

because there's there's only been some

1174

00:48:28,280 --> 00:48:25,800

theoretical modeling you know computer

1175

00:48:31,220 --> 00:48:28,290

modeling of these systems and people

1176
00:48:33,230 --> 00:48:31,230
haven't looked at how low of a mass you

1177
00:48:35,180 --> 00:48:33,240
could have her the companion I guess is

1178
00:48:37,820 --> 00:48:35,190
that having a intermediate-mass black

1179
00:48:41,000 --> 00:48:37,830
holes or something that's a thousand or

1180
00:48:42,530 --> 00:48:41,010
a few thousand solar masses and a

1181
00:48:44,240 --> 00:48:42,540
supermassive black hole say something

1182
00:48:46,520 --> 00:48:44,250
that's a million to a billion solar

1183
00:48:50,150 --> 00:48:46,530
masses if you had that pair you probably

1184
00:48:51,589 --> 00:48:50,160
would do okay and and then you could do

1185
00:48:54,290 --> 00:48:51,599
there is still this scenario where you

1186
00:48:56,780 --> 00:48:54,300
could do it with a single black hole to

1187
00:48:58,760 --> 00:48:56,790
do that you need you need to start off

1188
00:49:01,670 --> 00:48:58,770

with three stars the triple star system

1189

00:49:02,600 --> 00:49:01,680

and those are those are just rare it's

1190

00:49:04,370 --> 00:49:02,610

not impossible

1191

00:49:08,390 --> 00:49:04,380

talking about 13 that we've seen all

1192

00:49:11,300 --> 00:49:08,400

that you know more rare than that uh no

1193

00:49:12,710 --> 00:49:11,310

so sooo that I it doesn't necessarily

1194

00:49:15,620 --> 00:49:12,720

have to be more rare than that I think

1195

00:49:18,380 --> 00:49:15,630

the the reason why the one reason why we

1196

00:49:20,720 --> 00:49:18,390

go to the binaries that really helps is

1197

00:49:23,480 --> 00:49:20,730

that we have all this evidence for

1198

00:49:25,910 --> 00:49:23,490

mergers and we know that when you have

1199

00:49:27,890 --> 00:49:25,920

binary you know you know that the two

1200

00:49:30,290 --> 00:49:27,900

versus three stars that's not as

1201
00:49:32,360 --> 00:49:30,300
important as just elevating the overall

1202
00:49:35,000 --> 00:49:32,370
rate of ejection and that happens when

1203
00:49:36,740 --> 00:49:35,010
you just have these two black holes yeah

1204
00:49:38,690 --> 00:49:36,750
and I think the rate was again you say a

1205
00:49:41,180 --> 00:49:38,700
hundred per year versus one per year

1206
00:49:43,640 --> 00:49:41,190
well one per hundred years in the Milky

1207
00:49:45,050 --> 00:49:43,650
Way or even if you could even stretch it

1208
00:49:47,120 --> 00:49:45,060
further depending on you know it could

1209
00:49:48,890 --> 00:49:47,130
be one per thousand years and then up to

1210
00:49:51,560 --> 00:49:48,900
a thousand per year so it's really like

1211
00:49:53,090 --> 00:49:51,570
it's significantly different right right

1212
00:49:55,810 --> 00:49:53,100
okay well very good question Craig thank

1213
00:49:58,520 --> 00:49:55,820

you okay so Adams energy is asking again

1214

00:50:00,530 --> 00:49:58,530

another question normally we would

1215

00:50:03,380 --> 00:50:00,540

expect binary stars to take a long time

1216

00:50:06,170 --> 00:50:03,390

to merge but these stars must merge much

1217

00:50:08,660 --> 00:50:06,180

much quicker can Ryan estimate how long

1218

00:50:13,060 --> 00:50:08,670

it takes for these a ejected by an Aries

1219

00:50:16,970 --> 00:50:13,070

to go bang this is a beautiful question

1220

00:50:21,230 --> 00:50:16,980

so for these cases we we can determine

1221

00:50:23,300 --> 00:50:21,240

this at least on average so we know for

1222

00:50:25,700 --> 00:50:23,310

the objects that are coming right at us

1223

00:50:28,700 --> 00:50:25,710

we know how fast they're moving and then

1224

00:50:31,220 --> 00:50:28,710

the ones that that are very far away we

1225

00:50:33,260 --> 00:50:31,230

have a rough estimate of how far away

1226

00:50:35,180 --> 00:50:33,270

they are from their galaxies now of

1227

00:50:37,820 --> 00:50:35,190

course they could be you know out in

1228

00:50:39,230 --> 00:50:37,830

front of us and then in projection they

1229

00:50:41,090 --> 00:50:39,240

look like they're they're closer than

1230

00:50:42,800 --> 00:50:41,100

what they really are but if you take

1231

00:50:44,900 --> 00:50:42,810

those two things we have a velocity in a

1232

00:50:49,820 --> 00:50:44,910

distance then you can measure a time

1233

00:50:51,770 --> 00:50:49,830

right so it must have gone some speed

1234

00:50:54,410 --> 00:50:51,780

for some amount of time to get to that

1235

00:50:57,370 --> 00:50:54,420

distance if you do that you end up

1236

00:51:00,950 --> 00:50:57,380

getting a time of about 50 million years

1237

00:51:03,950 --> 00:51:00,960

so that sounds like a long time it's

1238

00:51:07,660 --> 00:51:03,960

actually a very short time in terms of

1239

00:51:11,480 --> 00:51:07,670

the the life of a star or in terms of

1240

00:51:14,020 --> 00:51:11,490

the age of the universe and so this is

1241

00:51:16,550 --> 00:51:14,030

one of the important things is that if

1242

00:51:18,680 --> 00:51:16,560

if you have some few

1243

00:51:21,650 --> 00:51:18,690

between say when the stars were born and

1244

00:51:24,350 --> 00:51:21,660

when they explode and and it's

1245

00:51:26,450 --> 00:51:24,360

sufficiently short then you'll see them

1246

00:51:28,760 --> 00:51:26,460

all over the place and you should see

1247

00:51:30,950 --> 00:51:28,770

them close to where they're born and we

1248

00:51:33,410 --> 00:51:30,960

don't see that in this case so it has to

1249

00:51:36,230 --> 00:51:33,420

have a very long fuse normally say

1250

00:51:39,110 --> 00:51:36,240

longer than the age of the universe so

1251
00:51:41,060 --> 00:51:39,120
the typical objects that explode as

1252
00:51:43,670 --> 00:51:41,070
these thousand richer supernovae they

1253
00:51:45,890 --> 00:51:43,680
typically won't explode for say you know

1254
00:51:48,350 --> 00:51:45,900
twenty or fifty or a hundred billion

1255
00:51:51,050 --> 00:51:48,360
years much longer than the age of the

1256
00:51:53,690 --> 00:51:51,060
universe but through this interaction we

1257
00:51:55,580 --> 00:51:53,700
were able to shorten that fuse and so

1258
00:51:57,830 --> 00:51:55,590
then we're you know it who knows how

1259
00:51:59,720 --> 00:51:57,840
long it took maybe five billion years or

1260
00:52:02,090 --> 00:51:59,730
ten billion years before the star

1261
00:52:03,740 --> 00:52:02,100
actually gets kicked out but then after

1262
00:52:06,100 --> 00:52:03,750
that it's only about fifty million years

1263
00:52:08,270 --> 00:52:06,110

before it explodes Wow so that rapidly

1264

00:52:10,070 --> 00:52:08,280

accelerates the time that would take

1265

00:52:12,290 --> 00:52:10,080

direct to make a blow-up that's amazing

1266

00:52:13,730 --> 00:52:12,300

okay well two-toed it's sort of so to go

1267

00:52:16,010 --> 00:52:13,740

back to our analogy with the homeless

1268

00:52:18,320 --> 00:52:16,020

and knowing that where that guy is on

1269

00:52:19,940 --> 00:52:18,330

the outside of town and how we got there

1270

00:52:22,310 --> 00:52:19,950

you're saying you got kicked out of town

1271

00:52:24,920 --> 00:52:22,320

is that what it is yeah it's somebody

1272

00:52:26,180 --> 00:52:24,930

somebody drove him out of town yeah he

1273

00:52:27,980 --> 00:52:26,190

got drove out it that's what he's doing

1274

00:52:29,870 --> 00:52:27,990

there great question I'd appreciate that

1275

00:52:32,630 --> 00:52:29,880

okay one more question for model men

1276

00:52:36,050 --> 00:52:32,640

cheer he's asking I think this was to

1277

00:52:38,840 --> 00:52:36,060

you Carol it's like doctor see what PhD

1278

00:52:40,550 --> 00:52:38,850

are you I know someone who will just end

1279

00:52:42,170 --> 00:52:40,560

of someone who is just beginning to

1280

00:52:45,190 --> 00:52:42,180

venture into the physicists field so

1281

00:52:48,020 --> 00:52:45,200

what's your PhD astronomy physics

1282

00:52:50,870 --> 00:52:48,030

physics and astronomy and any advice to

1283

00:52:52,550 --> 00:52:50,880

those just starting out if that's what

1284

00:52:54,710 --> 00:52:52,560

you love to do go for it there's no

1285

00:52:56,150 --> 00:52:54,720

reason not to it's fabulous there's all

1286

00:53:00,260 --> 00:52:56,160

kinds of opportunities

1287

00:53:03,650 --> 00:53:00,270

I mean besides hangouts there's no and

1288

00:53:06,410 --> 00:53:03,660

research on supernovae there there are

1289

00:53:08,120 --> 00:53:06,420

lots of things to do in astronomy in

1290

00:53:11,690 --> 00:53:08,130

space science so that's what you know

1291

00:53:14,630 --> 00:53:11,700

okay yeah good question on thank you

1292

00:53:16,040 --> 00:53:14,640

thanks for asking so okay so Ryan before

1293

00:53:17,900 --> 00:53:16,050

we leave I just want to real quickly

1294

00:53:19,490 --> 00:53:17,910

delve into some of the datasets you use

1295

00:53:22,160 --> 00:53:19,500

you said you use the Hubble archival

1296

00:53:24,850 --> 00:53:22,170

data with this this is data that's open

1297

00:53:27,350 --> 00:53:24,860

up to everyone you go to them at the the

1298

00:53:29,580 --> 00:53:27,360

master archive or the Hubble legacy

1299

00:53:31,380 --> 00:53:29,590

archive and you can get these data

1300

00:53:33,780 --> 00:53:31,390

what else did you use besides Hubble

1301

00:53:37,260 --> 00:53:33,790

data for your analysis yeah so first

1302

00:53:39,000 --> 00:53:37,270

before before I go on I mean I should

1303

00:53:41,100 --> 00:53:39,010

just say that the Hubble archive is one

1304

00:53:43,530 --> 00:53:41,110

of the best things in all of science and

1305

00:53:44,760 --> 00:53:43,540

I encourage people even if they're not

1306

00:53:47,100 --> 00:53:44,770

interested in doing some sort of

1307

00:53:49,410 --> 00:53:47,110

research you can just look up your

1308

00:53:51,870 --> 00:53:49,420

favorite part of the sky choose your

1309

00:53:54,110 --> 00:53:51,880

favorite object and look at beautiful

1310

00:53:56,790 --> 00:53:54,120

images that are not you know nobody else

1311

00:53:58,680 --> 00:53:56,800

has necessarily looked at exactly what

1312

00:53:59,970 --> 00:53:58,690

you're seeing and they have this there's

1313

00:54:02,220 --> 00:53:59,980

something called the Hubble legacy

1314

00:54:04,500 --> 00:54:02,230

archive where they they have a webpage

1315

00:54:06,720 --> 00:54:04,510

it's it's like Google Maps you can you

1316

00:54:08,460 --> 00:54:06,730

know you can zoom in and zoom out and

1317

00:54:10,410 --> 00:54:08,470

move things around it's really really

1318

00:54:13,710 --> 00:54:10,420

nice so I encourage everybody to look at

1319

00:54:15,540 --> 00:54:13,720

that you hear a leak well we'll just as

1320

00:54:18,120 --> 00:54:15,550

easy to say its archive that is TS CI

1321

00:54:22,700 --> 00:54:18,130

dot edu and you can go right from there

1322

00:54:28,440 --> 00:54:22,710

also I think hla dot stsci that the

1323

00:54:32,460 --> 00:54:28,450

legacy archive so in addition to Hubble

1324

00:54:35,070 --> 00:54:32,470

data I mainly used spectra that came

1325

00:54:38,580 --> 00:54:35,080

from the Lick Observatory the Keck

1326
00:54:42,720 --> 00:54:38,590
Observatory and Subaru which is another

1327
00:54:45,360 --> 00:54:42,730
telescope in in Hawaii and and then I

1328
00:54:48,420 --> 00:54:45,370
used a handful of other data sets that

1329
00:54:49,950 --> 00:54:48,430
for little bits and pieces so for a

1330
00:54:51,600 --> 00:54:49,960
handful of the galaxies there were

1331
00:54:54,900 --> 00:54:51,610
spectra in the Sloan Digital Sky Survey

1332
00:54:58,110 --> 00:54:54,910
things like that it really was pulling

1333
00:55:00,900 --> 00:54:58,120
whatever I could to try to understand

1334
00:55:02,520 --> 00:55:00,910
this whole topic so are you going to you

1335
00:55:04,080 --> 00:55:02,530
said that the further observations that

1336
00:55:05,490 --> 00:55:04,090
we're gonna be needed to kind of you

1337
00:55:06,750 --> 00:55:05,500
know make you feel a little bit more

1338
00:55:09,240 --> 00:55:06,760

confident about these would be to try

1339

00:55:10,530 --> 00:55:09,250

and resolve these in these binary

1340

00:55:12,720 --> 00:55:10,540

supermassive black holes in these

1341

00:55:14,220 --> 00:55:12,730

particular galaxies is using spectra any

1342

00:55:18,900 --> 00:55:14,230

plans to do that or are you writing on

1343

00:55:20,490 --> 00:55:18,910

two proposals now or yes so so the the

1344

00:55:22,530 --> 00:55:20,500

the great thing is at the University of

1345

00:55:25,080 --> 00:55:22,540

Illinois we just hired a new faculty

1346

00:55:28,100 --> 00:55:25,090

member a new professor whose specialty

1347

00:55:30,510 --> 00:55:28,110

is binary supermassive black holes oh

1348

00:55:32,760 --> 00:55:30,520

we're looking into doing something about

1349

00:55:35,940 --> 00:55:32,770

this and then I should also point out

1350

00:55:39,240 --> 00:55:35,950

that in the schedule for the for the

1351
00:55:42,060 --> 00:55:39,250
Hubble Space Telescope is to image some

1352
00:55:43,220 --> 00:55:42,070
of these other supernovae where they

1353
00:55:45,500 --> 00:55:43,230
where they happened

1354
00:55:47,720 --> 00:55:45,510
and so while we have images of a handful

1355
00:55:49,490 --> 00:55:47,730
of them pretty soon we're gonna we're

1356
00:55:52,250 --> 00:55:49,500
going to have almost all of them will

1357
00:55:54,890 --> 00:55:52,260
have Hubble images of them so I mean all

1358
00:55:57,620 --> 00:55:54,900
of them all of the 13 or 13 I think and

1359
00:56:00,160 --> 00:55:57,630
I think out of the 13 will will end up

1360
00:56:03,320 --> 00:56:00,170
with something like seven or eight

1361
00:56:07,310 --> 00:56:03,330
Hubble images whereas right now we we

1362
00:56:09,560 --> 00:56:07,320
don't have nearly that many and so so

1363
00:56:10,940 --> 00:56:09,570

that's that's going to be great and so

1364

00:56:13,580 --> 00:56:10,950

that'll be another way with the high

1365

00:56:14,990 --> 00:56:13,590

resolution images of Hubble they have a

1366

00:56:16,670 --> 00:56:15,000

better idea of what's going on at the

1367

00:56:17,900 --> 00:56:16,680

Centers of their galaxies well that's

1368

00:56:19,609 --> 00:56:17,910

grad sounds standing what hope do we

1369

00:56:20,750 --> 00:56:19,619

hope you'll come back and share with us

1370

00:56:23,030 --> 00:56:20,760

what you find out once you get those

1371

00:56:25,490 --> 00:56:23,040

images as well as if you do manage to

1372

00:56:26,960 --> 00:56:25,500

get some more of the of the evidence of

1373

00:56:29,210 --> 00:56:26,970

the super of the binary black holes that

1374

00:56:30,560 --> 00:56:29,220

would be awesome as well so thank you

1375

00:56:31,970 --> 00:56:30,570

very much Ryan this has been a great

1376

00:56:33,800 --> 00:56:31,980

hangout we appreciate you joining us

1377

00:56:37,190 --> 00:56:33,810

where it's always fun yeah we're running

1378

00:56:38,330 --> 00:56:37,200

out of time but I guess I Carol I guess

1379

00:56:40,400 --> 00:56:38,340

we've got another one in the books that

1380

00:56:42,800 --> 00:56:40,410

I we hope you guys will join us next

1381

00:56:44,300 --> 00:56:42,810

week we are still working on the title

1382

00:56:45,620 --> 00:56:44,310

and what the subject will be because

1383

00:56:48,580 --> 00:56:45,630

Carol and I are still scrambling to get

1384

00:56:52,040 --> 00:56:48,590

a prize mode now that's right

1385

00:56:54,800 --> 00:56:52,050

and I really appreciate Brian coming on

1386

00:56:58,910 --> 00:56:54,810

at the last minute I do - Thank You Ryan

1387

00:57:00,320 --> 00:56:58,920

there's been a last-minute yeah thank

1388

00:57:01,340 --> 00:57:00,330

you so much this has been great I want

1389

00:57:03,200 --> 00:57:01,350

to thank all of you for asking questions

1390

00:57:05,000 --> 00:57:03,210

and even your comments this has been

1391

00:57:07,190 --> 00:57:05,010

really fun until next week we'll see you

1392

00:57:09,920 --> 00:57:07,200

or another Hubble hangout thank you all