

1
00:00:04,609 --> 00:00:08,730
hello everybody and welcome to this

2
00:00:06,960 --> 00:00:10,529
week's Hubbell hangout my name is Tony

3
00:00:08,730 --> 00:00:12,780
Darnell and I work at the Space

4
00:00:10,529 --> 00:00:16,138
Telescope Science Institute and today we

5
00:00:12,779 --> 00:00:18,539
have another always awesome hangout plan

6
00:00:16,138 --> 00:00:20,850
for you today it turns out that the

7
00:00:18,539 --> 00:00:22,859
Milky Way has these very strange lobes

8
00:00:20,850 --> 00:00:24,868
on either side of it and astronomers

9
00:00:22,859 --> 00:00:26,430
using Hubble have have actually been

10
00:00:24,868 --> 00:00:29,428
able to measure some of the properties

11
00:00:26,429 --> 00:00:30,689
of these lobes using a quasar and we're

12
00:00:29,428 --> 00:00:32,070
going to talk about some of the details

13
00:00:30,689 --> 00:00:33,659
with that today with one of the

14
00:00:32,070 --> 00:00:36,450
astronomers here but before I get to the

15
00:00:33,659 --> 00:00:37,859
introductions let me tell you well let

16
00:00:36,450 --> 00:00:40,410
me first of all let me welcome my

17
00:00:37,859 --> 00:00:42,479
cohorts with me as always is dr. Carol

18
00:00:40,409 --> 00:00:46,109
Christian she's the outreach scientist

19
00:00:42,479 --> 00:00:48,238
for Hubble hi Carol and Scott Lewis the

20
00:00:46,109 --> 00:00:50,579
driver oh the Internet's extraordinaire

21
00:00:48,238 --> 00:00:57,259
hi Scott extraordinaire I like it's

22
00:00:50,579 --> 00:01:00,808
getting longer I lined up the third year

23
00:00:57,259 --> 00:01:02,308
so so we'd like to get your comments and

24
00:01:00,808 --> 00:01:03,869
questions throughout the Hangout if you

25
00:01:02,308 --> 00:01:05,338
are so inclined you can do that in a

26
00:01:03,869 --> 00:01:07,618
number of ways the easiest and my

27
00:01:05,338 --> 00:01:09,959
favorite way is to use the Q&A app but

28
00:01:07,618 --> 00:01:12,780
you can also comment on the event page

29

00:01:09,959 --> 00:01:15,089
in Google+ that we are broadcasting from

30
00:01:12,780 --> 00:01:16,560
as well as the YouTube page we're

31
00:01:15,090 --> 00:01:21,270
looking at all of those comments as well

32
00:01:16,560 --> 00:01:24,900
and so and finally on Twitter if you use

33
00:01:21,269 --> 00:01:26,429
the Hangout Hubble hangout Scott will be

34
00:01:24,900 --> 00:01:27,990
monitoring that and letting me know if

35
00:01:26,430 --> 00:01:29,549
there's any good tweets or comments that

36
00:01:27,989 --> 00:01:31,170
way and we will read them out as they

37
00:01:29,549 --> 00:01:34,590
come or toward the end so please

38
00:01:31,170 --> 00:01:37,618
interact with us so joining me today is

39
00:01:34,590 --> 00:01:39,630
an astronomer from these also from the

40
00:01:37,618 --> 00:01:43,078
Space Telescope Science Institute dr.

41
00:01:39,629 --> 00:01:44,578
Andy Fox hi Andy hi Tony hey ding I'm

42
00:01:43,078 --> 00:01:47,309
good thank you thank you for taking time

43
00:01:44,578 --> 00:01:49,319

out to join us so you've made some

44

00:01:47,310 --> 00:01:52,200

pretty interesting measurements for us

45

00:01:49,319 --> 00:01:54,809

using Hubble you have pointed it at a

46

00:01:52,200 --> 00:01:57,478

quasar that just so happened to be in a

47

00:01:54,810 --> 00:02:00,420

good spot to measure these very strange

48

00:01:57,478 --> 00:02:04,228

things that I I guess only until only

49

00:02:00,420 --> 00:02:06,000

recently have been discovered these

50

00:02:04,228 --> 00:02:08,699

features of our galaxy these strange

51

00:02:06,000 --> 00:02:11,430

kind of lobe things correct that is

52

00:02:08,699 --> 00:02:13,629

right in fact these lobes are called the

53

00:02:11,430 --> 00:02:17,260

Fermi bubbles were only discovered in

54

00:02:13,629 --> 00:02:20,049

20:10 in their gamma-ray emission by a

55

00:02:17,259 --> 00:02:22,000

satellite that NASA operates called the

56

00:02:20,050 --> 00:02:23,740

Fermi satellite so really only in the

57

00:02:22,000 --> 00:02:26,770

last five years have we known about this

58
00:02:23,740 --> 00:02:29,050
new component of our galaxy and we were

59
00:02:26,770 --> 00:02:31,380
able to use Hubble tour to measure how

60
00:02:29,050 --> 00:02:34,480
fast the gas was moving into these lobes

61
00:02:31,379 --> 00:02:36,490
what that gas is composed of in terms of

62
00:02:34,479 --> 00:02:37,780
its chemical elements and this was the

63
00:02:36,490 --> 00:02:39,210
first time we were able to really nail

64
00:02:37,780 --> 00:02:42,189
down some of these properties

65
00:02:39,210 --> 00:02:43,360
well it's awesome and I want to get to

66
00:02:42,189 --> 00:02:44,620
those measurements in just a minute but

67
00:02:43,360 --> 00:02:47,580
Scott can you put up that diagram that

68
00:02:44,620 --> 00:02:50,830
shows the Fermi bubbles for me bubbles

69
00:02:47,580 --> 00:02:52,600
doo-doo-doo sorry all right so here's

70
00:02:50,830 --> 00:02:56,200
what they look like or at least this is

71
00:02:52,599 --> 00:02:58,780
a artist impression of what they look

72
00:02:56,199 --> 00:03:01,810
like correct that is right so what you

73
00:02:58,780 --> 00:03:03,640
can see here is the disk of our Milky

74
00:03:01,810 --> 00:03:05,259
Way this is a side-on view of what our

75
00:03:03,639 --> 00:03:07,989
galaxy would look like from someone

76
00:03:05,259 --> 00:03:10,299
sitting outside the disk of the galaxy

77
00:03:07,990 --> 00:03:13,600
comes across at a diagonal there and

78
00:03:10,300 --> 00:03:16,240
those two purple lobes are centered on

79
00:03:13,599 --> 00:03:21,069
the the core of the galaxy in the center

80
00:03:16,240 --> 00:03:23,680
of the Milky Way you can see there is a

81
00:03:21,069 --> 00:03:26,530
lot of emission along the base of the

82
00:03:23,680 --> 00:03:28,420
lobes as you get closest to the center

83
00:03:26,530 --> 00:03:30,819
of the galaxy and these things they're

84
00:03:28,419 --> 00:03:32,229
really emitting light all across the

85
00:03:30,819 --> 00:03:34,269
electromagnetic spectrum they were

86

00:03:32,229 --> 00:03:37,030
discovered in gamma rays it turns out

87
00:03:34,270 --> 00:03:39,850
they also emit x-rays being microwaves

88
00:03:37,030 --> 00:03:41,650
and radio waves so they've started to be

89
00:03:39,849 --> 00:03:43,959
studied all these different wavelengths

90
00:03:41,650 --> 00:03:45,400
and we're piecing together the

91
00:03:43,959 --> 00:03:46,539
information we're getting from those

92
00:03:45,400 --> 00:03:48,010
different wavelengths to try and

93
00:03:46,539 --> 00:03:50,379
understand where they come from what

94
00:03:48,009 --> 00:03:52,239
they're doing so you see as you said at

95
00:03:50,379 --> 00:03:54,039
the beginning this is we've known about

96
00:03:52,240 --> 00:03:56,770
these for about five years obviously

97
00:03:54,039 --> 00:03:59,349
this is a vantage point that sadly we

98
00:03:56,770 --> 00:04:01,830
can never observe these things from but

99
00:03:59,349 --> 00:04:05,199
we do have you do have some of the

100
00:04:01,830 --> 00:04:07,570

images of the of these bubbles in the

101

00:04:05,199 --> 00:04:12,039

Fermi data correct that is absolutely

102

00:04:07,569 --> 00:04:14,079

right okay in in the Fermi data you

103

00:04:12,039 --> 00:04:17,459

certainly see these two lobes they look

104

00:04:14,080 --> 00:04:20,430

like balloons so can you put those up

105

00:04:17,459 --> 00:04:23,199

above and below the center of the galaxy

106

00:04:20,430 --> 00:04:23,620

I'll just wait for those to come up yeah

107

00:04:23,199 --> 00:04:26,349

here we are

108

00:04:23,620 --> 00:04:27,939

thanks god this is uh so this is an

109

00:04:26,350 --> 00:04:31,030

all-sky map

110

00:04:27,939 --> 00:04:31,540

it shows the full night sky just as we

111

00:04:31,029 --> 00:04:33,339

used to

112

00:04:31,540 --> 00:04:35,379

projecting you know there's the surface

113

00:04:33,339 --> 00:04:37,539

of the earth onto a map we do the same

114

00:04:35,379 --> 00:04:40,389

thing in so-called galactic coordinates

115
00:04:37,540 --> 00:04:42,310
and you can see right across the middle

116
00:04:40,389 --> 00:04:44,439
of this map that's what we call the

117
00:04:42,310 --> 00:04:46,329
Galactic equator that's the disk of the

118
00:04:44,439 --> 00:04:48,129
galaxy where almost all the stars in our

119
00:04:46,329 --> 00:04:50,079
galaxy are located is in that disk

120
00:04:48,129 --> 00:04:51,819
that's that bright band that's this is

121
00:04:50,079 --> 00:04:53,859
right bad okay so let's talk a little

122
00:04:51,819 --> 00:04:55,540
bit about where is Fermi I'll at when

123
00:04:53,860 --> 00:04:57,850
it's taking is it is it in orbit above

124
00:04:55,540 --> 00:04:59,770
Earth is it somewhere in the solar it

125
00:04:57,850 --> 00:05:01,600
says somewhere relatively close to Earth

126
00:04:59,769 --> 00:05:03,009
correct very close - that's right so

127
00:05:01,600 --> 00:05:04,750
it's in it's in orbit around the Earth

128
00:05:03,009 --> 00:05:08,889
very similar to the way that Hubble is

129
00:05:04,750 --> 00:05:12,040
okay so this is the the image you get

130
00:05:08,889 --> 00:05:14,680
basically looking from the earth and if

131
00:05:12,040 --> 00:05:16,450
it's this map is centered so that if you

132
00:05:14,680 --> 00:05:18,550
look towards the galactic center that's

133
00:05:16,449 --> 00:05:22,360
right in the center here of the image

134
00:05:18,550 --> 00:05:24,730
and you see there's two orange red lobes

135
00:05:22,360 --> 00:05:25,900
going out to either side what we call

136
00:05:24,730 --> 00:05:28,330
the northern hemisphere in a Sun

137
00:05:25,899 --> 00:05:29,889
hemisphere of the galaxy they're not

138
00:05:28,329 --> 00:05:31,839
quite symmetric there's a little bit

139
00:05:29,889 --> 00:05:34,629
more of the emission in the north and in

140
00:05:31,839 --> 00:05:38,019
the south but you do see the the same

141
00:05:34,629 --> 00:05:40,870
height extending into the into the halo

142
00:05:38,019 --> 00:05:42,519
of the galaxy in both sides and this is

143

00:05:40,870 --> 00:05:45,100
the raw data there was actually

144
00:05:42,519 --> 00:05:49,629
discovered from that Fermi satellite

145
00:05:45,100 --> 00:05:52,930
that it led to people dubbing them the

146
00:05:49,629 --> 00:05:54,430
Fermi bubbles yeah so these were so

147
00:05:52,930 --> 00:05:57,129
these were first observed in gamma rays

148
00:05:54,430 --> 00:05:59,560
and this is what our sky looks like in

149
00:05:57,129 --> 00:06:01,870
gamma rays there's also so the disk

150
00:05:59,560 --> 00:06:04,990
itself is very bright you see a lot of

151
00:06:01,870 --> 00:06:07,750
lot of photons there one of the colors

152
00:06:04,990 --> 00:06:10,930
mean well it's colored it's color-coded

153
00:06:07,750 --> 00:06:12,370
by the intensity by how bright in gamma

154
00:06:10,930 --> 00:06:15,389
rays it is but I should point out that

155
00:06:12,370 --> 00:06:18,668
the disk here they've actually

156
00:06:15,389 --> 00:06:20,469
subtracted off the contribution from the

157
00:06:18,668 --> 00:06:25,779

disk because the disk is glowing in

158

00:06:20,470 --> 00:06:27,520

gamma rays much brighter than the Fermi

159

00:06:25,779 --> 00:06:30,250

levels and the Sun they're smaller

160

00:06:27,519 --> 00:06:32,139

oh so in order to see it at all you had

161

00:06:30,250 --> 00:06:33,668

you have to subtract all that out you

162

00:06:32,139 --> 00:06:36,478

have to subtract off the disk and that

163

00:06:33,668 --> 00:06:39,310

is actually quite a complicated process

164

00:06:36,478 --> 00:06:40,870

this is a this is a cleaned up map that

165

00:06:39,310 --> 00:06:45,459

you're seeing right here

166

00:06:40,870 --> 00:06:47,110

which brings out the size is that why

167

00:06:45,459 --> 00:06:48,758

those are those those black areas there

168

00:06:47,110 --> 00:06:51,189

is that did that come out of the indi

169

00:06:48,759 --> 00:06:53,080

subtraction that's right yes okay all

170

00:06:51,189 --> 00:06:55,180

right please you subtracted out the

171

00:06:53,079 --> 00:06:57,788

contribution of the disk because it's so

172
00:06:55,180 --> 00:06:59,259
bright and gamma rays that you can't see

173
00:06:57,788 --> 00:07:02,139
these lobes now you can see the lobes

174
00:06:59,259 --> 00:07:05,370
and what we have is we can see kind of a

175
00:07:02,139 --> 00:07:08,050
little map of our own all-sky map of the

176
00:07:05,370 --> 00:07:10,870
of gamma and gamma rays are these other

177
00:07:08,050 --> 00:07:13,449
features like the ones that are like in

178
00:07:10,870 --> 00:07:16,209
the upper right part of the lobe there

179
00:07:13,449 --> 00:07:18,310
is is that part of our galaxy or is that

180
00:07:16,209 --> 00:07:21,218
background sky is that part of the lobes

181
00:07:18,310 --> 00:07:23,228
how do you know well it's very hard to

182
00:07:21,218 --> 00:07:25,180
know and actually that's so that's an

183
00:07:23,228 --> 00:07:27,098
open question you as you see as you go

184
00:07:25,180 --> 00:07:29,468
up into the northern Fermi bubble you

185
00:07:27,098 --> 00:07:32,050
keep going to the north you do see that

186
00:07:29,468 --> 00:07:33,819
oranjee region and that some of that may

187
00:07:32,050 --> 00:07:35,829
be associated physically with the Fermi

188
00:07:33,819 --> 00:07:36,400
bubbles but some of it could be in the

189
00:07:35,829 --> 00:07:38,468
foreground

190
00:07:36,399 --> 00:07:40,870
I mean there are spiral arms of our

191
00:07:38,468 --> 00:07:43,050
galaxy between us and a galactic center

192
00:07:40,870 --> 00:07:46,180
and those spiral arms can blow up

193
00:07:43,050 --> 00:07:48,340
material it can blow gas us into the

194
00:07:46,180 --> 00:07:50,379
halo which can also end up giving you X

195
00:07:48,339 --> 00:07:52,478
where I mentioned gamma-ray emission so

196
00:07:50,379 --> 00:07:56,289
it's actually very hard to tell from a

197
00:07:52,478 --> 00:07:57,610
map like this what is very close to the

198
00:07:56,288 --> 00:08:00,668
galactic center and what is somewhere

199
00:07:57,610 --> 00:08:02,889
else we'll get into that's where the

200

00:08:00,668 --> 00:08:05,680
Hubble data is actually very useful

201
00:08:02,889 --> 00:08:06,879
because Hubble is able to look at this

202
00:08:05,680 --> 00:08:09,370
from a different perspective from a

203
00:08:06,879 --> 00:08:10,778
different angle with its different types

204
00:08:09,370 --> 00:08:12,819
of data and that can give you more

205
00:08:10,778 --> 00:08:14,649
information about where things are so

206
00:08:12,819 --> 00:08:16,449
based on this image all we know is where

207
00:08:14,649 --> 00:08:19,658
it's bright and gamma rays we don't know

208
00:08:16,449 --> 00:08:22,180
how far away it is or where you know any

209
00:08:19,658 --> 00:08:24,250
any location information you got it

210
00:08:22,180 --> 00:08:26,228
exactly all this is is total intensity

211
00:08:24,250 --> 00:08:29,139
so it's got to be careful with this

212
00:08:26,228 --> 00:08:31,149
alone what you really understand and

213
00:08:29,139 --> 00:08:32,349
what you don't okay you also took the is

214
00:08:31,149 --> 00:08:34,319

we also have images in other wavelengths

215

00:08:32,349 --> 00:08:37,930

don't we that's correct

216

00:08:34,320 --> 00:08:40,240

so I have a question so that loopy thing

217

00:08:37,929 --> 00:08:43,658

off to the left

218

00:08:40,240 --> 00:08:45,579

what are those loopy things do you have

219

00:08:43,658 --> 00:08:47,559

you figured out what those loops are are

220

00:08:45,578 --> 00:08:50,759

you talking about to the far left of the

221

00:08:47,559 --> 00:08:50,759

image here no no and

222

00:08:54,860 --> 00:09:01,320

hi Jerry yes um again this could be this

223

00:08:59,970 --> 00:09:03,570

could be related to the southern

224

00:09:01,320 --> 00:09:05,940

fermi-level but it's not a definitive

225

00:09:03,570 --> 00:09:07,950

connection we don't know for sure though

226

00:09:05,940 --> 00:09:10,260

that the distance of the galactic center

227

00:09:07,950 --> 00:09:14,009

oh right right

228

00:09:10,259 --> 00:09:15,480

just very suggestive okay Thanks so we

229
00:09:14,009 --> 00:09:17,069
saw these things in gamma rays and then

230
00:09:15,480 --> 00:09:18,420
we looked at it in other wavelengths sky

231
00:09:17,070 --> 00:09:20,450
you want to put it up of another one up

232
00:09:18,419 --> 00:09:22,799
there we go what here we are in

233
00:09:20,450 --> 00:09:24,089
microwave and radio and it's real

234
00:09:22,799 --> 00:09:26,159
they're really bright in there too

235
00:09:24,089 --> 00:09:29,640
that's right now this is a microwave

236
00:09:26,159 --> 00:09:30,838
image and the sharp-eyed viewers looking

237
00:09:29,639 --> 00:09:33,059
at this will notice that this is

238
00:09:30,839 --> 00:09:35,850
actually from 2004 which is before the

239
00:09:33,059 --> 00:09:39,689
Fermi bubbles were formally discovered

240
00:09:35,850 --> 00:09:45,028
okay this is from a 2004 reason for that

241
00:09:39,690 --> 00:09:46,860
is there had been this this glow above

242
00:09:45,028 --> 00:09:49,259
and below the center of the galaxy and

243
00:09:46,860 --> 00:09:52,409
microwaves but no one was really sure

244
00:09:49,259 --> 00:09:54,179
whether that was a real signal or

245
00:09:52,409 --> 00:09:56,549
whether it was something to do with the

246
00:09:54,179 --> 00:09:58,169
way that you subtract the disk because

247
00:09:56,549 --> 00:09:59,549
just like with the last image you can

248
00:09:58,169 --> 00:10:01,169
see the black man in the middle here

249
00:09:59,549 --> 00:10:03,120
that's where the disk of our galaxy

250
00:10:01,169 --> 00:10:07,199
emits microwaves and that has to be

251
00:10:03,120 --> 00:10:09,328
subtracted off so there was a hint of

252
00:10:07,200 --> 00:10:12,450
something going on in the microwave data

253
00:10:09,328 --> 00:10:14,849
from 2004 but when the gamma ray data

254
00:10:12,450 --> 00:10:17,310
came out in 2010 then you know it was

255
00:10:14,850 --> 00:10:18,720
bright in the same regions we have the

256
00:10:17,309 --> 00:10:21,000
lobes both in the north in the south

257

00:10:18,720 --> 00:10:23,100
then because you're seeing the signal at

258
00:10:21,000 --> 00:10:24,419
totally different wavelengths people

259
00:10:23,100 --> 00:10:26,759
really believed it and you that that was

260
00:10:24,419 --> 00:10:30,269
a genuine structure that they had

261
00:10:26,759 --> 00:10:32,240
detected okay so these are since this is

262
00:10:30,269 --> 00:10:34,500
a relatively new discovery do we know

263
00:10:32,240 --> 00:10:37,110
anything else about we do we know why

264
00:10:34,500 --> 00:10:40,950
they're there I mean are these lobes a

265
00:10:37,110 --> 00:10:43,050
common occurrence in in galaxies so

266
00:10:40,950 --> 00:10:45,028
there's a - very good questions on the

267
00:10:43,049 --> 00:10:49,679
first one why they're there

268
00:10:45,028 --> 00:10:51,958
we have we have two basic ideas of where

269
00:10:49,679 --> 00:10:54,149
they are coming from and what is

270
00:10:51,958 --> 00:10:55,439
powering them and they're both to do

271
00:10:54,149 --> 00:10:57,299

with the center of the Milky Way because

272

00:10:55,440 --> 00:10:59,550

we know that the center of the galaxy is

273

00:10:57,299 --> 00:11:01,229

a very energetic place and we know

274

00:10:59,549 --> 00:11:04,229

there's a supermassive black hole there

275

00:11:01,230 --> 00:11:06,389

with a mass several million times as

276

00:11:04,230 --> 00:11:07,200

high as the sun's mass so one

277

00:11:06,389 --> 00:11:09,330

possibility

278

00:11:07,200 --> 00:11:11,610

is that that supermassive black hole at

279

00:11:09,330 --> 00:11:13,770

the center of our galaxy is accreting

280

00:11:11,610 --> 00:11:16,019

matter from its surroundings and after

281

00:11:13,769 --> 00:11:18,269

the gas accretes towards the black hole

282

00:11:16,019 --> 00:11:21,389

it gets ejected and blown out into the

283

00:11:18,269 --> 00:11:24,809

halo and that blow out can create these

284

00:11:21,389 --> 00:11:26,069

bubbles another possibility is but only

285

00:11:24,809 --> 00:11:28,019

when it's blowing out right because

286
00:11:26,070 --> 00:11:30,450
right now for example it's not really

287
00:11:28,019 --> 00:11:31,980
eating anything up so late so only when

288
00:11:30,450 --> 00:11:34,170
it's active yeah because we know that

289
00:11:31,980 --> 00:11:35,550
black holes have active phases or not

290
00:11:34,169 --> 00:11:37,919
active phases so if it's actively

291
00:11:35,549 --> 00:11:41,189
accreting gas then it would be driving

292
00:11:37,919 --> 00:11:42,809
stuff out into the halo if it's in a

293
00:11:41,190 --> 00:11:46,110
quiet phase it wouldn't be doing that so

294
00:11:42,809 --> 00:11:48,779
that's definitely a stop-start episodic

295
00:11:46,110 --> 00:11:53,100
type of event so that's the black hole

296
00:11:48,779 --> 00:11:57,089
theory the other idea is whether star

297
00:11:53,100 --> 00:11:58,800
formation can be driving these bubbles

298
00:11:57,090 --> 00:12:01,290
into the halo so when you get star

299
00:11:58,799 --> 00:12:03,479
formation happening at a very high rate

300
00:12:01,289 --> 00:12:05,459
in other words lots of stars forming

301
00:12:03,480 --> 00:12:07,139
lots of stars running out of fuel some

302
00:12:05,460 --> 00:12:10,139
of them will go will turn into supernova

303
00:12:07,139 --> 00:12:11,730
supernova can explode and drive gas out

304
00:12:10,139 --> 00:12:13,830
of the disk of the galaxy up into the

305
00:12:11,730 --> 00:12:15,870
halo and we know that there are a lot of

306
00:12:13,830 --> 00:12:16,980
very massive stars close to the center

307
00:12:15,870 --> 00:12:19,409
of the galaxy because they've been

308
00:12:16,980 --> 00:12:20,879
observed so it could be that there was

309
00:12:19,409 --> 00:12:23,569
massive stars near the center of the

310
00:12:20,879 --> 00:12:28,110
galaxy have been turning into supernovae

311
00:12:23,570 --> 00:12:30,990
blowing bubbles out into the into what

312
00:12:28,110 --> 00:12:33,029
is now called the Fermi bubble so the

313
00:12:30,990 --> 00:12:35,070
we're not sure which of those two it is

314

00:12:33,029 --> 00:12:37,079
that is actually dominating but most of

315
00:12:35,070 --> 00:12:38,610
the rapidstar are the the active star

316
00:12:37,080 --> 00:12:41,070
formation in our galaxy isn't it going

317
00:12:38,610 --> 00:12:43,050
on at the leading edges of the spiral

318
00:12:41,070 --> 00:12:46,410
arms mostly and or it is the center of

319
00:12:43,049 --> 00:12:48,809
the galaxy hi active activity in star

320
00:12:46,409 --> 00:12:51,839
burn it is there's a lot of starburst

321
00:12:48,809 --> 00:12:53,729
activity in the nucleus of the galaxy it

322
00:12:51,840 --> 00:12:57,680
just as there also is in the spiral arms

323
00:12:53,730 --> 00:13:00,450
as you say but if you look at how much

324
00:12:57,679 --> 00:13:02,879
how much deformation is going on like

325
00:13:00,450 --> 00:13:05,430
per unit area of the disk is very high

326
00:13:02,879 --> 00:13:06,809
near the center of the galaxy and that's

327
00:13:05,429 --> 00:13:09,000
that's the number that you want to be

328
00:13:06,809 --> 00:13:11,129

high to to be able to drive out of wind

329

00:13:09,000 --> 00:13:14,120

I think we have one more slide in

330

00:13:11,129 --> 00:13:17,189

another wavelength is that true actually

331

00:13:14,120 --> 00:13:18,029

it's just this one okay okay so I wanted

332

00:13:17,190 --> 00:13:21,240

to make sure I got all the wavelengths

333

00:13:18,029 --> 00:13:23,039

that we had so and again again the black

334

00:13:21,240 --> 00:13:26,129

fanta cost there is the subtraction of

335

00:13:23,039 --> 00:13:27,809

the disk of our galaxy in there this

336

00:13:26,129 --> 00:13:30,419

doesn't so that you can actually see

337

00:13:27,809 --> 00:13:32,939

these things because the the signal from

338

00:13:30,419 --> 00:13:34,679

the disk is so strong correct yes it's

339

00:13:32,940 --> 00:13:36,510

really a contrast thing because if you

340

00:13:34,679 --> 00:13:37,919

put on that disk emission it would be so

341

00:13:36,509 --> 00:13:39,990

bright that everything else in the

342

00:13:37,919 --> 00:13:42,479

background would be lost in a noise okay

343
00:13:39,990 --> 00:13:43,950
so I have it okay so I have a question

344
00:13:42,480 --> 00:13:45,149
from Seb dust bunny I'm gonna go ahead

345
00:13:43,950 --> 00:13:46,620
and read it it's a little bit ahead of

346
00:13:45,149 --> 00:13:49,500
where I wanted to be but he goes has

347
00:13:46,620 --> 00:13:52,080
evidence of these bubbles seen in other

348
00:13:49,500 --> 00:13:54,269
galaxies and does it require a side-on

349
00:13:52,080 --> 00:13:56,730
view so that one goes back to my

350
00:13:54,269 --> 00:13:58,769
question or how common are these do you

351
00:13:56,730 --> 00:14:01,649
have any sense of things been seen in

352
00:13:58,769 --> 00:14:04,350
other galaxies at all so as far as

353
00:14:01,649 --> 00:14:07,528
gamma-ray bubbles go the answer is no we

354
00:14:04,350 --> 00:14:09,600
don't have any cases of other galaxies

355
00:14:07,528 --> 00:14:14,278
where we've seen these the problem is

356
00:14:09,600 --> 00:14:15,810
that we're not sensitive to detecting a

357
00:14:14,278 --> 00:14:17,490
gamma-ray emission from other galaxies

358
00:14:15,809 --> 00:14:19,319
in other words the reason we're not

359
00:14:17,490 --> 00:14:21,240
seeing them is not necessarily that they

360
00:14:19,320 --> 00:14:23,550
don't exist but it's that the light

361
00:14:21,240 --> 00:14:25,709
would be so faint that our telescopes

362
00:14:23,549 --> 00:14:27,659
aren't able to detect it and say whether

363
00:14:25,708 --> 00:14:29,129
it's there or not so our gamma-ray

364
00:14:27,659 --> 00:14:30,269
telescopes aren't powerful enough that's

365
00:14:29,129 --> 00:14:32,750
what you're saying that's another way of

366
00:14:30,269 --> 00:14:34,980
saying it so the satellite is is

367
00:14:32,750 --> 00:14:37,200
sensitive enough that it can see these

368
00:14:34,980 --> 00:14:38,610
bubbles in a milky way but even then it

369
00:14:37,200 --> 00:14:40,230
took this very careful job of

370
00:14:38,610 --> 00:14:42,120
subtracting the emission from the disk

371

00:14:40,230 --> 00:14:43,680
and a lot of processing to do that so

372
00:14:42,120 --> 00:14:46,110
that was a very challenging discovery

373
00:14:43,679 --> 00:14:48,509
even in our own Milky Way so when you go

374
00:14:46,110 --> 00:14:50,399
to another galaxy which is much further

375
00:14:48,509 --> 00:14:52,828
away so the emission is much fainter

376
00:14:50,399 --> 00:14:54,570
once by the time it's got to us it's so

377
00:14:52,828 --> 00:14:56,759
challenging that we haven't been able to

378
00:14:54,570 --> 00:14:58,829
see them but even is that true even for

379
00:14:56,759 --> 00:15:00,929
the more nearby galaxies I mean the last

380
00:14:58,828 --> 00:15:03,149
part of his question is or could this

381
00:15:00,929 --> 00:15:05,039
image or could imaging this in Andromeda

382
00:15:03,149 --> 00:15:06,570
be tried could you see that's maybe in a

383
00:15:05,039 --> 00:15:09,629
closed galaxy like the Andromeda galaxy

384
00:15:06,570 --> 00:15:12,180
you could try this in x-rays in

385
00:15:09,629 --> 00:15:13,919

Andromeda certainly in radio waves so in

386

00:15:12,179 --> 00:15:17,399

other wavelengths it's certainly true

387

00:15:13,919 --> 00:15:19,528

that we've seen extended halos and even

388

00:15:17,399 --> 00:15:24,120

bubble type structures in galaxies and

389

00:15:19,528 --> 00:15:26,338

galaxy clusters so particularly radio

390

00:15:24,120 --> 00:15:28,190

waves people have studied bubble

391

00:15:26,339 --> 00:15:30,959

structures in radio waves in other

392

00:15:28,190 --> 00:15:32,970

galaxies for some time but the gamma ray

393

00:15:30,958 --> 00:15:34,859

part of it and they and that's what led

394

00:15:32,970 --> 00:15:37,889

to this Fermi bubble name

395

00:15:34,860 --> 00:15:41,610

at the moment that's our own galaxy even

396

00:15:37,889 --> 00:15:44,879

Andromeda the closest big spiral galaxy

397

00:15:41,610 --> 00:15:46,230

to the Milky Way would if it had Fermi

398

00:15:44,879 --> 00:15:48,240

bubbles that were the same size as the

399

00:15:46,230 --> 00:15:50,610

Milky Way they would be too faint for us

400
00:15:48,240 --> 00:15:52,169
to see without current telescopes got it

401
00:15:50,610 --> 00:15:54,570
okay thanks ed that was a good question

402
00:15:52,169 --> 00:15:56,279
and so it would seem to me like you said

403
00:15:54,570 --> 00:15:58,620
there's two prevailing theories about

404
00:15:56,279 --> 00:16:01,500
what's causing these things and one of

405
00:15:58,620 --> 00:16:03,269
them was the black hole our supermassive

406
00:16:01,500 --> 00:16:06,629
black hole in the center of our galaxy I

407
00:16:03,269 --> 00:16:07,919
wonder wouldn't there be an NR and of

408
00:16:06,629 --> 00:16:10,259
course there are active and inactive

409
00:16:07,919 --> 00:16:12,329
periods of that black hole don't you

410
00:16:10,259 --> 00:16:15,539
think that would have a characteristic

411
00:16:12,330 --> 00:16:19,100
pattern to it if to these bubbles if it

412
00:16:15,539 --> 00:16:23,669
were sometimes being contributed to by a

413
00:16:19,100 --> 00:16:25,889
black hole Jets and other times not you

414
00:16:23,669 --> 00:16:27,719
understand what I'm asking yeah so

415
00:16:25,889 --> 00:16:30,509
wouldn't you expect to see some kind of

416
00:16:27,720 --> 00:16:33,540
I don't know rings or patterning to the

417
00:16:30,509 --> 00:16:37,169
bubbles yes I see what you're saying

418
00:16:33,539 --> 00:16:38,579
so we happen to have observed the

419
00:16:37,169 --> 00:16:43,110
bubbles as they are right now

420
00:16:38,580 --> 00:16:45,480
so our work with the Hubble telescope

421
00:16:43,110 --> 00:16:47,129
has actually given us an age of how long

422
00:16:45,480 --> 00:16:49,379
has it taken the gas to flow out from

423
00:16:47,129 --> 00:16:51,120
the center of the galaxy to where we

424
00:16:49,379 --> 00:16:53,789
observe it in this outflow where it's

425
00:16:51,120 --> 00:16:55,590
feeding the Fermi bubbles okay and that

426
00:16:53,789 --> 00:16:59,039
age is to about two or three million

427
00:16:55,590 --> 00:17:00,570
years so what not saying is that we two

428

00:16:59,039 --> 00:17:02,519
or three million years ago there was an

429
00:17:00,570 --> 00:17:06,330
event at the galactic center which blew

430
00:17:02,519 --> 00:17:08,309
out material and it is currently reached

431
00:17:06,329 --> 00:17:10,169
where we see it on the sky if someone

432
00:17:08,309 --> 00:17:12,960
was to come back in another two million

433
00:17:10,170 --> 00:17:14,700
years from now or you know whatever

434
00:17:12,960 --> 00:17:16,650
number of million years and observe it

435
00:17:14,700 --> 00:17:18,750
they would find the structure has got to

436
00:17:16,650 --> 00:17:20,310
a different stage so we're only looking

437
00:17:18,750 --> 00:17:23,430
at it at one point in time that's the

438
00:17:20,309 --> 00:17:25,019
difficulty and we've been able to chart

439
00:17:23,430 --> 00:17:27,210
how it's changing then we could really

440
00:17:25,019 --> 00:17:30,210
see how often is it expanding or is it

441
00:17:27,210 --> 00:17:32,190
going to reach maximum size okay we're

442
00:17:30,210 --> 00:17:33,960

just limited by the fact we can only see

443

00:17:32,190 --> 00:17:35,910

it right now at the current time you got

444

00:17:33,960 --> 00:17:41,870

it okay that's good so let's get to your

445

00:17:35,910 --> 00:17:41,870

measurements then so you looked at these

446

00:17:42,079 --> 00:17:46,199

bubbles are in a very interesting way

447

00:17:44,579 --> 00:17:47,589

they would turn Zout there was a quasar

448

00:17:46,200 --> 00:17:50,390

that happened

449

00:17:47,589 --> 00:17:52,730

to be in a certain location that was

450

00:17:50,390 --> 00:17:54,500

very fortuitous why don't you want you

451

00:17:52,730 --> 00:17:59,210

give us the background of the

452

00:17:54,500 --> 00:18:00,769

observations that you made sure so if we

453

00:17:59,210 --> 00:18:01,610

can pull up the slide to help show this

454

00:18:00,769 --> 00:18:02,900

that would be great

455

00:18:01,609 --> 00:18:04,839

that's right there's a schematic if you

456

00:18:02,900 --> 00:18:07,070

could do that Scot thank you what we've

457
00:18:04,839 --> 00:18:11,269
what we've been doing is thinking about

458
00:18:07,069 --> 00:18:13,490
how to use the Hubble telescope to study

459
00:18:11,269 --> 00:18:15,379
these Fermi bubbles and here you can see

460
00:18:13,490 --> 00:18:16,640
this is another side on view of what

461
00:18:15,380 --> 00:18:18,920
these things would look like from the

462
00:18:16,640 --> 00:18:21,020
outside of galaxy you know the Hubble

463
00:18:18,920 --> 00:18:24,259
telescope is over there in the disk on

464
00:18:21,019 --> 00:18:27,980
the right now we identified quasars that

465
00:18:24,259 --> 00:18:31,099
is very bright sources of radiation that

466
00:18:27,980 --> 00:18:34,279
happened to lie behind the bubbles so

467
00:18:31,099 --> 00:18:36,669
there's the sight line in yellow towards

468
00:18:34,279 --> 00:18:39,079
a bright quasar which in our case was

469
00:18:36,670 --> 00:18:41,660
just at the right place of the sky it

470
00:18:39,079 --> 00:18:43,879
had the right coordinates to lie close

471
00:18:41,660 --> 00:18:47,120
to the bottom of the northern fermi

472
00:18:43,880 --> 00:18:48,770
bubble one of the two bubbles and what

473
00:18:47,119 --> 00:18:50,539
we can do is we can take the light from

474
00:18:48,769 --> 00:18:53,000
this quasar in fact the ultraviolet

475
00:18:50,539 --> 00:18:54,980
light which Hubble is sensitive to

476
00:18:53,000 --> 00:18:57,410
because it's up in orbit above the

477
00:18:54,980 --> 00:18:58,730
Earth's atmosphere so it can it can make

478
00:18:57,410 --> 00:19:00,200
measurements all the way down into the

479
00:18:58,730 --> 00:19:02,450
ultraviolet which you can't do from the

480
00:19:00,200 --> 00:19:04,730
ground and by analyzing that ultraviolet

481
00:19:02,450 --> 00:19:08,539
light we can say something about the

482
00:19:04,730 --> 00:19:10,610
outflowing gas in the Fermi bubble and

483
00:19:08,539 --> 00:19:12,710
the reason is is that that outflowing

484
00:19:10,609 --> 00:19:14,899
gas leaves its signature in the

485

00:19:12,710 --> 00:19:18,380
ultraviolet light it leaves a signature

486
00:19:14,900 --> 00:19:21,259
in which frequencies of light which

487
00:19:18,380 --> 00:19:24,559
colors of light are absorbed and taken

488
00:19:21,259 --> 00:19:26,509
out of there of the spectrum so we do

489
00:19:24,558 --> 00:19:30,279
what we call a spectroscopic analysis

490
00:19:26,509 --> 00:19:32,359
and we measure lines of certain elements

491
00:19:30,279 --> 00:19:33,769
spectral lines which appear in the

492
00:19:32,359 --> 00:19:36,558
ultraviolet and that's a way of

493
00:19:33,769 --> 00:19:39,230
measuring the the properties of the gas

494
00:19:36,558 --> 00:19:41,359
that's in these bubbles and that was how

495
00:19:39,230 --> 00:19:44,558
we were able for the first time to

496
00:19:41,359 --> 00:19:47,149
measure what is the velocity of the gas

497
00:19:44,558 --> 00:19:49,428
coming out of the milky way's nucleus

498
00:19:47,150 --> 00:19:50,900
into the Fermi levels and we were also

499
00:19:49,429 --> 00:19:53,380

able to say something about what's its

500

00:19:50,900 --> 00:19:56,419

compositions and which elements are

501

00:19:53,380 --> 00:19:57,830

actually present in that gas because

502

00:19:56,419 --> 00:19:59,870

that also gives you a clue about where

503

00:19:57,829 --> 00:20:01,039

these things came from okay let's start

504

00:19:59,869 --> 00:20:02,869

with what they're made of for

505

00:20:01,039 --> 00:20:03,980

what did you discover what's what are

506

00:20:02,869 --> 00:20:06,109

these cat what are these clouds made of

507

00:20:03,980 --> 00:20:10,730

so the elements that we detected are

508

00:20:06,109 --> 00:20:13,909

silicon carbon and aluminum each of

509

00:20:10,730 --> 00:20:15,440

those elements has several of these

510

00:20:13,910 --> 00:20:16,759

spectral lines that fall in the

511

00:20:15,440 --> 00:20:18,289

ultraviolet that we can measure or we

512

00:20:16,759 --> 00:20:21,069

can see how strong how much of these

513

00:20:18,289 --> 00:20:23,690

elements are present in the in the gas

514
00:20:21,069 --> 00:20:26,269
sorry do you do you have the spectrum

515
00:20:23,690 --> 00:20:32,870
I was just going to say it looks like

516
00:20:26,269 --> 00:20:37,099
it's not okay on the image press release

517
00:20:32,869 --> 00:20:39,349
but we can use this one okay so this is

518
00:20:37,099 --> 00:20:41,299
this is the sort of data that we that we

519
00:20:39,349 --> 00:20:45,019
really work with when we get down to the

520
00:20:41,299 --> 00:20:46,639
details of analyzing the the Hubble data

521
00:20:45,019 --> 00:20:48,579
this is the spectrum which shows

522
00:20:46,640 --> 00:20:51,290
intensity or how much light there is

523
00:20:48,579 --> 00:20:53,419
against velocity along the line of sight

524
00:20:51,289 --> 00:20:55,430
and this is for a particular line this

525
00:20:53,420 --> 00:20:56,870
is twice ionized silicon and silicon

526
00:20:55,430 --> 00:21:00,980
atoms that have had two electrons

527
00:20:56,869 --> 00:21:03,109
removed from them now that gives you a

528
00:21:00,980 --> 00:21:04,519
feature at a very certain wavelength in

529
00:21:03,109 --> 00:21:05,929
the spectrum and we know exactly where

530
00:21:04,519 --> 00:21:09,170
that is in the spectrum so we know where

531
00:21:05,930 --> 00:21:10,730
to look what you see here is different

532
00:21:09,170 --> 00:21:12,350
components and those components are

533
00:21:10,730 --> 00:21:15,069
shaded in different colors this one

534
00:21:12,349 --> 00:21:18,709
shaded in blue at negative velocities

535
00:21:15,069 --> 00:21:21,950
two on the on the other side at positive

536
00:21:18,710 --> 00:21:23,750
velocities in yellow and in orange what

537
00:21:21,950 --> 00:21:26,990
this is telling you is it's basically

538
00:21:23,750 --> 00:21:30,170
using the Doppler effect the component

539
00:21:26,990 --> 00:21:31,789
that is shaded in blue that is moving

540
00:21:30,170 --> 00:21:36,080
towards us it's what we call blue

541
00:21:31,789 --> 00:21:39,710
shifted right it's gas that is we think

542

00:21:36,079 --> 00:21:41,659
on the near side of this outflowing cone

543
00:21:39,710 --> 00:21:43,759
of gas that comes out from the galactic

544
00:21:41,660 --> 00:21:45,980
center the yellow and the orange

545
00:21:43,759 --> 00:21:47,690
components are red shifted then light

546
00:21:45,980 --> 00:21:50,000
has been shifted towards the red and

547
00:21:47,690 --> 00:21:51,860
that's what you get from the far side of

548
00:21:50,000 --> 00:21:54,319
the outflow which is on the other side

549
00:21:51,859 --> 00:21:56,059
of the galactic center so just in this

550
00:21:54,319 --> 00:21:57,500
one sight line we can see these gas

551
00:21:56,059 --> 00:21:58,819
components some of which is coming

552
00:21:57,500 --> 00:22:01,160
towards you some of which is going away

553
00:21:58,819 --> 00:22:03,829
from you and that's exactly what you get

554
00:22:01,160 --> 00:22:07,460
from one of these nuclear outflows that

555
00:22:03,829 --> 00:22:09,500
comes out in a cone shaped pattern and

556
00:22:07,460 --> 00:22:10,759

so the silicon I'm going to get to the

557

00:22:09,500 --> 00:22:13,039
speeds and the velocities in just a

558

00:22:10,759 --> 00:22:15,140
minute but I want to I want to go what

559

00:22:13,039 --> 00:22:17,159
does the elements themselves

560

00:22:15,140 --> 00:22:19,200
telling you that does it give you any

561

00:22:17,160 --> 00:22:20,790
information about what their source

562

00:22:19,200 --> 00:22:23,400
might be what might be causing these

563

00:22:20,789 --> 00:22:25,339
well it does give you it does give you

564

00:22:23,400 --> 00:22:27,780
information but unfortunately it's not

565

00:22:25,339 --> 00:22:30,149
conclusive in telling you if it's the

566

00:22:27,779 --> 00:22:32,309
black hole or the star formation okay so

567

00:22:30,150 --> 00:22:34,050
look at the carbon and the aluminum we

568

00:22:32,309 --> 00:22:36,089
do know that those elements are all

569

00:22:34,049 --> 00:22:38,039
produced in stars in star formation they

570

00:22:36,089 --> 00:22:39,720
get they get forged in the cores of

571
00:22:38,039 --> 00:22:42,210
massive stars and they eventually do get

572
00:22:39,720 --> 00:22:44,610
released but what you don't know is how

573
00:22:42,210 --> 00:22:47,190
long ago that happened so it could have

574
00:22:44,609 --> 00:22:51,119
been that these elements are produced in

575
00:22:47,190 --> 00:22:52,799
stars they're released into the space

576
00:22:51,119 --> 00:22:55,589
between stars and then some of that gets

577
00:22:52,799 --> 00:22:57,599
accreted onto the the central black hole

578
00:22:55,589 --> 00:23:00,059
or it could have been that they just get

579
00:22:57,599 --> 00:23:03,179
loans directly out from from the

580
00:23:00,059 --> 00:23:05,099
supernovae in other words it doesn't

581
00:23:03,180 --> 00:23:06,840
really tell you for sure whether it's

582
00:23:05,099 --> 00:23:08,849
the star formation model or the black

583
00:23:06,839 --> 00:23:10,919
hole model but it does tell you that at

584
00:23:08,849 --> 00:23:14,149
some point this gas was processed

585
00:23:10,920 --> 00:23:16,860
through star formations clues to its

586
00:23:14,150 --> 00:23:18,150
origin so it's still there's still the

587
00:23:16,859 --> 00:23:21,119
jury's still out there's just not a

588
00:23:18,150 --> 00:23:23,130
there's not a conclusive fingerprint

589
00:23:21,119 --> 00:23:25,679
here in just the spectrum itself just

590
00:23:23,130 --> 00:23:27,630
the elements themselves so uh but I want

591
00:23:25,680 --> 00:23:29,310
to get to the velocity now and talk of

592
00:23:27,630 --> 00:23:30,540
so but before I do the Doppler effect

593
00:23:29,309 --> 00:23:32,700
that you're talking about let me just

594
00:23:30,539 --> 00:23:34,920
try and see if I can give a little bit a

595
00:23:32,700 --> 00:23:39,600
basic background on this if you take a

596
00:23:34,920 --> 00:23:42,810
spectrum of of an object at rest you

597
00:23:39,599 --> 00:23:45,779
will see certain lines dark and bright

598
00:23:42,809 --> 00:23:48,990
lines appear at it's very specific spots

599

00:23:45,779 --> 00:23:51,180
in the spectrum depending on what the

600
00:23:48,990 --> 00:23:53,220
element is and if that thing is moving

601
00:23:51,180 --> 00:23:54,600
what you will whatever it is you're

602
00:23:53,220 --> 00:23:56,700
measuring you will actually see all of

603
00:23:54,599 --> 00:23:59,159
those lines shifted one way or another

604
00:23:56,700 --> 00:24:00,750
and it will be shifted how much is

605
00:23:59,160 --> 00:24:02,640
shifted gives you an idea of how fast

606
00:24:00,750 --> 00:24:04,740
it's going and which direction it

607
00:24:02,640 --> 00:24:07,020
shifted tells you whether it's coming

608
00:24:04,740 --> 00:24:10,109
towards you or away from you so that is

609
00:24:07,019 --> 00:24:12,750
how the Doppler shift is used in spectra

610
00:24:10,109 --> 00:24:15,509
and you can see it in this in this graph

611
00:24:12,750 --> 00:24:18,720
alright so that the dotted line that

612
00:24:15,509 --> 00:24:22,400
goes horizontally is essentially the

613
00:24:18,720 --> 00:24:26,240

ambient intensity and the light comes

614

00:24:22,400 --> 00:24:27,778

light comes from another source and hits

615

00:24:26,240 --> 00:24:30,358

silicon atom

616

00:24:27,778 --> 00:24:32,940

and is absorbed and so that central line

617

00:24:30,358 --> 00:24:36,028

is most of the silicon but if that

618

00:24:32,940 --> 00:24:39,058

silicon atom is moving and in case many

619

00:24:36,028 --> 00:24:43,618

silicon atoms moving or sort of an above

620

00:24:39,058 --> 00:24:46,319

motion light has to when it's absorbed

621

00:24:43,618 --> 00:24:48,449

is shifted either if the material is

622

00:24:46,319 --> 00:24:51,479

moving towards us or away and our

623

00:24:48,450 --> 00:24:54,389

analogy is always the train whistle here

624

00:24:51,479 --> 00:24:56,909

I pitch a neutral tone and then the low

625

00:24:54,388 --> 00:24:59,248

pitch as a train goes past you if it's

626

00:24:56,909 --> 00:25:04,399

blowing its whistle the whole time so

627

00:24:59,249 --> 00:25:06,719

that's also how speed radar works so I

628
00:25:04,398 --> 00:25:08,158
actually once got out of a ticket

629
00:25:06,719 --> 00:25:09,389
because I explained the Doppler effect

630
00:25:08,159 --> 00:25:11,879
to a cop

631
00:25:09,388 --> 00:25:13,439
I don't know he gave me a warning

632
00:25:11,878 --> 00:25:15,868
because I had given him a physics lesson

633
00:25:13,440 --> 00:25:18,749
but anyway I wouldn't try them but

634
00:25:15,868 --> 00:25:21,509
anyway by physics

635
00:25:18,749 --> 00:25:23,219
yeah really so so that's how they tell

636
00:25:21,509 --> 00:25:24,899
that the material is moving because

637
00:25:23,219 --> 00:25:28,409
there's nothing else I'm sore being in

638
00:25:24,898 --> 00:25:31,228
that region except the silicon good so

639
00:25:28,409 --> 00:25:32,609
and so now now Andy why don't you tell

640
00:25:31,229 --> 00:25:34,919
us a little bit about these speeds then

641
00:25:32,608 --> 00:25:36,749
you've got them at more or less going

642
00:25:34,919 --> 00:25:38,849
out at about plus or minus 200

643
00:25:36,749 --> 00:25:41,788
kilometers per second right that's right

644
00:25:38,848 --> 00:25:44,189
so that these velocities are what we

645
00:25:41,788 --> 00:25:45,808
measure along the line of sight so in

646
00:25:44,190 --> 00:25:47,219
other words when you look towards this

647
00:25:45,808 --> 00:25:50,819
quasar which is close to the galactic

648
00:25:47,219 --> 00:25:52,859
center the blue stuff is coming towards

649
00:25:50,819 --> 00:25:55,648
you about minus 250 kilometers per

650
00:25:52,858 --> 00:25:58,528
second or so the orange component is

651
00:25:55,648 --> 00:26:00,778
plus 250 kilometers per second but what

652
00:25:58,528 --> 00:26:03,179
we have to do is we have to realize that

653
00:26:00,778 --> 00:26:05,690
we're just seeing a projection along our

654
00:26:03,179 --> 00:26:08,159
line of sight of the outflow because it

655
00:26:05,690 --> 00:26:11,249
our understanding is that most of the

656

00:26:08,159 --> 00:26:13,859
gas is moving directly out from the

657
00:26:11,249 --> 00:26:16,108
galactic center so up into the halo of

658
00:26:13,858 --> 00:26:17,699
the galaxy what you see is the

659
00:26:16,108 --> 00:26:19,528
projection of that onto our line of

660
00:26:17,700 --> 00:26:21,359
sight so we had to do a little bit of

661
00:26:19,528 --> 00:26:24,329
geometry to determine what is the

662
00:26:21,358 --> 00:26:26,189
outflow speed the actual the total

663
00:26:24,329 --> 00:26:28,199
velocity of the gas that moves away from

664
00:26:26,190 --> 00:26:30,269
the center of the galaxy because that's

665
00:26:28,200 --> 00:26:32,369
not the same as what we see along our

666
00:26:30,269 --> 00:26:35,038
line of sight I don't understand so you

667
00:26:32,368 --> 00:26:37,138
this is a measurement of one specific

668
00:26:35,038 --> 00:26:39,179
path of the better light that the quasar

669
00:26:37,138 --> 00:26:40,409
went through so you know about the gas

670
00:26:39,179 --> 00:26:42,240

right there

671

00:26:40,410 --> 00:26:44,580

you do and what what did you do now to

672

00:26:42,240 --> 00:26:47,160

figure out the rest I don't know so

673

00:26:44,579 --> 00:26:48,869

you're measuring along that line of

674

00:26:47,160 --> 00:26:51,630

sight towards this particular quasar

675

00:26:48,869 --> 00:26:53,159

right you have one data point right one

676

00:26:51,630 --> 00:26:55,530

of these components are coming towards

677

00:26:53,160 --> 00:26:57,480

you or away from you but in reality this

678

00:26:55,529 --> 00:26:59,670

gas is moving in three dimensions not

679

00:26:57,480 --> 00:27:01,950

just in one dimension towards us or away

680

00:26:59,670 --> 00:27:04,650

from us so we have to do some geometry

681

00:27:01,950 --> 00:27:07,380

to determine how far it is it actually

682

00:27:04,650 --> 00:27:09,030

moving directly up if you imagine you're

683

00:27:07,380 --> 00:27:11,850

looking at that side view of the galaxy

684

00:27:09,029 --> 00:27:15,149

again the real the direction that this

685
00:27:11,849 --> 00:27:18,000
outflow is going is out into the halo up

686
00:27:15,150 --> 00:27:19,350
above from the galactic center so you're

687
00:27:18,000 --> 00:27:20,970
just what you were seeing in the

688
00:27:19,349 --> 00:27:24,240
spectrum is the component of that that

689
00:27:20,970 --> 00:27:25,950
is that is along your line of sight so

690
00:27:24,240 --> 00:27:27,750
they said that's just an extra stage

691
00:27:25,950 --> 00:27:30,029
that goes into our calculations that

692
00:27:27,750 --> 00:27:32,970
goes from our line-of-sight velocity to

693
00:27:30,029 --> 00:27:35,549
what is the actual outflow velocity in

694
00:27:32,970 --> 00:27:37,829
three dimensions which is how fast it is

695
00:27:35,549 --> 00:27:39,329
it is the gas launched from the galactic

696
00:27:37,829 --> 00:27:43,589
center because that number is much

697
00:27:39,329 --> 00:27:45,659
faster it's more like wow that's really

698
00:27:43,589 --> 00:27:48,240
fast so this there's a related comment

699
00:27:45,660 --> 00:27:49,769
in question here from Adam synergy and I

700
00:27:48,240 --> 00:27:51,509
wanted to highlight this he's going so

701
00:27:49,769 --> 00:27:53,369
this observation is just the beginning

702
00:27:51,509 --> 00:27:54,809
right surely you will need to repeat

703
00:27:53,369 --> 00:27:57,209
this many times with different

704
00:27:54,809 --> 00:27:58,440
background quasars to fully map the

705
00:27:57,210 --> 00:28:00,269
Fermi bubbles and you're saying there's

706
00:27:58,440 --> 00:28:02,160
a technique here for getting that

707
00:28:00,269 --> 00:28:04,049
information yeah now that's a very good

708
00:28:02,160 --> 00:28:06,840
question we do need to do that we we

709
00:28:04,049 --> 00:28:08,369
began our program with this one sight

710
00:28:06,839 --> 00:28:10,349
line because it just happened to lie in

711
00:28:08,369 --> 00:28:12,329
such a great place this is the best

712
00:28:10,349 --> 00:28:14,129
quasar we have in terms of being close

713

00:28:12,329 --> 00:28:16,230
to the galactic center where the wind is

714
00:28:14,130 --> 00:28:18,060
going to be strongest because whatever

715
00:28:16,230 --> 00:28:19,650
is producing this it's something to do

716
00:28:18,059 --> 00:28:21,149
with a galactic center it's either stars

717
00:28:19,650 --> 00:28:23,250
near the galactic center or it's the

718
00:28:21,150 --> 00:28:24,840
black hole optic electric center so we

719
00:28:23,250 --> 00:28:27,000
were looking for targets as close as

720
00:28:24,839 --> 00:28:29,159
possible to that point and this was the

721
00:28:27,000 --> 00:28:31,980
best quasar but our full sample is more

722
00:28:29,160 --> 00:28:33,930
like 20 or so quasars some of which are

723
00:28:31,980 --> 00:28:38,009
inside the Fermi bubbles some of which

724
00:28:33,930 --> 00:28:39,810
are just outside and we have the ongoing

725
00:28:38,009 --> 00:28:42,539
task right now of analyzing all that

726
00:28:39,809 --> 00:28:44,819
that data and measuring the absorption

727
00:28:42,539 --> 00:28:46,109

lines that we see in the just the same

728

00:28:44,819 --> 00:28:47,519

techniques we've been talking about we

729

00:28:46,109 --> 00:28:49,709

need to do that for the full sample not

730

00:28:47,519 --> 00:28:51,359

just this one case good a good question

731

00:28:49,710 --> 00:28:52,829

Adam thank you and Craig Landon I'm

732

00:28:51,359 --> 00:28:53,849

gonna get to yours in just a minute but

733

00:28:52,829 --> 00:28:57,689

so

734

00:28:53,849 --> 00:28:59,609

the the the the measurements you've got

735

00:28:57,690 --> 00:29:01,169

tell you a little bit about how these

736

00:28:59,609 --> 00:29:02,609

things are moving fast by the way these

737

00:29:01,169 --> 00:29:05,490

things are really moving out there and

738

00:29:02,609 --> 00:29:07,019

you said something earlier about this

739

00:29:05,490 --> 00:29:09,240

happened what was a two and a half

740

00:29:07,019 --> 00:29:11,759

million years ago or whatever it was it

741

00:29:09,240 --> 00:29:14,099

caused and is the way you found that out

742
00:29:11,759 --> 00:29:15,480
by running the the clock backwards going

743
00:29:14,099 --> 00:29:18,209
backward and you know how fast they are

744
00:29:15,480 --> 00:29:19,470
right now so you just figured out to get

745
00:29:18,210 --> 00:29:20,250
where they are now I must have taken

746
00:29:19,470 --> 00:29:21,509
them this long

747
00:29:20,250 --> 00:29:26,038
that's exactly right that's the

748
00:29:21,509 --> 00:29:29,099
calculation we did we so we measured the

749
00:29:26,038 --> 00:29:30,690
outflow velocity and found about 900 or

750
00:29:29,099 --> 00:29:32,579
a thousand kilometers per second and

751
00:29:30,690 --> 00:29:37,259
that's about two million miles per hour

752
00:29:32,579 --> 00:29:38,250
and more million miles an hour two

753
00:29:37,259 --> 00:29:39,869
million miles an hour

754
00:29:38,250 --> 00:29:42,509
gushing out from the galactic center

755
00:29:39,869 --> 00:29:44,939
because we know how far from a galactic

756
00:29:42,509 --> 00:29:47,009
center is reached we know the distance

757
00:29:44,940 --> 00:29:48,538
right so we've got a distance we've got

758
00:29:47,009 --> 00:29:51,509
a velocity we could turn back the clock

759
00:29:48,538 --> 00:29:53,129
and figure out the time and when you do

760
00:29:51,509 --> 00:29:55,650
that calculation the answer is somewhere

761
00:29:53,130 --> 00:29:58,590
between two and a half to three or four

762
00:29:55,650 --> 00:30:00,419
million years so it tells you that

763
00:29:58,589 --> 00:30:03,928
that's how long it's taken for the gas

764
00:30:00,419 --> 00:30:06,360
to to be driven away from the galactic

765
00:30:03,929 --> 00:30:07,530
center to where we see it or to put it

766
00:30:06,359 --> 00:30:08,729
differently it just tells you that two

767
00:30:07,529 --> 00:30:10,470
or three million years ago there was a

768
00:30:08,730 --> 00:30:13,019
very energetic event there were some

769
00:30:10,470 --> 00:30:16,220
fireworks something happened that was

770

00:30:13,019 --> 00:30:18,779
capable of driving this stuff out

771
00:30:16,220 --> 00:30:24,120
producing what we now see and Scott's

772
00:30:18,779 --> 00:30:25,710
got a very France friendly looking it's

773
00:30:24,119 --> 00:30:27,058
the chromatic up here to sort of show

774
00:30:25,710 --> 00:30:30,210
what we've been talking about all this

775
00:30:27,058 --> 00:30:32,339
time you could see the the where the red

776
00:30:30,210 --> 00:30:34,829
and the blue areas of the spectrum are

777
00:30:32,339 --> 00:30:38,939
in the little diagram in the lower left

778
00:30:34,829 --> 00:30:40,168
and the so it gives a sense a little bit

779
00:30:38,940 --> 00:30:41,419
more of what we were just talking about

780
00:30:40,169 --> 00:30:43,620
but this is more of an artist

781
00:30:41,419 --> 00:30:48,059
representation of that where the other

782
00:30:43,619 --> 00:30:54,209
stuff was actual and the others was

783
00:30:48,058 --> 00:30:55,678
actual data so okay so let's see we let

784
00:30:54,210 --> 00:30:58,500

me get to Craig Landon here he's got a

785

00:30:55,679 --> 00:31:01,169

question here for us that is what might

786

00:30:58,500 --> 00:31:03,480

be the contribution of gravitational

787

00:31:01,169 --> 00:31:07,020

waves to what can be inferred from the

788

00:31:03,480 --> 00:31:08,700

views and different wavelengths so you

789

00:31:07,019 --> 00:31:10,289

can grab any waves affect these in any

790

00:31:08,700 --> 00:31:12,269

way from what you've seen in the

791

00:31:10,289 --> 00:31:12,990

different wavelengths or is it too early

792

00:31:12,269 --> 00:31:15,869

to tell

793

00:31:12,990 --> 00:31:18,210

I think I think it's too early to say

794

00:31:15,869 --> 00:31:21,000

what the contribution of gravitational

795

00:31:18,210 --> 00:31:22,559

waves would be if I mean if there was a

796

00:31:21,000 --> 00:31:24,089

place where that would be relevant it

797

00:31:22,559 --> 00:31:26,399

would probably be very close to the

798

00:31:24,089 --> 00:31:28,769

center of the black at the black hole

799
00:31:26,400 --> 00:31:30,750
itself where you have a several million

800
00:31:28,769 --> 00:31:33,990
solar mass object which is certainly

801
00:31:30,750 --> 00:31:37,470
going to be disturbing the space-time

802
00:31:33,990 --> 00:31:38,640
around it but we we don't we don't see

803
00:31:37,470 --> 00:31:40,829
what a connection would be right now

804
00:31:38,640 --> 00:31:44,330
between these these observations of

805
00:31:40,829 --> 00:31:47,519
gravitational waves cool thanks Craig so

806
00:31:44,329 --> 00:31:49,799
how do we know how hot these things are

807
00:31:47,519 --> 00:31:53,490
we know how the temperature the gas well

808
00:31:49,799 --> 00:31:56,599
the gas that we're seeing in the Hubble

809
00:31:53,490 --> 00:31:58,920
data it's actually not that heart by

810
00:31:56,599 --> 00:32:03,319
astronomers standards it's probably

811
00:31:58,920 --> 00:32:03,320
around 10,000 degrees Kelvin which is

812
00:32:03,380 --> 00:32:09,660
17,000 Fahrenheit or so every day

813
00:32:08,250 --> 00:32:12,059
standards but in terms of like

814
00:32:09,660 --> 00:32:13,380
interstellar space that's not so hot

815
00:32:12,059 --> 00:32:14,940
there's a plenty of stuff which is at a

816
00:32:13,380 --> 00:32:17,640
million degrees or ten million degrees

817
00:32:14,940 --> 00:32:18,750
or hotter right and it's also not very

818
00:32:17,640 --> 00:32:20,040
dense right I was going to get to

819
00:32:18,750 --> 00:32:23,730
density too while we're talking about

820
00:32:20,039 --> 00:32:26,399
temperature are these very dense no not

821
00:32:23,730 --> 00:32:27,720
really I mean it the typical densities

822
00:32:26,400 --> 00:32:29,730
you have in these things are something

823
00:32:27,720 --> 00:32:33,150
like one atom per cubic centimeter

824
00:32:29,730 --> 00:32:35,339
okay char extraordinaire allele oh by

825
00:32:33,150 --> 00:32:37,380
our standards on earth but that's the

826
00:32:35,339 --> 00:32:41,490
sort of number you come across in

827

00:32:37,380 --> 00:32:42,900
interstellar space but the interesting

828
00:32:41,490 --> 00:32:45,380
thing about the temperature is if I can

829
00:32:42,900 --> 00:32:48,690
just come back to this point is sure

830
00:32:45,380 --> 00:32:52,410
people have been studying winds coming

831
00:32:48,690 --> 00:32:53,910
out of other galaxies and they haven't

832
00:32:52,410 --> 00:32:55,380
been able to see the bubbles because of

833
00:32:53,910 --> 00:32:57,269
what we talked about and gamma rays are

834
00:32:55,380 --> 00:33:00,090
too faint but they have been able to see

835
00:32:57,269 --> 00:33:02,879
winds and and when they studied winds

836
00:33:00,089 --> 00:33:05,699
and it's widely accepted that most of

837
00:33:02,880 --> 00:33:07,920
the wind and energy that comes out from

838
00:33:05,700 --> 00:33:10,620
the center of galaxies is very hot where

839
00:33:07,920 --> 00:33:12,300
it's it's extremely hard to detect so

840
00:33:10,619 --> 00:33:14,729
it's possible that what we're seeing in

841
00:33:12,299 --> 00:33:17,009

this cooler gas and with the Hubble data

842

00:33:14,730 --> 00:33:18,960
are just small clouds that are being

843

00:33:17,009 --> 00:33:21,539
taken along for the ride in the outflow

844

00:33:18,960 --> 00:33:23,220
we're not really seeing

845

00:33:21,539 --> 00:33:25,170
the bulk of the mass the bulk of the

846

00:33:23,220 --> 00:33:27,329
energy in the wind we're just seeing

847

00:33:25,170 --> 00:33:29,310
small pockets of material that are

848

00:33:27,329 --> 00:33:31,619
relatively dense and are being taken

849

00:33:29,309 --> 00:33:33,299
along for the ride now this is really

850

00:33:31,619 --> 00:33:36,139
interesting I hadn't heard this so in

851

00:33:33,299 --> 00:33:38,159
galactic winds you're the entire

852

00:33:36,140 --> 00:33:39,720
describe what those would be like I

853

00:33:38,160 --> 00:33:42,240
don't I I'm having trouble visually is

854

00:33:39,720 --> 00:33:46,440
it the entire galaxy blowing out well

855

00:33:42,240 --> 00:33:48,660
yes it could be galactic wide winds I'm

856
00:33:46,440 --> 00:33:52,110
focusing here more on the Galactic

857
00:33:48,660 --> 00:33:54,480
nuclear winds okay but if you if you if

858
00:33:52,109 --> 00:33:55,649
you look at the the supernova model

859
00:33:54,480 --> 00:33:58,500
where it's the supernovae that are

860
00:33:55,650 --> 00:34:00,180
powering the outflow those explosions

861
00:33:58,500 --> 00:34:02,240
heat the gas to extremely high

862
00:34:00,180 --> 00:34:06,150
temperatures well over a million degrees

863
00:34:02,240 --> 00:34:09,900
that is the type of gas that can expand

864
00:34:06,150 --> 00:34:11,910
and blow a wind out into the halo so you

865
00:34:09,900 --> 00:34:14,579
could think of that as the real hot wind

866
00:34:11,909 --> 00:34:16,500
and a little cool cool clumps that we

867
00:34:14,579 --> 00:34:18,509
see they're just catching a ride they're

868
00:34:16,500 --> 00:34:20,909
just surfing the waves up into the halo

869
00:34:18,510 --> 00:34:23,550
but this is the interesting thing so

870
00:34:20,909 --> 00:34:25,319
we're not really seeing all of the gas

871
00:34:23,550 --> 00:34:27,240
by any means we're just seeing the small

872
00:34:25,320 --> 00:34:29,700
clumps that are at the right temperature

873
00:34:27,239 --> 00:34:31,139
that Hubble can see them because for all

874
00:34:29,699 --> 00:34:32,399
the wonderful things that Hubble can do

875
00:34:31,139 --> 00:34:34,949
in the ultraviolet it can't actually

876
00:34:32,400 --> 00:34:37,950
measure the really hot million degree

877
00:34:34,949 --> 00:34:39,480
phase it is where theorists think most

878
00:34:37,949 --> 00:34:40,168
of them when most of the energy is being

879
00:34:39,480 --> 00:34:42,240
carried

880
00:34:40,168 --> 00:34:43,829
okay so what's confusing about that to

881
00:34:42,239 --> 00:34:45,659
me is that we can see these winds in

882
00:34:43,829 --> 00:34:50,039
other galaxies but we can't see it in

883
00:34:45,659 --> 00:34:52,918
our own we can see winds and in x-rays

884

00:34:50,039 --> 00:34:56,789
the one thing we can we can in our

885
00:34:52,918 --> 00:34:59,940
galaxy or in distant galaxies well both

886
00:34:56,789 --> 00:35:01,980
okay the difficulty in our own galaxy is

887
00:34:59,940 --> 00:35:03,230
that you've got this problem of being

888
00:35:01,980 --> 00:35:05,670
able to see the forest for the trees

889
00:35:03,230 --> 00:35:06,240
because we're right here in the disk of

890
00:35:05,670 --> 00:35:08,309
the galaxy

891
00:35:06,239 --> 00:35:10,469
okay so we're rotating there's a lot of

892
00:35:08,309 --> 00:35:13,469
foreground material right between us and

893
00:35:10,469 --> 00:35:15,029
the galactic center so ironically it's

894
00:35:13,469 --> 00:35:16,980
actually harder sometimes to figure out

895
00:35:15,030 --> 00:35:19,110
what's going on at the centre of the

896
00:35:16,980 --> 00:35:20,940
Milky Way then you look at another

897
00:35:19,110 --> 00:35:23,490
galaxy it's further away but you've got

898
00:35:20,940 --> 00:35:26,429

a clean shot at it so you can you don't

899

00:35:23,489 --> 00:35:28,289

have all the foreground issues to deal

900

00:35:26,429 --> 00:35:29,819

with okay so it's the same probably have

901

00:35:28,289 --> 00:35:32,309

a seeing the bubbles at all you've got

902

00:35:29,820 --> 00:35:34,320

so much our galaxy is so bright that

903

00:35:32,309 --> 00:35:37,409

it's in the way of seeing these winds

904

00:35:34,320 --> 00:35:40,620

in any meaningful way so yeah okay

905

00:35:37,409 --> 00:35:42,980

laughing right okay well uh so that we

906

00:35:40,619 --> 00:35:45,119

have another comment here from oh and we

907

00:35:42,980 --> 00:35:47,099

Philippe Philippe OH

908

00:35:45,119 --> 00:35:49,679

Conte is it possible that the event

909

00:35:47,099 --> 00:35:51,299

horizon is something like a sphere and

910

00:35:49,679 --> 00:35:53,460

so the bubbles are just formed by

911

00:35:51,300 --> 00:35:55,380

materials that are going towards the

912

00:35:53,460 --> 00:35:57,840

horizon from both sides

913
00:35:55,380 --> 00:36:00,809
I guess that's more of a geometry of the

914
00:35:57,840 --> 00:36:03,059
of the black hole contribution question

915
00:36:00,809 --> 00:36:03,480
right that's a that's an interesting

916
00:36:03,059 --> 00:36:05,759
thought

917
00:36:03,480 --> 00:36:09,630
so if the Fermi bubbles are being

918
00:36:05,760 --> 00:36:11,550
powered by the black hole then of course

919
00:36:09,630 --> 00:36:13,349
nothing can escape from the event

920
00:36:11,550 --> 00:36:15,000
horizon of that black hole but you can

921
00:36:13,349 --> 00:36:17,339
get material which escapes from the

922
00:36:15,000 --> 00:36:18,929
region just around the event horizon so

923
00:36:17,340 --> 00:36:21,450
if we have this accretion disk which is

924
00:36:18,929 --> 00:36:23,639
where the gas gets really hot and is

925
00:36:21,449 --> 00:36:25,769
falling towards and swirling onto the

926
00:36:23,639 --> 00:36:30,690
black hole that's the region where you

927
00:36:25,769 --> 00:36:32,849
can get outflows that drive into the

928
00:36:30,690 --> 00:36:33,900
bubbles maybe even Jets as well we

929
00:36:32,849 --> 00:36:38,429
haven't talked about Jets

930
00:36:33,900 --> 00:36:40,410
but there is one theoretical model which

931
00:36:38,429 --> 00:36:42,480
says that you can drive these Jets out

932
00:36:40,409 --> 00:36:45,619
from the supermassive black hole and

933
00:36:42,480 --> 00:36:48,090
that is what is contributing towards the

934
00:36:45,619 --> 00:36:49,199
Fermi bubbles oh okay that's right so

935
00:36:48,090 --> 00:36:53,070
that would be these high energy Jets

936
00:36:49,199 --> 00:36:54,899
that are in very active galactic nuclei

937
00:36:53,070 --> 00:36:57,180
or black holes that's right and you see

938
00:36:54,900 --> 00:37:00,690
these Jets around other active galactic

939
00:36:57,179 --> 00:37:02,759
nuclei other galaxies exactly but they

940
00:37:00,690 --> 00:37:05,309
would be formed somewhere fairly close

941

00:37:02,760 --> 00:37:07,830
into the center of the black hole but

942
00:37:05,309 --> 00:37:10,349
still outside the event horizon okay

943
00:37:07,829 --> 00:37:14,489
good that's a good question okay so all

944
00:37:10,349 --> 00:37:17,849
right so so I may I may have missed this

945
00:37:14,489 --> 00:37:22,079
but but so there's this bubble but so

946
00:37:17,849 --> 00:37:25,469
it's it's the waste if you will is tight

947
00:37:22,079 --> 00:37:28,440
at least the way you have detected it is

948
00:37:25,469 --> 00:37:30,769
tight near the plane is there still as a

949
00:37:28,440 --> 00:37:35,010
mission within the plane of the galaxy

950
00:37:30,769 --> 00:37:35,880
caused by the same sources right that's

951
00:37:35,010 --> 00:37:39,480
right yes

952
00:37:35,880 --> 00:37:42,809
it's not necessarily it could be but

953
00:37:39,480 --> 00:37:44,579
nuts is necessarily white bipolar like

954
00:37:42,809 --> 00:37:45,809
that is that right yes that's right so

955
00:37:44,579 --> 00:37:47,650

that waste is telling you something

956

00:37:45,809 --> 00:37:50,199

important because

957

00:37:47,650 --> 00:37:52,000

what we think is happening is that the

958

00:37:50,199 --> 00:37:54,099

the firming bubble however it gets

959

00:37:52,000 --> 00:37:57,309

created it has to expand into something

960

00:37:54,099 --> 00:38:01,150

and the denser material in it then it

961

00:37:57,309 --> 00:38:03,639

expands into the harder it is to to get

962

00:38:01,150 --> 00:38:06,400

bigger whereas the less dense the easier

963

00:38:03,639 --> 00:38:08,289

it is to expand so naturally the bubbles

964

00:38:06,400 --> 00:38:10,059

just inflate and get bigger away from

965

00:38:08,289 --> 00:38:13,210

the galactic center in the vertical

966

00:38:10,059 --> 00:38:14,529

direction but in the waste direction

967

00:38:13,210 --> 00:38:15,909

sort of towards the sides they're

968

00:38:14,530 --> 00:38:17,380

probably encountering a lot more

969

00:38:15,909 --> 00:38:19,420

resistance because there's a lot more

970
00:38:17,380 --> 00:38:22,000
gas there there's a lot more interesting

971
00:38:19,420 --> 00:38:23,650
material and that's what's confining the

972
00:38:22,000 --> 00:38:26,469
bubbles and we think that that's where

973
00:38:23,650 --> 00:38:28,119
the waste structure the shape of these

974
00:38:26,469 --> 00:38:31,809
things comes from it's sort of set by

975
00:38:28,119 --> 00:38:34,029
what is restricting the stuff that's in

976
00:38:31,809 --> 00:38:38,199
the way right and we can't detect that

977
00:38:34,030 --> 00:38:40,060
way that way but in the plane we can't

978
00:38:38,199 --> 00:38:42,399
do this observation because there's all

979
00:38:40,059 --> 00:38:43,690
this other yeah besides we go through a

980
00:38:42,400 --> 00:38:48,190
lot of trouble to subtract all that out

981
00:38:43,690 --> 00:38:50,079
anyhow so it would be a tiny little yeah

982
00:38:48,190 --> 00:38:53,559
if we could see it at all okay so

983
00:38:50,079 --> 00:38:56,289
red-hot bagel is asking this might be a

984
00:38:53,559 --> 00:38:58,269
dumb question no such thing on our

985
00:38:56,289 --> 00:38:59,619
hangouts thank you for asking it's a

986
00:38:58,269 --> 00:39:02,079
really good question yes it's actually

987
00:38:59,619 --> 00:39:04,029
not a dumb question but how exactly do

988
00:39:02,079 --> 00:39:06,630
you measure the temperatures of these

989
00:39:04,030 --> 00:39:11,769
gases okay

990
00:39:06,630 --> 00:39:15,420
not a bad question at all we have access

991
00:39:11,769 --> 00:39:18,219
in the Cobbold ultraviolet data to

992
00:39:15,420 --> 00:39:19,990
different different lines I showed a

993
00:39:18,219 --> 00:39:23,980
line earlier on when we had a graphic up

994
00:39:19,989 --> 00:39:26,229
of twice ionized silicon so a silicon

995
00:39:23,980 --> 00:39:28,480
atom that's being ionized as I had two

996
00:39:26,230 --> 00:39:30,670
electrons taken out of it now the level

997
00:39:28,480 --> 00:39:32,199
of ionization so how many electrons has

998

00:39:30,670 --> 00:39:34,420
been removed tells you something about

999
00:39:32,199 --> 00:39:37,299
the temperature because the hotter the

1000
00:39:34,420 --> 00:39:39,130
gas the more electrons will be removed

1001
00:39:37,300 --> 00:39:41,850
from all the atoms whereas difficult is

1002
00:39:39,130 --> 00:39:46,210
very cool the gas can be atomic or even

1003
00:39:41,849 --> 00:39:47,289
molecular so twice ionized silicon the

1004
00:39:46,210 --> 00:39:49,559
one that is shown in that particular

1005
00:39:47,289 --> 00:39:51,719
graph just happens to live in

1006
00:39:49,559 --> 00:39:55,449
interstellar gas at temperatures of

1007
00:39:51,719 --> 00:39:57,519
approximately 10,000 Kelvin you have to

1008
00:39:55,449 --> 00:39:58,210
describe for us twice ionized what do

1009
00:39:57,519 --> 00:40:01,059
you mean by that

1010
00:39:58,210 --> 00:40:03,490
so that means it's minus twice

1011
00:40:01,059 --> 00:40:04,750
I mean come on Tony I mean two electrons

1012
00:40:03,489 --> 00:40:06,879

have been taken out of it so if you

1013

00:40:04,750 --> 00:40:07,269

start with a neutral silicon atom thank

1014

00:40:06,880 --> 00:40:08,829

you

1015

00:40:07,269 --> 00:40:12,969

you take two electrons out you're left

1016

00:40:08,829 --> 00:40:14,799

with what we call high silicon atoms and

1017

00:40:12,969 --> 00:40:17,409

that leaves its imprint at a certain

1018

00:40:14,800 --> 00:40:18,550

wavelength good I just wanted to get

1019

00:40:17,409 --> 00:40:19,899

that clear because a lot of it's not

1020

00:40:18,550 --> 00:40:21,010

clear what you know of the word ionized

1021

00:40:19,900 --> 00:40:22,990

is a big one so I wanna make sure we

1022

00:40:21,010 --> 00:40:25,120

explained out that it's not a very very

1023

00:40:22,989 --> 00:40:28,169

big long thermometer that we shove out

1024

00:40:25,119 --> 00:40:30,670

there we have ways of using the light to

1025

00:40:28,170 --> 00:40:33,070

to actually get the information the

1026

00:40:30,670 --> 00:40:35,349

spectra it's actually what's going on in

1027
00:40:33,070 --> 00:40:37,269
those in those gases and in those ions

1028
00:40:35,349 --> 00:40:38,679
to that let's go that's right and and

1029
00:40:37,269 --> 00:40:39,940
these ions each live at different

1030
00:40:38,679 --> 00:40:42,399
temperatures so that's the short answer

1031
00:40:39,940 --> 00:40:44,409
is that this one lives and approximately

1032
00:40:42,400 --> 00:40:48,070
10,000 Kelvin but it's certainly not a

1033
00:40:44,409 --> 00:40:49,989
very precise broke it could be eight

1034
00:40:48,070 --> 00:40:50,650
thousand ten thousand somewhere in that

1035
00:40:49,989 --> 00:40:53,319
ballpark

1036
00:40:50,650 --> 00:40:55,150
thank you red-hot bagel that was good

1037
00:40:53,320 --> 00:40:57,660
question very good question

1038
00:40:55,150 --> 00:41:01,450
so we touched on this briefly earlier

1039
00:40:57,659 --> 00:41:03,219
and I want to follow up with your

1040
00:41:01,449 --> 00:41:04,989
looking at other quasars I want to talk

1041
00:41:03,219 --> 00:41:08,379
about what's next what's the future here

1042
00:41:04,989 --> 00:41:10,329
what do you have up coming up for us in

1043
00:41:08,380 --> 00:41:13,180
terms of learning more about these Fermi

1044
00:41:10,329 --> 00:41:15,610
bubbles do you have anything planned so

1045
00:41:13,179 --> 00:41:17,409
we do we have the other quasars as I

1046
00:41:15,610 --> 00:41:19,269
mentioned there's about 20 of them that

1047
00:41:17,409 --> 00:41:21,190
we have we've we've got the data it's

1048
00:41:19,269 --> 00:41:23,889
just a question of measure analyzing all

1049
00:41:21,190 --> 00:41:28,300
these lines okay and and modeling the

1050
00:41:23,889 --> 00:41:30,039
outflow we also have some stars so it

1051
00:41:28,300 --> 00:41:33,400
turns out that the Milky Way is

1052
00:41:30,039 --> 00:41:34,779
cooperating and it gives us some similar

1053
00:41:33,400 --> 00:41:37,150
stars which are some of them actually

1054
00:41:34,780 --> 00:41:38,440
are in the Fermi bubbles and this is

1055

00:41:37,150 --> 00:41:40,809
really interesting because you think of

1056
00:41:38,440 --> 00:41:43,570
these Fermi bubbles is very energetic

1057
00:41:40,809 --> 00:41:45,429
places but there are these single stars

1058
00:41:43,570 --> 00:41:47,920
that happen to live in the halo of the

1059
00:41:45,429 --> 00:41:49,480
galaxy not in a disk but up there and we

1060
00:41:47,920 --> 00:41:51,670
know how far away they are these are

1061
00:41:49,480 --> 00:41:53,260
just errant stars that happen to be up

1062
00:41:51,670 --> 00:41:54,490
above the plane of the galaxy yep

1063
00:41:53,260 --> 00:41:56,080
they're just wayward and they've

1064
00:41:54,489 --> 00:41:59,259
wandered up there however that their

1065
00:41:56,079 --> 00:42:01,059
history did that to them but we can use

1066
00:41:59,260 --> 00:42:03,130
them and do the same experiment but now

1067
00:42:01,059 --> 00:42:04,360
the difference with these stars is that

1068
00:42:03,130 --> 00:42:06,130
because they're in the Fermi bubble

1069
00:42:04,360 --> 00:42:07,539

you're only seeing half of the outflow

1070

00:42:06,130 --> 00:42:09,880

you're only seeing a part of it which is

1071

00:42:07,539 --> 00:42:11,320

on the near side right whereas when we

1072

00:42:09,880 --> 00:42:12,550

do the quasar experiment that we've

1073

00:42:11,320 --> 00:42:14,830

already done you can see all the way

1074

00:42:12,550 --> 00:42:16,120

through the full path of the outflows

1075

00:42:14,829 --> 00:42:20,019

you can see the front side of it and you

1076

00:42:16,119 --> 00:42:21,309

can see the back side of it but still

1077

00:42:20,019 --> 00:42:23,199

that's better than nothing right that's

1078

00:42:21,309 --> 00:42:27,639

more information than we didn't have

1079

00:42:23,199 --> 00:42:29,439

that we have and there are one or two

1080

00:42:27,639 --> 00:42:31,150

cases where we have a full Brown star

1081

00:42:29,440 --> 00:42:34,000

which is it would believe in the Fermi

1082

00:42:31,150 --> 00:42:35,860

bubbles and a background quasar which is

1083

00:42:34,000 --> 00:42:40,239

very close to it on the sky so we can

1084
00:42:35,860 --> 00:42:42,309
compare the absorption spectrum and so

1085
00:42:40,239 --> 00:42:44,709
we can say something about well if we

1086
00:42:42,309 --> 00:42:46,119
see this feature in one side line and we

1087
00:42:44,710 --> 00:42:49,030
don't see it in the other one that gives

1088
00:42:46,119 --> 00:42:52,719
us some information about where it is in

1089
00:42:49,030 --> 00:42:53,980
turn so when you get not not that I want

1090
00:42:52,719 --> 00:42:55,779
to push you or anything but were you

1091
00:42:53,980 --> 00:42:58,570
gonna get all this done and come back

1092
00:42:55,780 --> 00:43:01,840
and tell us how it what you found out is

1093
00:42:58,570 --> 00:43:04,120
there a timeline I am confident that we

1094
00:43:01,840 --> 00:43:06,579
can make some good progress on that

1095
00:43:04,119 --> 00:43:08,259
within this year and I've got a great

1096
00:43:06,579 --> 00:43:11,009
team of people working with me on this

1097
00:43:08,260 --> 00:43:13,780
on this project people focusing on

1098
00:43:11,010 --> 00:43:16,870
modeling we've also got some some radio

1099
00:43:13,780 --> 00:43:19,510
data which which gives us a new a new

1100
00:43:16,869 --> 00:43:21,009
set of observations on how much neutral

1101
00:43:19,510 --> 00:43:24,460
gas there is that goes along with this

1102
00:43:21,010 --> 00:43:26,530
ionized stuff radio data from Alma this

1103
00:43:24,460 --> 00:43:28,720
is actually from the Green Bank

1104
00:43:26,530 --> 00:43:31,390
telescope which is in West Virginia okay

1105
00:43:28,719 --> 00:43:34,029
the old that's all school it is it's

1106
00:43:31,389 --> 00:43:37,179
cool but it's a fantastic facility it's

1107
00:43:34,030 --> 00:43:41,050
it's it's been around a long time well

1108
00:43:37,179 --> 00:43:44,500
this is a huge single dish telescope and

1109
00:43:41,050 --> 00:43:46,539
it provides very very deep observations

1110
00:43:44,500 --> 00:43:48,670
so for what we needed to do it's as good

1111
00:43:46,539 --> 00:43:50,559
as we could get when my friends went to

1112

00:43:48,670 --> 00:43:53,500
UVA and she she was working out there

1113
00:43:50,559 --> 00:43:55,900
and say no cellphones own don't bring

1114
00:43:53,500 --> 00:43:57,940
anything like that right that's a big

1115
00:43:55,900 --> 00:43:59,980
thing to think about because when when

1116
00:43:57,940 --> 00:44:02,170
we're talking about these wavelengths of

1117
00:43:59,980 --> 00:44:04,179
light that's what's going on with our

1118
00:44:02,170 --> 00:44:06,099
everyday gadgets is that that is light

1119
00:44:04,179 --> 00:44:08,199
and it's going to be interfering so this

1120
00:44:06,099 --> 00:44:10,449
place in Virginia you have it's

1121
00:44:08,199 --> 00:44:13,389
completely when you're talking about

1122
00:44:10,449 --> 00:44:15,159
light preservation is first dark skies

1123
00:44:13,389 --> 00:44:17,109
well we have to do the same thing with

1124
00:44:15,159 --> 00:44:19,299
these types of telescopes to make sure

1125
00:44:17,110 --> 00:44:21,610
there's no interference from these

1126
00:44:19,300 --> 00:44:23,289

longer wavelengths of light as well it's

1127

00:44:21,610 --> 00:44:25,000
the radio equivalent of shining a

1128

00:44:23,289 --> 00:44:30,009
flashlight down the tube

1129

00:44:25,000 --> 00:44:31,599
right okay so I Scott I do you have I

1130

00:44:30,010 --> 00:44:33,880
missed any any is there any Twitter

1131

00:44:31,599 --> 00:44:35,830
things there's a budget there's a bunch

1132

00:44:33,880 --> 00:44:39,340
of tweets a lot of retweets going on

1133

00:44:35,829 --> 00:44:41,170
there is escrow gingersnap also notice a

1134

00:44:39,340 --> 00:44:44,140
me lens like I think my head might

1135

00:44:41,170 --> 00:44:46,450
explode right now from awesome space

1136

00:44:44,139 --> 00:44:49,719
news today on Rosetta and the Hubble

1137

00:44:46,449 --> 00:44:55,118
hangout and Vesta so we are adding to

1138

00:44:49,719 --> 00:44:57,789
her Minds lotion of all great and and

1139

00:44:55,119 --> 00:44:59,710
Francis ready also shared out the the

1140

00:44:57,789 --> 00:45:01,809
NASA video release which I have put into

1141
00:44:59,710 --> 00:45:04,420
the Google+ event page so I have link to

1142
00:45:01,809 --> 00:45:05,949
that and it's really good it's a really

1143
00:45:04,420 --> 00:45:09,700
good animation showing the Fermi

1144
00:45:05,949 --> 00:45:11,858
spacecraft and also the the animation

1145
00:45:09,699 --> 00:45:14,980
going on - as far as explaining what's

1146
00:45:11,858 --> 00:45:18,340
going on with the with these Fermi

1147
00:45:14,980 --> 00:45:21,969
levels excellent yeah I have a question

1148
00:45:18,340 --> 00:45:24,460
so in principle if you were given Hubble

1149
00:45:21,969 --> 00:45:26,649
Space Telescope you could do a whole

1150
00:45:24,460 --> 00:45:28,289
bunch of sightlines then all over the

1151
00:45:26,650 --> 00:45:30,338
place and then you'd want to repeat that

1152
00:45:28,289 --> 00:45:32,079
periodically just to see what the

1153
00:45:30,338 --> 00:45:34,088
changes are right so you can map the

1154
00:45:32,079 --> 00:45:36,969
whole thing and then see how it changes

1155
00:45:34,088 --> 00:45:39,880
is that right don't get that in

1156
00:45:36,969 --> 00:45:43,419
principle the problem is actually the

1157
00:45:39,880 --> 00:45:45,160
timescales you would need so if if I all

1158
00:45:43,420 --> 00:45:47,289
my colleagues could lift her like two

1159
00:45:45,159 --> 00:45:48,848
million years then yes this at a time we

1160
00:45:47,289 --> 00:45:51,608
think we would need to see these things

1161
00:45:48,849 --> 00:45:56,140
actually change on this but you could do

1162
00:45:51,608 --> 00:45:59,920
different sight lines you could you

1163
00:45:56,139 --> 00:46:02,379
would look for other quasars that happen

1164
00:45:59,920 --> 00:46:04,000
to lie close to the galactic center and

1165
00:46:02,380 --> 00:46:06,338
do the same thing we got really lucky

1166
00:46:04,000 --> 00:46:09,489
with this one quasar because there's a

1167
00:46:06,338 --> 00:46:12,039
lot of dust what we call dust is like

1168
00:46:09,489 --> 00:46:16,029
interstellar particles they block the

1169

00:46:12,039 --> 00:46:16,989
light from background quasars especially

1170
00:46:16,030 --> 00:46:19,269
when you get close to the galactic

1171
00:46:16,989 --> 00:46:21,819
center it just happens there's like a

1172
00:46:19,269 --> 00:46:24,039
little window through through the the

1173
00:46:21,820 --> 00:46:26,830
low halo of the galaxy and this quasar

1174
00:46:24,039 --> 00:46:28,630
is in that window but other places

1175
00:46:26,829 --> 00:46:30,098
nearby have so much dust that the light

1176
00:46:28,630 --> 00:46:32,410
doesn't get through which means you

1177
00:46:30,099 --> 00:46:35,170
can't find the quasars you need to do

1178
00:46:32,409 --> 00:46:37,239
this type of experiment so it's hard but

1179
00:46:35,170 --> 00:46:38,950
we had to really push down and find very

1180
00:46:37,239 --> 00:46:40,479
faint sources to do this

1181
00:46:38,949 --> 00:46:41,969
take a lot of time a lot of observing

1182
00:46:40,480 --> 00:46:44,440
time on the telescope to get this done

1183
00:46:41,969 --> 00:46:47,259

pesky dust we gotta get a vacuum cleaner

1184

00:46:44,440 --> 00:46:49,780

out there and cleared out of the way all

1185

00:46:47,260 --> 00:46:51,280

right well so dr. Andy Fox I want to

1186

00:46:49,780 --> 00:46:53,349

thank you very much for joining us on

1187

00:46:51,280 --> 00:46:55,089

our hangout is you are you will you come

1188

00:46:53,349 --> 00:46:58,420

back later once you've got more more

1189

00:46:55,088 --> 00:47:00,070

data sure yeah awesome good look for

1190

00:46:58,420 --> 00:47:03,220

anybody I want to want to follow up on

1191

00:47:00,070 --> 00:47:04,570

this and look here's a final slide I did

1192

00:47:03,219 --> 00:47:06,009

it also put the link out there and bout

1193

00:47:04,570 --> 00:47:08,019

to put up on Twitter here in a bit but

1194

00:47:06,010 --> 00:47:10,089

if you want to read more about the paper

1195

00:47:08,019 --> 00:47:11,980

that goes on here I have linked it into

1196

00:47:10,088 --> 00:47:13,719

the google event page I'll make sure it

1197

00:47:11,980 --> 00:47:15,820

gets put up onto YouTube and I'm just

1198
00:47:13,719 --> 00:47:19,239
about to tweet it out the you can go to

1199
00:47:15,820 --> 00:47:21,059
to archive and take a look at that paper

1200
00:47:19,239 --> 00:47:24,069
as well if you want to do a little bit

1201
00:47:21,059 --> 00:47:26,889
deeper digging into to the science

1202
00:47:24,070 --> 00:47:28,329
that's there good yes thanks for ya

1203
00:47:26,889 --> 00:47:29,739
thanks for reminding me about that so

1204
00:47:28,329 --> 00:47:31,210
deaf or them if you want to read the

1205
00:47:29,739 --> 00:47:33,279
actual paper there's a link to it as

1206
00:47:31,210 --> 00:47:34,539
well as the link to the press release on

1207
00:47:33,280 --> 00:47:37,900
Hubble site org

1208
00:47:34,539 --> 00:47:40,239
to learn more as well so that's it for

1209
00:47:37,900 --> 00:47:42,400
this week everybody next week Carol

1210
00:47:40,239 --> 00:47:45,338
Scott and I will be meeting with we have

1211
00:47:42,400 --> 00:47:47,858
another in our series of Hubble 25

1212
00:47:45,338 --> 00:47:49,480
hangouts to celebrate the 25th

1213
00:47:47,858 --> 00:47:50,710
anniversary of Hubble we'll have Carolyn

1214
00:47:49,480 --> 00:47:54,400
Collins peterson with us to talk more

1215
00:47:50,710 --> 00:47:56,710
about the illustrious history of Hubble

1216
00:47:54,400 --> 00:47:58,030
and as we as we said the last time we

1217
00:47:56,710 --> 00:48:00,250
did a history of Hubble hangout we're

1218
00:47:58,030 --> 00:48:02,589
gonna be doing many of these so because

1219
00:48:00,250 --> 00:48:04,179
25 years is a long time a lot of stuff

1220
00:48:02,588 --> 00:48:06,608
happens so we'll have her next week we

1221
00:48:04,179 --> 00:48:10,139
hope you'll tune in and and check us out

1222
00:48:06,608 --> 00:48:17,259
I'll create the events tomorrow and I

1223
00:48:10,139 --> 00:48:19,659
keep getting animals that isn't alright

1224
00:48:17,260 --> 00:48:32,380
are you going to the danger zone

1225
00:48:19,659 --> 00:48:35,129
yeah but you you probably you always

1226

00:48:32,380 --> 00:48:38,079
have a fun day with that ringtone yeah

1227
00:48:35,130 --> 00:48:39,369
danger zone okay everybody thank you

1228
00:48:38,079 --> 00:48:42,818
guys for watching we'll see you guys

1229
00:48:39,369 --> 00:48:47,039
next week as always keep looking up

1230
00:48:42,818 --> 00:48:47,039
looking up there you go okay