Slide6.PNG - Picasa Photo Viewer

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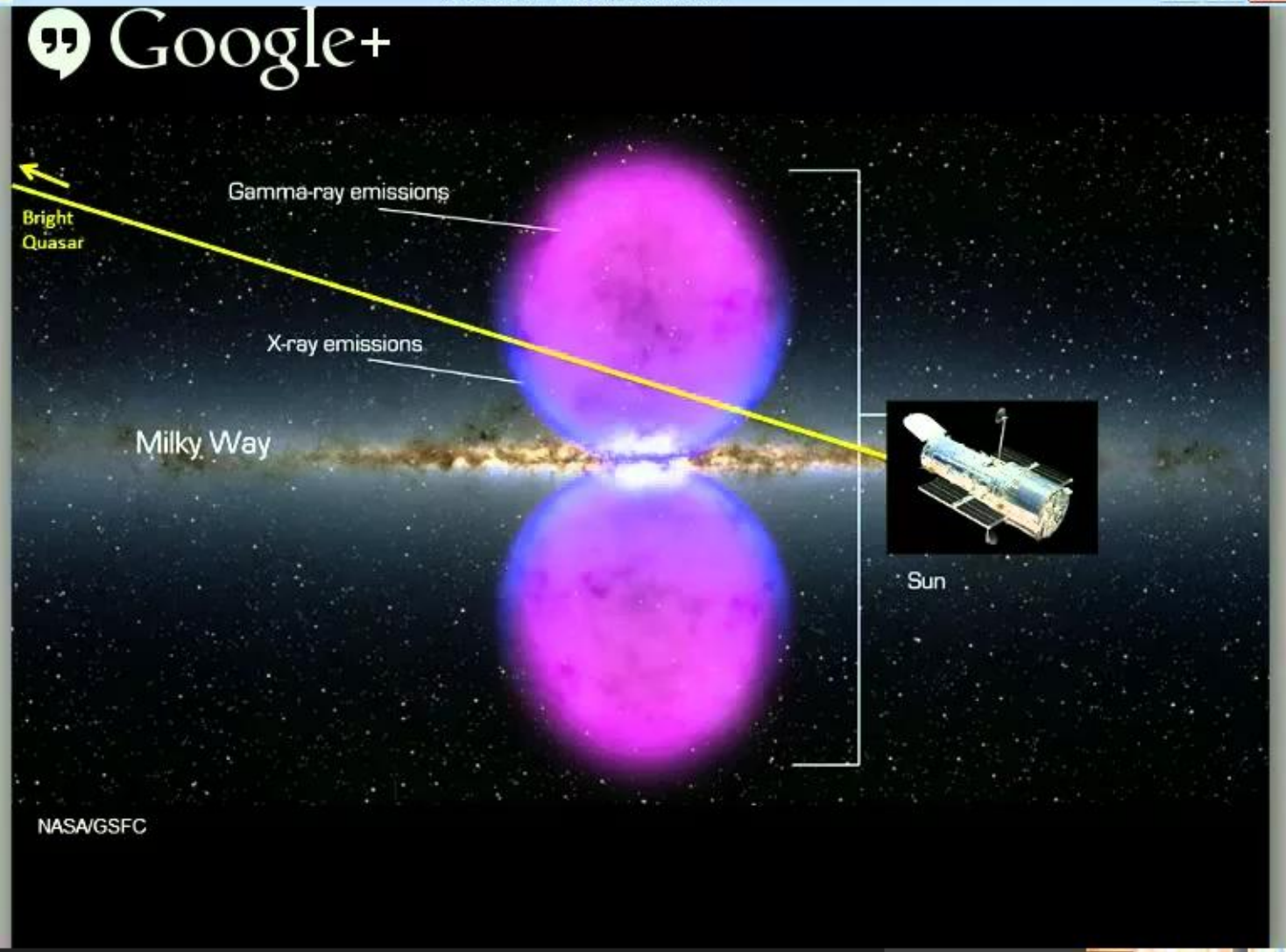


Scott

y Darnell

Andrew Fox

ol Christian

1
00:00:08,720 --> 00:00:06,950
hello everybody and welcome to this

2
00:00:10,520 --> 00:00:08,730
week's Hubbell hangout my name is Tony

3
00:00:12,770 --> 00:00:10,530
Darnell and I work at the Space

4
00:00:16,129 --> 00:00:12,780
Telescope Science Institute and today we

5
00:00:18,529 --> 00:00:16,139
have another always awesome hangout plan

6
00:00:20,840 --> 00:00:18,539
for you today it turns out that the

7
00:00:22,849 --> 00:00:20,850
Milky Way has these very strange lobes

8
00:00:24,859 --> 00:00:22,859
on either side of it and astronomers

9
00:00:26,420 --> 00:00:24,869
using Hubble have have actually been

10
00:00:29,419 --> 00:00:26,430
able to measure some of the properties

11
00:00:30,679 --> 00:00:29,429
of these lobes using a quasar and we're

12
00:00:32,060 --> 00:00:30,689
going to talk about some of the details

13
00:00:33,650 --> 00:00:32,070

with that today with one of the

14
00:00:36,440 --> 00:00:33,660
astronomers here but before I get to the

15
00:00:37,850 --> 00:00:36,450
introductions let me tell you well let

16
00:00:40,400 --> 00:00:37,860
me first of all let me welcome my

17
00:00:42,470 --> 00:00:40,410
cohorts with me as always is dr. Carol

18
00:00:46,100 --> 00:00:42,480
Christian she's the outreach scientist

19
00:00:48,229 --> 00:00:46,110
for Hubble hi Carol and Scott Lewis the

20
00:00:50,569 --> 00:00:48,239
driver oh the Internet's extraordinaire

21
00:00:57,250 --> 00:00:50,579
hi Scott extraordinaire I like it's

22
00:01:00,799 --> 00:00:57,260
getting longer I lined up the third yeah

23
00:01:02,299 --> 00:01:00,809
so so we'd like to get your comments and

24
00:01:03,860 --> 00:01:02,309
questions throughout the Hangout if you

25
00:01:05,329 --> 00:01:03,870
are so inclined you can do that in a

26
00:01:07,609 --> 00:01:05,339
number of ways the easiest and my

27
00:01:09,950 --> 00:01:07,619
favorite way is to use the Q&A app but

28
00:01:12,770 --> 00:01:09,960
you can also comment on the event page

29
00:01:15,080 --> 00:01:12,780
in Google+ that we are broadcasting from

30
00:01:16,550 --> 00:01:15,090
as well as the YouTube page we're

31
00:01:21,260 --> 00:01:16,560
looking at all of those comments as well

32
00:01:24,890 --> 00:01:21,270
and so and finally on Twitter if you use

33
00:01:26,420 --> 00:01:24,900
the Hangout Hubble hangout Scott will be

34
00:01:27,980 --> 00:01:26,430
monitoring that and letting me know if

35
00:01:29,539 --> 00:01:27,990
there's any good tweets or comments that

36
00:01:31,160 --> 00:01:29,549
way and we will read them out as they

37
00:01:34,580 --> 00:01:31,170
come or toward the end so please

38
00:01:37,609 --> 00:01:34,590

interact with us so joining me today is

39
00:01:39,620 --> 00:01:37,619
an astronomer from these also from the

40
00:01:43,069 --> 00:01:39,630
Space Telescope Science Institute dr.

41
00:01:44,569 --> 00:01:43,079
Andy Fox hi Andy hi Tony hey ding I'm

42
00:01:47,300 --> 00:01:44,579
good thank you thank you for taking time

43
00:01:49,310 --> 00:01:47,310
out to join us so you've made some

44
00:01:52,190 --> 00:01:49,320
pretty interesting measurements for us

45
00:01:54,800 --> 00:01:52,200
using Hubble you have pointed it at a

46
00:01:57,469 --> 00:01:54,810
quasar that just so happened to be in a

47
00:02:00,410 --> 00:01:57,479
good spot to measure these very strange

48
00:02:04,219 --> 00:02:00,420
things that I I guess only until only

49
00:02:05,990 --> 00:02:04,229
recently have been discovered these

50
00:02:08,690 --> 00:02:06,000
features of our galaxy these strange

51
00:02:11,420 --> 00:02:08,700
kind of lobe things correct that is

52
00:02:13,620 --> 00:02:11,430
right in fact these lobes are called the

53
00:02:17,250 --> 00:02:13,630
Fermi bubbles were only discovered in

54
00:02:20,040 --> 00:02:17,260
20:10 in their gamma-ray emission by a

55
00:02:21,990 --> 00:02:20,050
satellite that NASA operates called the

56
00:02:23,730 --> 00:02:22,000
Fermi satellite so really only in the

57
00:02:26,760 --> 00:02:23,740
last five years have we known about this

58
00:02:29,040 --> 00:02:26,770
new component of our galaxy and we were

59
00:02:31,370 --> 00:02:29,050
able to use Hubble tour to measure how

60
00:02:34,470 --> 00:02:31,380
fast the gas was moving into these lobes

61
00:02:36,480 --> 00:02:34,480
what that gas is composed of in terms of

62
00:02:37,770 --> 00:02:36,490
its chemical elements and this was the

63
00:02:39,200 --> 00:02:37,780

first time we were able to really nail

64
00:02:42,180 --> 00:02:39,210
down some of these properties

65
00:02:43,350 --> 00:02:42,190
well it's awesome and I want to get to

66
00:02:44,610 --> 00:02:43,360
those measurements in just a minute but

67
00:02:47,570 --> 00:02:44,620
Scott can you put up that diagram that

68
00:02:50,820 --> 00:02:47,580
shows the Fermi bubbles for me bubbles

69
00:02:52,590 --> 00:02:50,830
doo-doo-doo sorry all right so here's

70
00:02:56,190 --> 00:02:52,600
what they look like or at least this is

71
00:02:58,770 --> 00:02:56,200
a artist impression of what they look

72
00:03:01,800 --> 00:02:58,780
like correct that is right so what you

73
00:03:03,630 --> 00:03:01,810
can see here is the disk of our Milky

74
00:03:05,250 --> 00:03:03,640
Way this is a side-on view of what our

75
00:03:07,980 --> 00:03:05,260
galaxy would look like from someone

76
00:03:10,290 --> 00:03:07,990
sitting outside the disk of the galaxy

77
00:03:13,590 --> 00:03:10,300
comes across at a diagonal there and

78
00:03:16,230 --> 00:03:13,600
those two purple lobes are centered on

79
00:03:21,060 --> 00:03:16,240
the the core of the galaxy in the center

80
00:03:23,670 --> 00:03:21,070
of the Milky Way you can see there is a

81
00:03:26,520 --> 00:03:23,680
lot of emission along the base of the

82
00:03:28,410 --> 00:03:26,530
lobes as you get closest to the center

83
00:03:30,810 --> 00:03:28,420
of the galaxy and these things they're

84
00:03:32,220 --> 00:03:30,820
really emitting light all across the

85
00:03:34,260 --> 00:03:32,230
electromagnetic spectrum they were

86
00:03:37,020 --> 00:03:34,270
discovered in gamma rays it turns out

87
00:03:39,840 --> 00:03:37,030
they also emit x-rays being microwaves

88
00:03:41,640 --> 00:03:39,850

and radio waves so they've started to be

89
00:03:43,949 --> 00:03:41,650
studied all these different wavelengths

90
00:03:45,390 --> 00:03:43,959
and we're piecing together the

91
00:03:46,530 --> 00:03:45,400
information we're getting from those

92
00:03:48,000 --> 00:03:46,540
different wavelengths to try and

93
00:03:50,370 --> 00:03:48,010
understand where they come from what

94
00:03:52,230 --> 00:03:50,380
they're doing so you see as you said at

95
00:03:54,030 --> 00:03:52,240
the beginning this is we've known about

96
00:03:56,760 --> 00:03:54,040
these for about five years obviously

97
00:03:59,340 --> 00:03:56,770
this is a vantage point that sadly we

98
00:04:01,820 --> 00:03:59,350
can never observe these things from but

99
00:04:05,190 --> 00:04:01,830
we do have you do have some of the

100
00:04:07,560 --> 00:04:05,200
images of the of these bubbles in the

101
00:04:12,030 --> 00:04:07,570
Fermi data correct that is absolutely

102
00:04:14,070 --> 00:04:12,040
right okay in in the Fermi data you

103
00:04:17,449 --> 00:04:14,080
certainly see these two lobes they look

104
00:04:20,420 --> 00:04:17,459
like balloons so can you put those up

105
00:04:23,190 --> 00:04:20,430
above and below the center of the galaxy

106
00:04:23,610 --> 00:04:23,200
I'll just wait for those to come up yeah

107
00:04:26,340 --> 00:04:23,620
here we are

108
00:04:27,930 --> 00:04:26,350
thanks god this is uh so this is an

109
00:04:31,020 --> 00:04:27,940
all-sky map

110
00:04:31,530 --> 00:04:31,030
it shows the full night sky just as we

111
00:04:33,330 --> 00:04:31,540
used to

112
00:04:35,370 --> 00:04:33,340
projecting you know there's the surface

113
00:04:37,530 --> 00:04:35,380

of the earth onto a map we do the same

114
00:04:40,380 --> 00:04:37,540
thing in so-called galactic coordinates

115
00:04:42,300 --> 00:04:40,390
and you can see right across the middle

116
00:04:44,430 --> 00:04:42,310
of this map that's what we call the

117
00:04:46,320 --> 00:04:44,440
Galactic equator that's the disk of the

118
00:04:48,120 --> 00:04:46,330
galaxy where almost all the stars in our

119
00:04:50,070 --> 00:04:48,130
galaxy are located is in that disk

120
00:04:51,810 --> 00:04:50,080
that's that bright band that's this is

121
00:04:53,850 --> 00:04:51,820
right bad okay so let's talk a little

122
00:04:55,530 --> 00:04:53,860
bit about where is Fermi I'll at when

123
00:04:57,840 --> 00:04:55,540
it's taking is it is it in orbit above

124
00:04:59,760 --> 00:04:57,850
Earth is it somewhere in the solar it

125
00:05:01,590 --> 00:04:59,770
says somewhere relatively close to Earth

126
00:05:03,000 --> 00:05:01,600
correct very close - that's right so

127
00:05:04,740 --> 00:05:03,010
it's in it's in orbit around the Earth

128
00:05:08,880 --> 00:05:04,750
very similar to the way that Hubble is

129
00:05:12,030 --> 00:05:08,890
okay so this is the the image you get

130
00:05:14,670 --> 00:05:12,040
basically looking from the earth and if

131
00:05:16,440 --> 00:05:14,680
it's this map is centered so that if you

132
00:05:18,540 --> 00:05:16,450
look towards the galactic center that's

133
00:05:22,350 --> 00:05:18,550
right in the center here of the image

134
00:05:24,720 --> 00:05:22,360
and you see there's two orange red lobes

135
00:05:25,890 --> 00:05:24,730
going out to either side what we call

136
00:05:28,320 --> 00:05:25,900
the northern hemisphere in a Sun

137
00:05:29,880 --> 00:05:28,330
hemisphere of the galaxy they're not

138
00:05:31,830 --> 00:05:29,890

quite symmetric there's a little bit

139
00:05:34,620 --> 00:05:31,840
more of the emission in the north and in

140
00:05:38,010 --> 00:05:34,630
the south but you do see the the same

141
00:05:40,860 --> 00:05:38,020
height extending into the into the halo

142
00:05:42,510 --> 00:05:40,870
of the galaxy in both sides and this is

143
00:05:45,090 --> 00:05:42,520
the raw data there was actually

144
00:05:49,620 --> 00:05:45,100
discovered from that Fermi satellite

145
00:05:52,920 --> 00:05:49,630
that it led to people dubbing them the

146
00:05:54,420 --> 00:05:52,930
Fermi bubbles yeah so these were so

147
00:05:57,120 --> 00:05:54,430
these were first observed in gamma rays

148
00:05:59,550 --> 00:05:57,130
and this is what our sky looks like in

149
00:06:01,860 --> 00:05:59,560
gamma rays there's also so the disk

150
00:06:04,980 --> 00:06:01,870
itself is very bright you see a lot of

151
00:06:07,740 --> 00:06:04,990
lot of photons there one of the colors

152
00:06:10,920 --> 00:06:07,750
mean well it's colored it's color-coded

153
00:06:12,360 --> 00:06:10,930
by the intensity by how bright in gamma

154
00:06:15,380 --> 00:06:12,370
rays it is but I should point out that

155
00:06:18,659 --> 00:06:15,390
the disk here they've actually

156
00:06:20,460 --> 00:06:18,669
subtracted off the contribution from the

157
00:06:25,770 --> 00:06:20,470
disk because the disk is glowing in

158
00:06:27,510 --> 00:06:25,780
gamma rays much brighter than the Fermi

159
00:06:30,240 --> 00:06:27,520
levels and the Sun they're smaller

160
00:06:32,130 --> 00:06:30,250
oh so in order to see it at all you had

161
00:06:33,659 --> 00:06:32,140
you have to subtract all that out you

162
00:06:36,469 --> 00:06:33,669
have to subtract off the disk and that

163
00:06:39,300 --> 00:06:36,479

is actually quite a complicated process

164
00:06:40,860 --> 00:06:39,310
this is a this is a cleaned up map that

165
00:06:45,450 --> 00:06:40,870
you're seeing right here

166
00:06:47,100 --> 00:06:45,460
which brings out the size is that why

167
00:06:48,749 --> 00:06:47,110
those are those those black areas there

168
00:06:51,179 --> 00:06:48,759
is that did that come out of the indi

169
00:06:53,070 --> 00:06:51,189
subtraction that's right yes okay all

170
00:06:55,170 --> 00:06:53,080
right please you subtracted out the

171
00:06:57,779 --> 00:06:55,180
contribution of the disk because it's so

172
00:06:59,249 --> 00:06:57,789
bright and gamma rays that you can't see

173
00:07:02,129 --> 00:06:59,259
these lobes now you can see the lobes

174
00:07:05,360 --> 00:07:02,139
and what we have is we can see kind of a

175
00:07:08,040 --> 00:07:05,370
little map of our own all-sky map of the

176
00:07:10,860 --> 00:07:08,050
of gamma and gamma rays are these other

177
00:07:13,439 --> 00:07:10,870
features like the ones that are like in

178
00:07:16,200 --> 00:07:13,449
the upper right part of the lobe there

179
00:07:18,300 --> 00:07:16,210
is is that part of our galaxy or is that

180
00:07:21,209 --> 00:07:18,310
background sky is that part of the lobes

181
00:07:23,219 --> 00:07:21,219
how do you know well it's very hard to

182
00:07:25,170 --> 00:07:23,229
know and actually that's so that's an

183
00:07:27,089 --> 00:07:25,180
open question you as you see as you go

184
00:07:29,459 --> 00:07:27,099
up into the northern Fermi bubble you

185
00:07:32,040 --> 00:07:29,469
keep going to the north you do see that

186
00:07:33,809 --> 00:07:32,050
oranjee region and that some of that may

187
00:07:35,820 --> 00:07:33,819
be associated physically with the Fermi

188
00:07:36,390 --> 00:07:35,830

bubbles but some of it could be in the

189
00:07:38,459 --> 00:07:36,400
foreground

190
00:07:40,860 --> 00:07:38,469
I mean there are spiral arms of our

191
00:07:43,040 --> 00:07:40,870
galaxy between us and a galactic center

192
00:07:46,170 --> 00:07:43,050
and those spiral arms can blow up

193
00:07:48,330 --> 00:07:46,180
material it can blow gas us into the

194
00:07:50,369 --> 00:07:48,340
halo which can also end up giving you X

195
00:07:52,469 --> 00:07:50,379
where I mentioned gamma-ray emission so

196
00:07:56,279 --> 00:07:52,479
it's actually very hard to tell from a

197
00:07:57,600 --> 00:07:56,289
map like this what is very close to the

198
00:08:00,659 --> 00:07:57,610
galactic center and what is somewhere

199
00:08:02,879 --> 00:08:00,669
else we'll get into that's where the

200
00:08:05,670 --> 00:08:02,889
Hubble data is actually very useful

201
00:08:06,869 --> 00:08:05,680
because Hubble is able to look at this

202
00:08:09,360 --> 00:08:06,879
from a different perspective from a

203
00:08:10,769 --> 00:08:09,370
different angle with its different types

204
00:08:12,809 --> 00:08:10,779
of data and that can give you more

205
00:08:14,640 --> 00:08:12,819
information about where things are so

206
00:08:16,439 --> 00:08:14,650
based on this image all we know is where

207
00:08:19,649 --> 00:08:16,449
it's bright and gamma rays we don't know

208
00:08:22,170 --> 00:08:19,659
how far away it is or where you know any

209
00:08:24,240 --> 00:08:22,180
any location information you got it

210
00:08:26,219 --> 00:08:24,250
exactly all this is is total intensity

211
00:08:29,129 --> 00:08:26,229
so it's got to be careful with this

212
00:08:31,140 --> 00:08:29,139
alone what you really understand and

213
00:08:32,339 --> 00:08:31,150

what you don't okay you also took the is

214
00:08:34,310 --> 00:08:32,349
we also have images in other wavelengths

215
00:08:37,920 --> 00:08:34,320
don't we that's correct

216
00:08:40,230 --> 00:08:37,930
so I have a question so that loopy thing

217
00:08:43,649 --> 00:08:40,240
off to the left

218
00:08:45,569 --> 00:08:43,659
what are those loopy things do you have

219
00:08:47,550 --> 00:08:45,579
you figured out what those loops are are

220
00:08:54,850 --> 00:08:47,560
you talking about to the far left of the

221
00:09:01,310 --> 00:08:59,960
hi Jerry yes um again this could be this

222
00:09:03,560 --> 00:09:01,320
could be related to the southern

223
00:09:05,930 --> 00:09:03,570
fermi-level but it's not a definitive

224
00:09:07,940 --> 00:09:05,940
connection we don't know for sure though

225
00:09:10,250 --> 00:09:07,950
that the distance of the galactic center

226
00:09:14,000 --> 00:09:10,260
oh right right

227
00:09:15,470 --> 00:09:14,010
just very suggestive okay Thanks so we

228
00:09:17,060 --> 00:09:15,480
saw these things in gamma rays and then

229
00:09:18,410 --> 00:09:17,070
we looked at it in other wavelengths sky

230
00:09:20,440 --> 00:09:18,420
you want to put it up of another one up

231
00:09:22,790 --> 00:09:20,450
there we go what here we are in

232
00:09:24,079 --> 00:09:22,800
microwave and radio and it's real

233
00:09:26,150 --> 00:09:24,089
they're really bright in there too

234
00:09:29,630 --> 00:09:26,160
that's right now this is a microwave

235
00:09:30,829 --> 00:09:29,640
image and the sharp-eyed viewers looking

236
00:09:33,050 --> 00:09:30,839
at this will notice that this is

237
00:09:35,840 --> 00:09:33,060
actually from 2004 which is before the

238
00:09:39,680 --> 00:09:35,850

Fermi bubbles were formally discovered

239
00:09:45,019 --> 00:09:39,690
okay this is from a 2004 reason for that

240
00:09:46,850 --> 00:09:45,029
is there had been this this glow above

241
00:09:49,250 --> 00:09:46,860
and below the center of the galaxy and

242
00:09:52,400 --> 00:09:49,260
microwaves but no one was really sure

243
00:09:54,170 --> 00:09:52,410
whether that was a real signal or

244
00:09:56,540 --> 00:09:54,180
whether it was something to do with the

245
00:09:58,160 --> 00:09:56,550
way that you subtract the disk because

246
00:09:59,540 --> 00:09:58,170
just like with the last image you can

247
00:10:01,160 --> 00:09:59,550
see the black man in the middle here

248
00:10:03,110 --> 00:10:01,170
that's where the disk of our galaxy

249
00:10:07,190 --> 00:10:03,120
emits microwaves and that has to be

250
00:10:09,319 --> 00:10:07,200
subtracted off so there was a hint of

251
00:10:12,440 --> 00:10:09,329
something going on in the microwave data

252
00:10:14,840 --> 00:10:12,450
from 2004 but when the gamma ray data

253
00:10:17,300 --> 00:10:14,850
came out in 2010 then you know it was

254
00:10:18,710 --> 00:10:17,310
bright in the same regions we have the

255
00:10:20,990 --> 00:10:18,720
lobes both in the north in the south

256
00:10:23,090 --> 00:10:21,000
then because you're seeing the signal at

257
00:10:24,410 --> 00:10:23,100
totally different wavelengths people

258
00:10:26,750 --> 00:10:24,420
really believed it and you that that was

259
00:10:30,260 --> 00:10:26,760
a genuine structure that they had

260
00:10:32,230 --> 00:10:30,270
detected okay so these are since this is

261
00:10:34,490 --> 00:10:32,240
a relatively new discovery do we know

262
00:10:37,100 --> 00:10:34,500
anything else about we do we know why

263
00:10:40,940 --> 00:10:37,110

they're there I mean are these lobes a

264
00:10:43,040 --> 00:10:40,950
common occurrence in in galaxies so

265
00:10:45,019 --> 00:10:43,050
there's a - very good questions on the

266
00:10:49,670 --> 00:10:45,029
first one why they're there

267
00:10:51,949 --> 00:10:49,680
we have we have two basic ideas of where

268
00:10:54,139 --> 00:10:51,959
they are coming from and what is

269
00:10:55,430 --> 00:10:54,149
powering them and they're both to do

270
00:10:57,290 --> 00:10:55,440
with the center of the Milky Way because

271
00:10:59,540 --> 00:10:57,300
we know that the center of the galaxy is

272
00:11:01,220 --> 00:10:59,550
a very energetic place and we know

273
00:11:04,220 --> 00:11:01,230
there's a supermassive black hole there

274
00:11:06,380 --> 00:11:04,230
with a mass several million times as

275
00:11:07,190 --> 00:11:06,390
high as the sun's mass so one

276
00:11:09,320 --> 00:11:07,200
possibility

277
00:11:11,600 --> 00:11:09,330
is that that supermassive black hole at

278
00:11:13,760 --> 00:11:11,610
the center of our galaxy is accreting

279
00:11:16,010 --> 00:11:13,770
matter from its surroundings and after

280
00:11:18,260 --> 00:11:16,020
the gas accretes towards the black hole

281
00:11:21,380 --> 00:11:18,270
it gets ejected and blown out into the

282
00:11:24,800 --> 00:11:21,390
halo and that blow out can create these

283
00:11:26,060 --> 00:11:24,810
bubbles another possibility is but only

284
00:11:28,010 --> 00:11:26,070
when it's blowing out right because

285
00:11:30,440 --> 00:11:28,020
right now for example it's not really

286
00:11:31,970 --> 00:11:30,450
eating anything up so late so only when

287
00:11:34,160 --> 00:11:31,980
it's active yeah because we know that

288
00:11:35,540 --> 00:11:34,170

black holes have active phases or not

289
00:11:37,910 --> 00:11:35,550
active phases so if it's actively

290
00:11:41,180 --> 00:11:37,920
accreting gas then it would be driving

291
00:11:42,800 --> 00:11:41,190
stuff out into the halo if it's in a

292
00:11:46,100 --> 00:11:42,810
quiet phase it wouldn't be doing that so

293
00:11:48,770 --> 00:11:46,110
that's definitely a stop-start episodic

294
00:11:53,090 --> 00:11:48,780
type of event so that's the black hole

295
00:11:57,080 --> 00:11:53,100
theory the other idea is whether star

296
00:11:58,790 --> 00:11:57,090
formation can be driving these bubbles

297
00:12:01,280 --> 00:11:58,800
into the halo so when you get star

298
00:12:03,470 --> 00:12:01,290
formation happening at a very high rate

299
00:12:05,450 --> 00:12:03,480
in other words lots of stars forming

300
00:12:07,130 --> 00:12:05,460
lots of stars running out of fuel some

301
00:12:10,130 --> 00:12:07,140
of them will go will turn into supernova

302
00:12:11,720 --> 00:12:10,140
supernova can explode and drive gas out

303
00:12:13,820 --> 00:12:11,730
of the disk of the galaxy up into the

304
00:12:15,860 --> 00:12:13,830
halo and we know that there are a lot of

305
00:12:16,970 --> 00:12:15,870
very massive stars close to the center

306
00:12:19,400 --> 00:12:16,980
of the galaxy because they've been

307
00:12:20,870 --> 00:12:19,410
observed so it could be that there was

308
00:12:23,560 --> 00:12:20,880
massive stars near the center of the

309
00:12:28,100 --> 00:12:23,570
galaxy have been turning into supernovae

310
00:12:30,980 --> 00:12:28,110
blowing bubbles out into the into what

311
00:12:33,020 --> 00:12:30,990
is now called the Fermi bubble so the

312
00:12:35,060 --> 00:12:33,030
we're not sure which of those two it is

313
00:12:37,070 --> 00:12:35,070

that is actually dominating but most of

314
00:12:38,600 --> 00:12:37,080
the rapidstar are the the active star

315
00:12:41,060 --> 00:12:38,610
formation in our galaxy isn't it going

316
00:12:43,040 --> 00:12:41,070
on at the leading edges of the spiral

317
00:12:46,400 --> 00:12:43,050
arms mostly and or it is the center of

318
00:12:48,800 --> 00:12:46,410
the galaxy hi active activity in star

319
00:12:51,830 --> 00:12:48,810
burn it is there's a lot of starburst

320
00:12:53,720 --> 00:12:51,840
activity in the nucleus of the galaxy it

321
00:12:57,670 --> 00:12:53,730
just as there also is in the spiral arms

322
00:13:00,440 --> 00:12:57,680
as you say but if you look at how much

323
00:13:02,870 --> 00:13:00,450
how much deformation is going on like

324
00:13:05,420 --> 00:13:02,880
per unit area of the disk is very high

325
00:13:06,800 --> 00:13:05,430
near the center of the galaxy and that's

326
00:13:08,990 --> 00:13:06,810
that's the number that you want to be

327
00:13:11,120 --> 00:13:09,000
high to to be able to drive out of wind

328
00:13:14,110 --> 00:13:11,130
I think we have one more slide in

329
00:13:17,180 --> 00:13:14,120
another wavelength is that true actually

330
00:13:18,020 --> 00:13:17,190
it's just this one okay okay so I wanted

331
00:13:21,230 --> 00:13:18,030
to make sure I got all the wavelengths

332
00:13:23,030 --> 00:13:21,240
that we had so and again again the black

333
00:13:26,120 --> 00:13:23,040
fanta cost there is the subtraction of

334
00:13:27,800 --> 00:13:26,130
the disk of our galaxy in there this

335
00:13:30,410 --> 00:13:27,810
doesn't so that you can actually see

336
00:13:32,930 --> 00:13:30,420
these things because the the signal from

337
00:13:34,670 --> 00:13:32,940
the disk is so strong correct yes it's

338
00:13:36,500 --> 00:13:34,680

really a contrast thing because if you

339
00:13:37,910 --> 00:13:36,510
put on that disk emission it would be so

340
00:13:39,980 --> 00:13:37,920
bright that everything else in the

341
00:13:42,470 --> 00:13:39,990
background would be lost in a noise okay

342
00:13:43,940 --> 00:13:42,480
so I have it okay so I have a question

343
00:13:45,139 --> 00:13:43,950
from Seb dust bunny I'm gonna go ahead

344
00:13:46,610 --> 00:13:45,149
and read it it's a little bit ahead of

345
00:13:49,490 --> 00:13:46,620
where I wanted to be but he goes has

346
00:13:52,070 --> 00:13:49,500
evidence of these bubbles seen in other

347
00:13:54,260 --> 00:13:52,080
galaxies and does it require a side-on

348
00:13:56,720 --> 00:13:54,270
view so that one goes back to my

349
00:13:58,760 --> 00:13:56,730
question or how common are these do you

350
00:14:01,639 --> 00:13:58,770
have any sense of things been seen in

351
00:14:04,340 --> 00:14:01,649
other galaxies at all so as far as

352
00:14:07,519 --> 00:14:04,350
gamma-ray bubbles go the answer is no we

353
00:14:09,590 --> 00:14:07,529
don't have any cases of other galaxies

354
00:14:14,269 --> 00:14:09,600
where we've seen these the problem is

355
00:14:15,800 --> 00:14:14,279
that we're not sensitive to detecting a

356
00:14:17,480 --> 00:14:15,810
gamma-ray emission from other galaxies

357
00:14:19,310 --> 00:14:17,490
in other words the reason we're not

358
00:14:21,230 --> 00:14:19,320
seeing them is not necessarily that they

359
00:14:23,540 --> 00:14:21,240
don't exist but it's that the light

360
00:14:25,699 --> 00:14:23,550
would be so faint that our telescopes

361
00:14:27,650 --> 00:14:25,709
aren't able to detect it and say whether

362
00:14:29,120 --> 00:14:27,660
it's there or not so our gamma-ray

363
00:14:30,260 --> 00:14:29,130

telescopes aren't powerful enough that's

364
00:14:32,740 --> 00:14:30,270
what you're saying that's another way of

365
00:14:34,970 --> 00:14:32,750
saying it so the satellite is is

366
00:14:37,190 --> 00:14:34,980
sensitive enough that it can see these

367
00:14:38,600 --> 00:14:37,200
bubbles in a milky way but even then it

368
00:14:40,220 --> 00:14:38,610
took this very careful job of

369
00:14:42,110 --> 00:14:40,230
subtracting the emission from the disk

370
00:14:43,670 --> 00:14:42,120
and a lot of processing to do that so

371
00:14:46,100 --> 00:14:43,680
that was a very challenging discovery

372
00:14:48,500 --> 00:14:46,110
even in our own Milky Way so when you go

373
00:14:50,389 --> 00:14:48,510
to another galaxy which is much further

374
00:14:52,819 --> 00:14:50,399
away so the emission is much fainter

375
00:14:54,560 --> 00:14:52,829
once by the time it's got to us it's so

376
00:14:56,750 --> 00:14:54,570
challenging that we haven't been able to

377
00:14:58,819 --> 00:14:56,760
see them but even is that true even for

378
00:15:00,920 --> 00:14:58,829
the more nearby galaxies I mean the last

379
00:15:03,139 --> 00:15:00,930
part of his question is or could this

380
00:15:05,030 --> 00:15:03,149
image or could imaging this in Andromeda

381
00:15:06,560 --> 00:15:05,040
be tried could you see that's maybe in a

382
00:15:09,620 --> 00:15:06,570
closed galaxy like the Andromeda galaxy

383
00:15:12,170 --> 00:15:09,630
you could try this in x-rays in

384
00:15:13,910 --> 00:15:12,180
Andromeda certainly in radio waves so in

385
00:15:17,389 --> 00:15:13,920
other wavelengths it's certainly true

386
00:15:19,519 --> 00:15:17,399
that we've seen extended halos and even

387
00:15:24,110 --> 00:15:19,529
bubble type structures in galaxies and

388
00:15:26,329 --> 00:15:24,120

galaxy clusters so particularly radio

389
00:15:28,180 --> 00:15:26,339
waves people have studied bubble

390
00:15:30,949 --> 00:15:28,190
structures in radio waves in other

391
00:15:32,960 --> 00:15:30,959
galaxies for some time but the gamma ray

392
00:15:34,850 --> 00:15:32,970
part of it and they and that's what led

393
00:15:37,880 --> 00:15:34,860
to this Fermi bubble name

394
00:15:41,600 --> 00:15:37,890
at the moment that's our own galaxy even

395
00:15:44,870 --> 00:15:41,610
Andromeda the closest big spiral galaxy

396
00:15:46,220 --> 00:15:44,880
to the Milky Way would if it had Fermi

397
00:15:48,230 --> 00:15:46,230
bubbles that were the same size as the

398
00:15:50,600 --> 00:15:48,240
Milky Way they would be too faint for us

399
00:15:52,160 --> 00:15:50,610
to see without current telescopes got it

400
00:15:54,560 --> 00:15:52,170
okay thanks ed that was a good question

401
00:15:56,270 --> 00:15:54,570
and so it would seem to me like you said

402
00:15:58,610 --> 00:15:56,280
there's two prevailing theories about

403
00:16:01,490 --> 00:15:58,620
what's causing these things and one of

404
00:16:03,260 --> 00:16:01,500
them was the black hole our supermassive

405
00:16:06,620 --> 00:16:03,270
black hole in the center of our galaxy I

406
00:16:07,910 --> 00:16:06,630
wonder wouldn't there be an NR and of

407
00:16:10,250 --> 00:16:07,920
course there are active and inactive

408
00:16:12,320 --> 00:16:10,260
periods of that black hole don't you

409
00:16:15,530 --> 00:16:12,330
think that would have a characteristic

410
00:16:19,090 --> 00:16:15,540
pattern to it if to these bubbles if it

411
00:16:23,660 --> 00:16:19,100
were sometimes being contributed to by a

412
00:16:25,880 --> 00:16:23,670
black hole Jets and other times not you

413
00:16:27,710 --> 00:16:25,890

understand what I'm asking yeah so

414
00:16:30,500 --> 00:16:27,720
wouldn't you expect to see some kind of

415
00:16:33,530 --> 00:16:30,510
I don't know rings or patterning to the

416
00:16:37,160 --> 00:16:33,540
bubbles yes I see what you're saying

417
00:16:38,570 --> 00:16:37,170
so we happen to have observed the

418
00:16:43,100 --> 00:16:38,580
bubbles as they are right now

419
00:16:45,470 --> 00:16:43,110
so our work with the Hubble telescope

420
00:16:47,120 --> 00:16:45,480
has actually given us an age of how long

421
00:16:49,370 --> 00:16:47,130
has it taken the gas to flow out from

422
00:16:51,110 --> 00:16:49,380
the center of the galaxy to where we

423
00:16:53,780 --> 00:16:51,120
observe it in this outflow where it's

424
00:16:55,580 --> 00:16:53,790
feeding the Fermi bubbles okay and that

425
00:16:59,030 --> 00:16:55,590
age is to about two or three million

426
00:17:00,560 --> 00:16:59,040
years so what not saying is that we two

427
00:17:02,510 --> 00:17:00,570
or three million years ago there was an

428
00:17:06,320 --> 00:17:02,520
event at the galactic center which blew

429
00:17:08,300 --> 00:17:06,330
out material and it is currently reached

430
00:17:10,160 --> 00:17:08,310
where we see it on the sky if someone

431
00:17:12,950 --> 00:17:10,170
was to come back in another two million

432
00:17:14,690 --> 00:17:12,960
years from now or you know whatever

433
00:17:16,640 --> 00:17:14,700
number of million years and observe it

434
00:17:18,740 --> 00:17:16,650
they would find the structure has got to

435
00:17:20,300 --> 00:17:18,750
a different stage so we're only looking

436
00:17:23,420 --> 00:17:20,310
at it at one point in time that's the

437
00:17:25,010 --> 00:17:23,430
difficulty and we've been able to chart

438
00:17:27,200 --> 00:17:25,020

how it's changing then we could really

439
00:17:30,200 --> 00:17:27,210
see how often is it expanding or is it

440
00:17:32,180 --> 00:17:30,210
going to reach maximum size okay we're

441
00:17:33,950 --> 00:17:32,190
just limited by the fact we can only see

442
00:17:35,900 --> 00:17:33,960
it right now at the current time you got

443
00:17:42,070 --> 00:17:35,910
it okay that's good so let's get to your

444
00:17:46,190 --> 00:17:44,570
bubbles are in a very interesting way

445
00:17:47,580 --> 00:17:46,200
they would turn Zout there was a quasar

446
00:17:50,380 --> 00:17:47,590
that happened

447
00:17:52,720 --> 00:17:50,390
to be in a certain location that was

448
00:17:54,490 --> 00:17:52,730
very fortuitous why don't you want you

449
00:17:59,200 --> 00:17:54,500
give us the background of the

450
00:18:00,760 --> 00:17:59,210
observations that you made sure so if we

451
00:18:01,600 --> 00:18:00,770
can pull up the slide to help show this

452
00:18:02,890 --> 00:18:01,610
that would be great

453
00:18:04,830 --> 00:18:02,900
that's right there's a schematic if you

454
00:18:07,060 --> 00:18:04,840
could do that Scot thank you what we've

455
00:18:11,260 --> 00:18:07,070
what we've been doing is thinking about

456
00:18:13,480 --> 00:18:11,270
how to use the Hubble telescope to study

457
00:18:15,370 --> 00:18:13,490
these Fermi bubbles and here you can see

458
00:18:16,630 --> 00:18:15,380
this is another side on view of what

459
00:18:18,910 --> 00:18:16,640
these things would look like from the

460
00:18:21,010 --> 00:18:18,920
outside of galaxy you know the Hubble

461
00:18:24,250 --> 00:18:21,020
telescope is over there in the disk on

462
00:18:27,970 --> 00:18:24,260
the right now we identified quasars that

463
00:18:31,090 --> 00:18:27,980

is very bright sources of radiation that

464
00:18:34,270 --> 00:18:31,100
happened to lie behind the bubbles so

465
00:18:36,660 --> 00:18:34,280
there's the sight line in yellow towards

466
00:18:39,070 --> 00:18:36,670
a bright quasar which in our case was

467
00:18:41,650 --> 00:18:39,080
just at the right place of the sky it

468
00:18:43,870 --> 00:18:41,660
had the right coordinates to lie close

469
00:18:47,110 --> 00:18:43,880
to the bottom of the northern fermi

470
00:18:48,760 --> 00:18:47,120
bubble one of the two bubbles and what

471
00:18:50,530 --> 00:18:48,770
we can do is we can take the light from

472
00:18:52,990 --> 00:18:50,540
this quasar in fact the ultraviolet

473
00:18:54,970 --> 00:18:53,000
light which Hubble is sensitive to

474
00:18:57,400 --> 00:18:54,980
because it's up in orbit above the

475
00:18:58,720 --> 00:18:57,410
Earth's atmosphere so it can it can make

476
00:19:00,190 --> 00:18:58,730
measurements all the way down into the

477
00:19:02,440 --> 00:19:00,200
ultraviolet which you can't do from the

478
00:19:04,720 --> 00:19:02,450
ground and by analyzing that ultraviolet

479
00:19:08,530 --> 00:19:04,730
light we can say something about the

480
00:19:10,600 --> 00:19:08,540
outflowing gas in the Fermi bubble and

481
00:19:12,700 --> 00:19:10,610
the reason is is that that outflowing

482
00:19:14,890 --> 00:19:12,710
gas leaves its signature in the

483
00:19:18,370 --> 00:19:14,900
ultraviolet light it leaves a signature

484
00:19:21,250 --> 00:19:18,380
in which frequencies of light which

485
00:19:24,549 --> 00:19:21,260
colors of light are absorbed and taken

486
00:19:26,500 --> 00:19:24,559
out of there of the spectrum so we do

487
00:19:30,270 --> 00:19:26,510
what we call a spectroscopic analysis

488
00:19:32,350 --> 00:19:30,280

and we measure lines of certain elements

489
00:19:33,760 --> 00:19:32,360
spectral lines which appear in the

490
00:19:36,549 --> 00:19:33,770
ultraviolet and that's a way of

491
00:19:39,220 --> 00:19:36,559
measuring the the properties of the gas

492
00:19:41,350 --> 00:19:39,230
that's in these bubbles and that was how

493
00:19:44,549 --> 00:19:41,360
we were able for the first time to

494
00:19:47,140 --> 00:19:44,559
measure what is the velocity of the gas

495
00:19:49,419 --> 00:19:47,150
coming out of the milky way's nucleus

496
00:19:50,890 --> 00:19:49,429
into the Fermi levels and we were also

497
00:19:53,370 --> 00:19:50,900
able to say something about what's its

498
00:19:56,409 --> 00:19:53,380
compositions and which elements are

499
00:19:57,820 --> 00:19:56,419
actually present in that gas because

500
00:19:59,860 --> 00:19:57,830
that also gives you a clue about where

501
00:20:01,030 --> 00:19:59,870
these things came from okay let's start

502
00:20:02,860 --> 00:20:01,040
with what they're made of for

503
00:20:03,970 --> 00:20:02,870
what did you discover what's what are

504
00:20:06,100 --> 00:20:03,980
these cat what are these clouds made of

505
00:20:10,720 --> 00:20:06,110
so the elements that we detected are

506
00:20:13,900 --> 00:20:10,730
silicon carbon and aluminum each of

507
00:20:15,430 --> 00:20:13,910
those elements has several of these

508
00:20:16,750 --> 00:20:15,440
spectral lines that fall in the

509
00:20:18,280 --> 00:20:16,760
ultraviolet that we can measure or we

510
00:20:21,060 --> 00:20:18,290
can see how strong how much of these

511
00:20:23,680 --> 00:20:21,070
elements are present in the in the gas

512
00:20:26,260 --> 00:20:23,690
sorry do you do you have the spectrum

513
00:20:32,860 --> 00:20:26,270

I was just going to say it looks like

514
00:20:37,090 --> 00:20:32,870
it's not okay on the image press release

515
00:20:39,340 --> 00:20:37,100
but we can use this one okay so this is

516
00:20:41,290 --> 00:20:39,350
this is the sort of data that we that we

517
00:20:45,010 --> 00:20:41,300
really work with when we get down to the

518
00:20:46,630 --> 00:20:45,020
details of analyzing the the Hubble data

519
00:20:48,570 --> 00:20:46,640
this is the spectrum which shows

520
00:20:51,280 --> 00:20:48,580
intensity or how much light there is

521
00:20:53,410 --> 00:20:51,290
against velocity along the line of sight

522
00:20:55,420 --> 00:20:53,420
and this is for a particular line this

523
00:20:56,860 --> 00:20:55,430
is twice ionized silicon and silicon

524
00:21:00,970 --> 00:20:56,870
atoms that have had two electrons

525
00:21:03,100 --> 00:21:00,980
removed from them now that gives you a

526
00:21:04,510 --> 00:21:03,110
feature at a very certain wavelength in

527
00:21:05,920 --> 00:21:04,520
the spectrum and we know exactly where

528
00:21:09,160 --> 00:21:05,930
that is in the spectrum so we know where

529
00:21:10,720 --> 00:21:09,170
to look what you see here is different

530
00:21:12,340 --> 00:21:10,730
components and those components are

531
00:21:15,060 --> 00:21:12,350
shaded in different colors this one

532
00:21:18,700 --> 00:21:15,070
shaded in blue at negative velocities

533
00:21:21,940 --> 00:21:18,710
two on the on the other side at positive

534
00:21:23,740 --> 00:21:21,950
velocities in yellow and in orange what

535
00:21:26,980 --> 00:21:23,750
this is telling you is it's basically

536
00:21:30,160 --> 00:21:26,990
using the Doppler effect the component

537
00:21:31,780 --> 00:21:30,170
that is shaded in blue that is moving

538
00:21:36,070 --> 00:21:31,790

towards us it's what we call blue

539
00:21:39,700 --> 00:21:36,080
shifted right it's gas that is we think

540
00:21:41,650 --> 00:21:39,710
on the near side of this outflowing cone

541
00:21:43,750 --> 00:21:41,660
of gas that comes out from the galactic

542
00:21:45,970 --> 00:21:43,760
center the yellow and the orange

543
00:21:47,680 --> 00:21:45,980
components are red shifted then light

544
00:21:49,990 --> 00:21:47,690
has been shifted towards the red and

545
00:21:51,850 --> 00:21:50,000
that's what you get from the far side of

546
00:21:54,310 --> 00:21:51,860
the outflow which is on the other side

547
00:21:56,050 --> 00:21:54,320
of the galactic center so just in this

548
00:21:57,490 --> 00:21:56,060
one sight line we can see these gas

549
00:21:58,810 --> 00:21:57,500
components some of which is coming

550
00:22:01,150 --> 00:21:58,820
towards you some of which is going away

551
00:22:03,820 --> 00:22:01,160
from you and that's exactly what you get

552
00:22:07,450 --> 00:22:03,830
from one of these nuclear outflows that

553
00:22:09,490 --> 00:22:07,460
comes out in a cone shaped pattern and

554
00:22:10,750 --> 00:22:09,500
so the silicon I'm going to get to the

555
00:22:13,030 --> 00:22:10,760
speeds and the velocities in just a

556
00:22:15,130 --> 00:22:13,040
minute but I want to I want to go what

557
00:22:17,150 --> 00:22:15,140
does the elements themselves

558
00:22:19,190 --> 00:22:17,160
telling you that does it give you any

559
00:22:20,780 --> 00:22:19,200
information about what their source

560
00:22:23,390 --> 00:22:20,790
might be what might be causing these

561
00:22:25,330 --> 00:22:23,400
well it does give you it does give you

562
00:22:27,770 --> 00:22:25,340
information but unfortunately it's not

563
00:22:30,140 --> 00:22:27,780

conclusive in telling you if it's the

564
00:22:32,300 --> 00:22:30,150
black hole or the star formation okay so

565
00:22:34,040 --> 00:22:32,310
look at the carbon and the aluminum we

566
00:22:36,080 --> 00:22:34,050
do know that those elements are all

567
00:22:38,030 --> 00:22:36,090
produced in stars in star formation they

568
00:22:39,710 --> 00:22:38,040
get they get forged in the cores of

569
00:22:42,200 --> 00:22:39,720
massive stars and they eventually do get

570
00:22:44,600 --> 00:22:42,210
released but what you don't know is how

571
00:22:47,180 --> 00:22:44,610
long ago that happened so it could have

572
00:22:51,110 --> 00:22:47,190
been that these elements are produced in

573
00:22:52,790 --> 00:22:51,120
stars they're released into the space

574
00:22:55,580 --> 00:22:52,800
between stars and then some of that gets

575
00:22:57,590 --> 00:22:55,590
accreted onto the the central black hole

576
00:23:00,050 --> 00:22:57,600
or it could have been that they just get

577
00:23:03,170 --> 00:23:00,060
loans directly out from from the

578
00:23:05,090 --> 00:23:03,180
supernovae in other words it doesn't

579
00:23:06,830 --> 00:23:05,100
really tell you for sure whether it's

580
00:23:08,840 --> 00:23:06,840
the star formation model or the black

581
00:23:10,910 --> 00:23:08,850
hole model but it does tell you that at

582
00:23:14,140 --> 00:23:10,920
some point this gas was processed

583
00:23:16,850 --> 00:23:14,150
through star formations clues to its

584
00:23:18,140 --> 00:23:16,860
origin so it's still there's still the

585
00:23:21,110 --> 00:23:18,150
jury's still out there's just not a

586
00:23:23,120 --> 00:23:21,120
there's not a conclusive fingerprint

587
00:23:25,670 --> 00:23:23,130
here in just the spectrum itself just

588
00:23:27,620 --> 00:23:25,680

the elements themselves so uh but I want

589
00:23:29,300 --> 00:23:27,630
to get to the velocity now and talk of

590
00:23:30,530 --> 00:23:29,310
so but before I do the Doppler effect

591
00:23:32,690 --> 00:23:30,540
that you're talking about let me just

592
00:23:34,910 --> 00:23:32,700
try and see if I can give a little bit a

593
00:23:39,590 --> 00:23:34,920
basic background on this if you take a

594
00:23:42,800 --> 00:23:39,600
spectrum of of an object at rest you

595
00:23:45,770 --> 00:23:42,810
will see certain lines dark and bright

596
00:23:48,980 --> 00:23:45,780
lines appear at it's very specific spots

597
00:23:51,170 --> 00:23:48,990
in the spectrum depending on what the

598
00:23:53,210 --> 00:23:51,180
element is and if that thing is moving

599
00:23:54,590 --> 00:23:53,220
what you will whatever it is you're

600
00:23:56,690 --> 00:23:54,600
measuring you will actually see all of

601
00:23:59,150 --> 00:23:56,700
those lines shifted one way or another

602
00:24:00,740 --> 00:23:59,160
and it will be shifted how much is

603
00:24:02,630 --> 00:24:00,750
shifted gives you an idea of how fast

604
00:24:04,730 --> 00:24:02,640
it's going and which direction it

605
00:24:07,010 --> 00:24:04,740
shifted tells you whether it's coming

606
00:24:10,100 --> 00:24:07,020
towards you or away from you so that is

607
00:24:12,740 --> 00:24:10,110
how the Doppler shift is used in spectra

608
00:24:15,500 --> 00:24:12,750
and you can see it in this in this graph

609
00:24:18,710 --> 00:24:15,510
alright so that the dotted line that

610
00:24:22,390 --> 00:24:18,720
goes horizontally is essentially the

611
00:24:26,230 --> 00:24:22,400
ambient intensity and the light comes

612
00:24:27,769 --> 00:24:26,240
light comes from another source and hits

613
00:24:30,349 --> 00:24:27,779

silicon atom

614
00:24:32,930 --> 00:24:30,359
and is absorbed and so that central line

615
00:24:36,019 --> 00:24:32,940
is most of the silicon but if that

616
00:24:39,049 --> 00:24:36,029
silicon atom is moving and in case many

617
00:24:43,609 --> 00:24:39,059
silicon atoms moving or sort of an above

618
00:24:46,310 --> 00:24:43,619
motion light has to when it's absorbed

619
00:24:48,440 --> 00:24:46,320
is shifted either if the material is

620
00:24:51,469 --> 00:24:48,450
moving towards us or away and our

621
00:24:54,379 --> 00:24:51,479
analogy is always the train whistle here

622
00:24:56,899 --> 00:24:54,389
I pitch a neutral tone and then the low

623
00:24:59,239 --> 00:24:56,909
pitch as a train goes past you if it's

624
00:25:04,389 --> 00:24:59,249
blowing its whistle the whole time so

625
00:25:06,709 --> 00:25:04,399
that's also how speed radar works so I

626
00:25:08,149 --> 00:25:06,719
actually once got out of a ticket

627
00:25:09,379 --> 00:25:08,159
because I explained the Doppler effect

628
00:25:11,869 --> 00:25:09,389
to a cop

629
00:25:13,430 --> 00:25:11,879
I don't know he gave me a warning

630
00:25:15,859 --> 00:25:13,440
because I had given him a physics lesson

631
00:25:18,739 --> 00:25:15,869
but anyway I wouldn't try them but

632
00:25:21,499 --> 00:25:18,749
anyway by physics

633
00:25:23,209 --> 00:25:21,509
yeah really so so that's how they tell

634
00:25:24,889 --> 00:25:23,219
that the material is moving because

635
00:25:28,399 --> 00:25:24,899
there's nothing else I'm sore being in

636
00:25:31,219 --> 00:25:28,409
that region except the silicon good so

637
00:25:32,599 --> 00:25:31,229
and so now now Andy why don't you tell

638
00:25:34,909 --> 00:25:32,609

us a little bit about these speeds then

639
00:25:36,739 --> 00:25:34,919
you've got them at more or less going

640
00:25:38,839 --> 00:25:36,749
out at about plus or minus 200

641
00:25:41,779 --> 00:25:38,849
kilometers per second right that's right

642
00:25:44,180 --> 00:25:41,789
so that these velocities are what we

643
00:25:45,799 --> 00:25:44,190
measure along the line of sight so in

644
00:25:47,209 --> 00:25:45,809
other words when you look towards this

645
00:25:50,810 --> 00:25:47,219
quasar which is close to the galactic

646
00:25:52,849 --> 00:25:50,820
center the blue stuff is coming towards

647
00:25:55,639 --> 00:25:52,859
you about minus 250 kilometers per

648
00:25:58,519 --> 00:25:55,649
second or so the orange component is

649
00:26:00,769 --> 00:25:58,529
plus 250 kilometers per second but what

650
00:26:03,169 --> 00:26:00,779
we have to do is we have to realize that

651
00:26:05,680 --> 00:26:03,179
we're just seeing a projection along our

652
00:26:08,149 --> 00:26:05,690
line of sight of the outflow because it

653
00:26:11,239 --> 00:26:08,159
our understanding is that most of the

654
00:26:13,849 --> 00:26:11,249
gas is moving directly out from the

655
00:26:16,099 --> 00:26:13,859
galactic center so up into the halo of

656
00:26:17,690 --> 00:26:16,109
the galaxy what you see is the

657
00:26:19,519 --> 00:26:17,700
projection of that onto our line of

658
00:26:21,349 --> 00:26:19,529
sight so we had to do a little bit of

659
00:26:24,320 --> 00:26:21,359
geometry to determine what is the

660
00:26:26,180 --> 00:26:24,330
outflow speed the actual the total

661
00:26:28,190 --> 00:26:26,190
velocity of the gas that moves away from

662
00:26:30,259 --> 00:26:28,200
the center of the galaxy because that's

663
00:26:32,359 --> 00:26:30,269

not the same as what we see along our

664
00:26:35,029 --> 00:26:32,369
line of sight I don't understand so you

665
00:26:37,129 --> 00:26:35,039
this is a measurement of one specific

666
00:26:39,169 --> 00:26:37,139
path of the better light that the quasar

667
00:26:40,400 --> 00:26:39,179
went through so you know about the gas

668
00:26:42,230 --> 00:26:40,410
right there

669
00:26:44,570 --> 00:26:42,240
you do and what what did you do now to

670
00:26:47,150 --> 00:26:44,580
figure out the rest I don't know so

671
00:26:48,860 --> 00:26:47,160
you're measuring along that line of

672
00:26:51,620 --> 00:26:48,870
sight towards this particular quasar

673
00:26:53,150 --> 00:26:51,630
right you have one data point right one

674
00:26:55,520 --> 00:26:53,160
of these components are coming towards

675
00:26:57,470 --> 00:26:55,530
you or away from you but in reality this

676
00:26:59,660 --> 00:26:57,480
gas is moving in three dimensions not

677
00:27:01,940 --> 00:26:59,670
just in one dimension towards us or away

678
00:27:04,640 --> 00:27:01,950
from us so we have to do some geometry

679
00:27:07,370 --> 00:27:04,650
to determine how far it is it actually

680
00:27:09,020 --> 00:27:07,380
moving directly up if you imagine you're

681
00:27:11,840 --> 00:27:09,030
looking at that side view of the galaxy

682
00:27:15,140 --> 00:27:11,850
again the real the direction that this

683
00:27:17,990 --> 00:27:15,150
outflow is going is out into the halo up

684
00:27:19,340 --> 00:27:18,000
above from the galactic center so you're

685
00:27:20,960 --> 00:27:19,350
just what you were seeing in the

686
00:27:24,230 --> 00:27:20,970
spectrum is the component of that that

687
00:27:25,940 --> 00:27:24,240
is that is along your line of sight so

688
00:27:27,740 --> 00:27:25,950

they said that's just an extra stage

689
00:27:30,020 --> 00:27:27,750
that goes into our calculations that

690
00:27:32,960 --> 00:27:30,030
goes from our line-of-sight velocity to

691
00:27:35,540 --> 00:27:32,970
what is the actual outflow velocity in

692
00:27:37,820 --> 00:27:35,550
three dimensions which is how fast it is

693
00:27:39,320 --> 00:27:37,830
it is the gas launched from the galactic

694
00:27:43,580 --> 00:27:39,330
center because that number is much

695
00:27:45,650 --> 00:27:43,590
faster it's more like wow that's really

696
00:27:48,230 --> 00:27:45,660
fast so this there's a related comment

697
00:27:49,760 --> 00:27:48,240
in question here from Adam synergy and I

698
00:27:51,500 --> 00:27:49,770
wanted to highlight this he's going so

699
00:27:53,360 --> 00:27:51,510
this observation is just the beginning

700
00:27:54,800 --> 00:27:53,370
right surely you will need to repeat

701
00:27:57,200 --> 00:27:54,810
this many times with different

702
00:27:58,430 --> 00:27:57,210
background quasars to fully map the

703
00:28:00,260 --> 00:27:58,440
Fermi bubbles and you're saying there's

704
00:28:02,150 --> 00:28:00,270
a technique here for getting that

705
00:28:04,040 --> 00:28:02,160
information yeah now that's a very good

706
00:28:06,830 --> 00:28:04,050
question we do need to do that we we

707
00:28:08,360 --> 00:28:06,840
began our program with this one sight

708
00:28:10,340 --> 00:28:08,370
line because it just happened to lie in

709
00:28:12,320 --> 00:28:10,350
such a great place this is the best

710
00:28:14,120 --> 00:28:12,330
quasar we have in terms of being close

711
00:28:16,220 --> 00:28:14,130
to the galactic center where the wind is

712
00:28:18,050 --> 00:28:16,230
going to be strongest because whatever

713
00:28:19,640 --> 00:28:18,060

is producing this it's something to do

714
00:28:21,140 --> 00:28:19,650
with a galactic center it's either stars

715
00:28:23,240 --> 00:28:21,150
near the galactic center or it's the

716
00:28:24,830 --> 00:28:23,250
black hole optic electric center so we

717
00:28:26,990 --> 00:28:24,840
were looking for targets as close as

718
00:28:29,150 --> 00:28:27,000
possible to that point and this was the

719
00:28:31,970 --> 00:28:29,160
best quasar but our full sample is more

720
00:28:33,920 --> 00:28:31,980
like 20 or so quasars some of which are

721
00:28:38,000 --> 00:28:33,930
inside the Fermi bubbles some of which

722
00:28:39,800 --> 00:28:38,010
are just outside and we have the ongoing

723
00:28:42,530 --> 00:28:39,810
task right now of analyzing all that

724
00:28:44,810 --> 00:28:42,540
that data and measuring the absorption

725
00:28:46,100 --> 00:28:44,820
lines that we see in the just the same

726
00:28:47,510 --> 00:28:46,110
techniques we've been talking about we

727
00:28:49,700 --> 00:28:47,520
need to do that for the full sample not

728
00:28:51,350 --> 00:28:49,710
just this one case good a good question

729
00:28:52,820 --> 00:28:51,360
Adam thank you and Craig Landon I'm

730
00:28:53,840 --> 00:28:52,830
gonna get to yours in just a minute but

731
00:28:57,680 --> 00:28:53,850
so

732
00:28:59,600 --> 00:28:57,690
the the the the measurements you've got

733
00:29:01,159 --> 00:28:59,610
tell you a little bit about how these

734
00:29:02,600 --> 00:29:01,169
things are moving fast by the way these

735
00:29:05,480 --> 00:29:02,610
things are really moving out there and

736
00:29:07,010 --> 00:29:05,490
you said something earlier about this

737
00:29:09,230 --> 00:29:07,020
happened what was a two and a half

738
00:29:11,750 --> 00:29:09,240

million years ago or whatever it was it

739
00:29:14,090 --> 00:29:11,760
caused and is the way you found that out

740
00:29:15,470 --> 00:29:14,100
by running the the clock backwards going

741
00:29:18,200 --> 00:29:15,480
backward and you know how fast they are

742
00:29:19,460 --> 00:29:18,210
right now so you just figured out to get

743
00:29:20,240 --> 00:29:19,470
where they are now I must have taken

744
00:29:21,500 --> 00:29:20,250
them this long

745
00:29:26,029 --> 00:29:21,510
that's exactly right that's the

746
00:29:29,090 --> 00:29:26,039
calculation we did we so we measured the

747
00:29:30,680 --> 00:29:29,100
outflow velocity and found about 900 or

748
00:29:32,570 --> 00:29:30,690
a thousand kilometers per second and

749
00:29:37,250 --> 00:29:32,580
that's about two million miles per hour

750
00:29:38,240 --> 00:29:37,260
and more million miles an hour two

751
00:29:39,860 --> 00:29:38,250
million miles an hour

752
00:29:42,500 --> 00:29:39,870
gushing out from the galactic center

753
00:29:44,930 --> 00:29:42,510
because we know how far from a galactic

754
00:29:47,000 --> 00:29:44,940
center is reached we know the distance

755
00:29:48,529 --> 00:29:47,010
right so we've got a distance we've got

756
00:29:51,500 --> 00:29:48,539
a velocity we could turn back the clock

757
00:29:53,120 --> 00:29:51,510
and figure out the time and when you do

758
00:29:55,640 --> 00:29:53,130
that calculation the answer is somewhere

759
00:29:58,580 --> 00:29:55,650
between two and a half to three or four

760
00:30:00,409 --> 00:29:58,590
million years so it tells you that

761
00:30:03,919 --> 00:30:00,419
that's how long it's taken for the gas

762
00:30:06,350 --> 00:30:03,929
to to be driven away from the galactic

763
00:30:07,520 --> 00:30:06,360

center to where we see it or to put it

764
00:30:08,720 --> 00:30:07,530
differently it just tells you that two

765
00:30:10,460 --> 00:30:08,730
or three million years ago there was a

766
00:30:13,010 --> 00:30:10,470
very energetic event there were some

767
00:30:16,210 --> 00:30:13,020
fireworks something happened that was

768
00:30:18,770 --> 00:30:16,220
capable of driving this stuff out

769
00:30:24,110 --> 00:30:18,780
producing what we now see and Scott's

770
00:30:25,700 --> 00:30:24,120
got a very France friendly looking it's

771
00:30:27,049 --> 00:30:25,710
the chromatic up here to sort of show

772
00:30:30,200 --> 00:30:27,059
what we've been talking about all this

773
00:30:32,330 --> 00:30:30,210
time you could see the the where the red

774
00:30:34,820 --> 00:30:32,340
and the blue areas of the spectrum are

775
00:30:38,930 --> 00:30:34,830
in the little diagram in the lower left

776
00:30:40,159 --> 00:30:38,940
and the so it gives a sense a little bit

777
00:30:41,409 --> 00:30:40,169
more of what we were just talking about

778
00:30:43,610 --> 00:30:41,419
but this is more of an artist

779
00:30:48,049 --> 00:30:43,620
representation of that where the other

780
00:30:54,200 --> 00:30:48,059
stuff was actual and the others was

781
00:30:55,669 --> 00:30:54,210
actual data so okay so let's see we let

782
00:30:58,490 --> 00:30:55,679
me get to Craig Landon here he's got a

783
00:31:01,159 --> 00:30:58,500
question here for us that is what might

784
00:31:03,470 --> 00:31:01,169
be the contribution of gravitational

785
00:31:07,010 --> 00:31:03,480
waves to what can be inferred from the

786
00:31:08,690 --> 00:31:07,020
views and different wavelengths so you

787
00:31:10,280 --> 00:31:08,700
can grab any waves affect these in any

788
00:31:12,260 --> 00:31:10,290

way from what you've seen in the

789
00:31:12,980 --> 00:31:12,270
different wavelengths or is it too early

790
00:31:15,860 --> 00:31:12,990
to tell

791
00:31:18,200 --> 00:31:15,870
I think I think it's too early to say

792
00:31:20,990 --> 00:31:18,210
what the contribution of gravitational

793
00:31:22,550 --> 00:31:21,000
waves would be if I mean if there was a

794
00:31:24,080 --> 00:31:22,560
place where that would be relevant it

795
00:31:26,390 --> 00:31:24,090
would probably be very close to the

796
00:31:28,760 --> 00:31:26,400
center of the black at the black hole

797
00:31:30,740 --> 00:31:28,770
itself where you have a several million

798
00:31:33,980 --> 00:31:30,750
solar mass object which is certainly

799
00:31:37,460 --> 00:31:33,990
going to be disturbing the space-time

800
00:31:38,630 --> 00:31:37,470
around it but we we don't we don't see

801
00:31:40,820 --> 00:31:38,640
what a connection would be right now

802
00:31:44,320 --> 00:31:40,830
between these these observations of

803
00:31:47,510 --> 00:31:44,330
gravitational waves cool thanks Craig so

804
00:31:49,790 --> 00:31:47,520
how do we know how hot these things are

805
00:31:53,480 --> 00:31:49,800
we know how the temperature the gas well

806
00:31:56,590 --> 00:31:53,490
the gas that we're seeing in the Hubble

807
00:31:58,910 --> 00:31:56,600
data it's actually not that heart by

808
00:32:03,370 --> 00:31:58,920
astronomers standards it's probably

809
00:32:09,650 --> 00:32:08,240
17,000 Fahrenheit or so every day

810
00:32:12,050 --> 00:32:09,660
standards but in terms of like

811
00:32:13,370 --> 00:32:12,060
interstellar space that's not so hot

812
00:32:14,930 --> 00:32:13,380
there's a plenty of stuff which is at a

813
00:32:17,630 --> 00:32:14,940

million degrees or ten million degrees

814
00:32:18,740 --> 00:32:17,640
or hotter right and it's also not very

815
00:32:20,030 --> 00:32:18,750
dense right I was going to get to

816
00:32:23,720 --> 00:32:20,040
density too while we're talking about

817
00:32:26,390 --> 00:32:23,730
temperature are these very dense no not

818
00:32:27,710 --> 00:32:26,400
really I mean it the typical densities

819
00:32:29,720 --> 00:32:27,720
you have in these things are something

820
00:32:33,140 --> 00:32:29,730
like one atom per cubic centimeter

821
00:32:35,330 --> 00:32:33,150
okay char extraordinaire allele oh by

822
00:32:37,370 --> 00:32:35,340
our standards on earth but that's the

823
00:32:41,480 --> 00:32:37,380
sort of number you come across in

824
00:32:42,890 --> 00:32:41,490
interstellar space but the interesting

825
00:32:45,370 --> 00:32:42,900
thing about the temperature is if I can

826
00:32:48,680 --> 00:32:45,380
just come back to this point is sure

827
00:32:52,400 --> 00:32:48,690
people have been studying winds coming

828
00:32:53,900 --> 00:32:52,410
out of other galaxies and they haven't

829
00:32:55,370 --> 00:32:53,910
been able to see the bubbles because of

830
00:32:57,260 --> 00:32:55,380
what we talked about and gamma rays are

831
00:33:00,080 --> 00:32:57,270
too faint but they have been able to see

832
00:33:02,870 --> 00:33:00,090
winds and and when they studied winds

833
00:33:05,690 --> 00:33:02,880
and it's widely accepted that most of

834
00:33:07,910 --> 00:33:05,700
the wind and energy that comes out from

835
00:33:10,610 --> 00:33:07,920
the center of galaxies is very hot where

836
00:33:12,290 --> 00:33:10,620
it's it's extremely hard to detect so

837
00:33:14,720 --> 00:33:12,300
it's possible that what we're seeing in

838
00:33:17,000 --> 00:33:14,730

this cooler gas and with the Hubble data

839
00:33:18,950 --> 00:33:17,010
are just small clouds that are being

840
00:33:21,530 --> 00:33:18,960
taken along for the ride in the outflow

841
00:33:23,210 --> 00:33:21,540
we're not really seeing

842
00:33:25,160 --> 00:33:23,220
the bulk of the mass the bulk of the

843
00:33:27,320 --> 00:33:25,170
energy in the wind we're just seeing

844
00:33:29,300 --> 00:33:27,330
small pockets of material that are

845
00:33:31,610 --> 00:33:29,310
relatively dense and are being taken

846
00:33:33,290 --> 00:33:31,620
along for the ride now this is really

847
00:33:36,130 --> 00:33:33,300
interesting I hadn't heard this so in

848
00:33:38,150 --> 00:33:36,140
galactic winds you're the entire

849
00:33:39,710 --> 00:33:38,160
describe what those would be like I

850
00:33:42,230 --> 00:33:39,720
don't I I'm having trouble visually is

851
00:33:46,430 --> 00:33:42,240
it the entire galaxy blowing out well

852
00:33:48,650 --> 00:33:46,440
yes it could be galactic wide winds I'm

853
00:33:52,100 --> 00:33:48,660
focusing here more on the Galactic

854
00:33:54,470 --> 00:33:52,110
nuclear winds okay but if you if you if

855
00:33:55,640 --> 00:33:54,480
you look at the the supernova model

856
00:33:58,490 --> 00:33:55,650
where it's the supernovae that are

857
00:34:00,170 --> 00:33:58,500
powering the outflow those explosions

858
00:34:02,230 --> 00:34:00,180
heat the gas to extremely high

859
00:34:06,140 --> 00:34:02,240
temperatures well over a million degrees

860
00:34:09,890 --> 00:34:06,150
that is the type of gas that can expand

861
00:34:11,900 --> 00:34:09,900
and blow a wind out into the halo so you

862
00:34:14,570 --> 00:34:11,910
could think of that as the real hot wind

863
00:34:16,490 --> 00:34:14,580

and a little cool cool clumps that we

864
00:34:18,500 --> 00:34:16,500
see they're just catching a ride they're

865
00:34:20,900 --> 00:34:18,510
just surfing the waves up into the halo

866
00:34:23,540 --> 00:34:20,910
but this is the interesting thing so

867
00:34:25,310 --> 00:34:23,550
we're not really seeing all of the gas

868
00:34:27,230 --> 00:34:25,320
by any means we're just seeing the small

869
00:34:29,690 --> 00:34:27,240
clumps that are at the right temperature

870
00:34:31,130 --> 00:34:29,700
that Hubble can see them because for all

871
00:34:32,390 --> 00:34:31,140
the wonderful things that Hubble can do

872
00:34:34,940 --> 00:34:32,400
in the ultraviolet it can't actually

873
00:34:37,940 --> 00:34:34,950
measure the really hot million degree

874
00:34:39,470 --> 00:34:37,950
phase it is where theorists think most

875
00:34:40,159 --> 00:34:39,480
of them when most of the energy is being

876
00:34:42,230 --> 00:34:40,169
carried

877
00:34:43,820 --> 00:34:42,240
okay so what's confusing about that to

878
00:34:45,650 --> 00:34:43,830
me is that we can see these winds in

879
00:34:50,030 --> 00:34:45,660
other galaxies but we can't see it in

880
00:34:52,909 --> 00:34:50,040
our own we can see winds and in x-rays

881
00:34:56,780 --> 00:34:52,919
the one thing we can we can in our

882
00:34:59,930 --> 00:34:56,790
galaxy or in distant galaxies well both

883
00:35:01,970 --> 00:34:59,940
okay the difficulty in our own galaxy is

884
00:35:03,220 --> 00:35:01,980
that you've got this problem of being

885
00:35:05,660 --> 00:35:03,230
able to see the forest for the trees

886
00:35:06,230 --> 00:35:05,670
because we're right here in the disk of

887
00:35:08,300 --> 00:35:06,240
the galaxy

888
00:35:10,460 --> 00:35:08,310

okay so we're rotating there's a lot of

889
00:35:13,460 --> 00:35:10,470
foreground material right between us and

890
00:35:15,020 --> 00:35:13,470
the galactic center so ironically it's

891
00:35:16,970 --> 00:35:15,030
actually harder sometimes to figure out

892
00:35:19,100 --> 00:35:16,980
what's going on at the centre of the

893
00:35:20,930 --> 00:35:19,110
Milky Way then you look at another

894
00:35:23,480 --> 00:35:20,940
galaxy it's further away but you've got

895
00:35:26,420 --> 00:35:23,490
a clean shot at it so you can you don't

896
00:35:28,280 --> 00:35:26,430
have all the foreground issues to deal

897
00:35:29,810 --> 00:35:28,290
with okay so it's the same probably have

898
00:35:32,300 --> 00:35:29,820
a seeing the bubbles at all you've got

899
00:35:34,310 --> 00:35:32,310
so much our galaxy is so bright that

900
00:35:37,400 --> 00:35:34,320
it's in the way of seeing these winds

901
00:35:40,610 --> 00:35:37,410
in any meaningful way so yeah okay

902
00:35:42,970 --> 00:35:40,620
laughing right okay well uh so that we

903
00:35:45,110 --> 00:35:42,980
have another comment here from oh and we

904
00:35:47,090 --> 00:35:45,120
Philippe Philippe OH

905
00:35:49,670 --> 00:35:47,100
Conte is it possible that the event

906
00:35:51,290 --> 00:35:49,680
horizon is something like a sphere and

907
00:35:53,450 --> 00:35:51,300
so the bubbles are just formed by

908
00:35:55,370 --> 00:35:53,460
materials that are going towards the

909
00:35:57,830 --> 00:35:55,380
horizon from both sides

910
00:36:00,800 --> 00:35:57,840
I guess that's more of a geometry of the

911
00:36:03,050 --> 00:36:00,810
of the black hole contribution question

912
00:36:03,470 --> 00:36:03,060
right that's a that's an interesting

913
00:36:05,750 --> 00:36:03,480

thought

914
00:36:09,620 --> 00:36:05,760
so if if the Fermi bubbles are being

915
00:36:11,540 --> 00:36:09,630
powered by the black hole then of course

916
00:36:13,340 --> 00:36:11,550
nothing can escape from the event

917
00:36:14,990 --> 00:36:13,350
horizon of that black hole but you can

918
00:36:17,330 --> 00:36:15,000
get material which escapes from the

919
00:36:18,920 --> 00:36:17,340
region just around the event horizon so

920
00:36:21,440 --> 00:36:18,930
if we have this accretion disk which is

921
00:36:23,630 --> 00:36:21,450
where the gas gets really hot and is

922
00:36:25,760 --> 00:36:23,640
falling towards and swirling onto the

923
00:36:30,680 --> 00:36:25,770
black hole that's the region where you

924
00:36:32,840 --> 00:36:30,690
can get outflows that drive into the

925
00:36:33,890 --> 00:36:32,850
bubbles maybe even Jets as well we

926
00:36:38,420 --> 00:36:33,900
haven't talked about Jets

927
00:36:40,400 --> 00:36:38,430
but there is one theoretical model which

928
00:36:42,470 --> 00:36:40,410
says that you can drive these Jets out

929
00:36:45,610 --> 00:36:42,480
from the supermassive black hole and

930
00:36:48,080 --> 00:36:45,620
that is what is contributing towards the

931
00:36:49,190 --> 00:36:48,090
Fermi bubbles oh okay that's right so

932
00:36:53,060 --> 00:36:49,200
that would be these high energy Jets

933
00:36:54,890 --> 00:36:53,070
that are in very active galactic nuclei

934
00:36:57,170 --> 00:36:54,900
or black holes that's right and you see

935
00:37:00,680 --> 00:36:57,180
these Jets around other active galactic

936
00:37:02,750 --> 00:37:00,690
nuclei other galaxies exactly but they

937
00:37:05,300 --> 00:37:02,760
would be formed somewhere fairly close

938
00:37:07,820 --> 00:37:05,310

into the center of the black hole but

939
00:37:10,340 --> 00:37:07,830
still outside the event horizon okay

940
00:37:14,480 --> 00:37:10,350
good that's a good question okay so all

941
00:37:17,840 --> 00:37:14,490
right so so I may I may have missed this

942
00:37:22,070 --> 00:37:17,850
but but so there's this bubble but so

943
00:37:25,460 --> 00:37:22,080
it's it's the waste if you will is tight

944
00:37:28,430 --> 00:37:25,470
at least the way you have detected it is

945
00:37:30,760 --> 00:37:28,440
tight near the plane is there still as a

946
00:37:35,000 --> 00:37:30,770
mission within the plane of the galaxy

947
00:37:35,870 --> 00:37:35,010
caused by the same sources right that's

948
00:37:39,470 --> 00:37:35,880
right yes

949
00:37:42,800 --> 00:37:39,480
it's not necessarily it could be but

950
00:37:44,570 --> 00:37:42,810
nuts is necessarily white bipolar like

951
00:37:45,800 --> 00:37:44,580
that is that right yes that's right so

952
00:37:47,640 --> 00:37:45,810
that waste is telling you something

953
00:37:50,190 --> 00:37:47,650
important because

954
00:37:51,990 --> 00:37:50,200
what we think is happening is that the

955
00:37:54,090 --> 00:37:52,000
the firming bubble however it gets

956
00:37:57,300 --> 00:37:54,100
created it has to expand into something

957
00:38:01,140 --> 00:37:57,310
and the denser material in it then it

958
00:38:03,630 --> 00:38:01,150
expands into the harder it is to to get

959
00:38:06,390 --> 00:38:03,640
bigger whereas the less dense the easier

960
00:38:08,280 --> 00:38:06,400
it is to expand so naturally the bubbles

961
00:38:10,050 --> 00:38:08,290
just inflate and get bigger away from

962
00:38:13,200 --> 00:38:10,060
the galactic center in the vertical

963
00:38:14,520 --> 00:38:13,210

direction but in the waste direction

964
00:38:15,900 --> 00:38:14,530
sort of towards the sides they're

965
00:38:17,370 --> 00:38:15,910
probably encountering a lot more

966
00:38:19,410 --> 00:38:17,380
resistance because there's a lot more

967
00:38:21,990 --> 00:38:19,420
gas there there's a lot more interesting

968
00:38:23,640 --> 00:38:22,000
material and that's what's confining the

969
00:38:26,460 --> 00:38:23,650
bubbles and we think that that's where

970
00:38:28,110 --> 00:38:26,470
the waste structure the shape of these

971
00:38:31,800 --> 00:38:28,120
things comes from it's sort of set by

972
00:38:34,020 --> 00:38:31,810
what is restricting the stuff that's in

973
00:38:38,190 --> 00:38:34,030
the way right and we can't detect that

974
00:38:40,050 --> 00:38:38,200
way that way but in the plane we can't

975
00:38:42,390 --> 00:38:40,060
do this observation because there's all

976
00:38:43,680 --> 00:38:42,400
this other yeah besides we go through a

977
00:38:48,180 --> 00:38:43,690
lot of trouble to subtract all that out

978
00:38:50,070 --> 00:38:48,190
anyhow so it would be a tiny little yeah

979
00:38:53,550 --> 00:38:50,080
if we could see it at all okay so

980
00:38:56,280 --> 00:38:53,560
red-hot bagel is asking this might be a

981
00:38:58,260 --> 00:38:56,290
dumb question no such thing on our

982
00:38:59,610 --> 00:38:58,270
hangouts thank you for asking it's a

983
00:39:02,070 --> 00:38:59,620
really good question yes it's actually

984
00:39:04,020 --> 00:39:02,080
not a dumb question but how exactly do

985
00:39:06,620 --> 00:39:04,030
you measure the temperatures of these

986
00:39:11,760 --> 00:39:06,630
gases okay

987
00:39:15,410 --> 00:39:11,770
not a bad question at all we have access

988
00:39:18,210 --> 00:39:15,420

in the Cobbold ultraviolet data to

989
00:39:19,980 --> 00:39:18,220
different different lines I showed a

990
00:39:23,970 --> 00:39:19,990
line earlier on when we had a graphic up

991
00:39:26,220 --> 00:39:23,980
of twice ionized silicon so a silicon

992
00:39:28,470 --> 00:39:26,230
atom that's being ionized as I had two

993
00:39:30,660 --> 00:39:28,480
electrons taken out of it now the level

994
00:39:32,190 --> 00:39:30,670
of ionization so how many electrons has

995
00:39:34,410 --> 00:39:32,200
been removed tells you something about

996
00:39:37,290 --> 00:39:34,420
the temperature because the hotter the

997
00:39:39,120 --> 00:39:37,300
gas the more electrons will be removed

998
00:39:41,840 --> 00:39:39,130
from all the atoms whereas difficult is

999
00:39:46,200 --> 00:39:41,850
very cool the gas can be atomic or even

1000
00:39:47,280 --> 00:39:46,210
molecular so twice ionized silicon the

1001
00:39:49,550 --> 00:39:47,290
one that is shown in that particular

1002
00:39:51,710 --> 00:39:49,560
graph just happens to live in

1003
00:39:55,440 --> 00:39:51,720
interstellar gas at temperatures of

1004
00:39:57,510 --> 00:39:55,450
approximately 10,000 Kelvin you have to

1005
00:39:58,200 --> 00:39:57,520
describe for us twice ionized what do

1006
00:40:01,050 --> 00:39:58,210
you mean by that

1007
00:40:03,480 --> 00:40:01,060
so that means it's minus twice

1008
00:40:04,740 --> 00:40:03,490
I mean come on Tony I mean two electrons

1009
00:40:06,870 --> 00:40:04,750
have been taken out of it so if you

1010
00:40:07,260 --> 00:40:06,880
start with a neutral silicon atom thank

1011
00:40:12,960 --> 00:40:07,270
you

1012
00:40:14,790 --> 00:40:12,970
with what we call high silicon atoms and

1013
00:40:17,400 --> 00:40:14,800

that leaves its imprint at a certain

1014
00:40:18,540 --> 00:40:17,410
wavelength good I just wanted to get

1015
00:40:19,890 --> 00:40:18,550
that clear because a lot of it's not

1016
00:40:21,000 --> 00:40:19,900
clear what you know of the word ionized

1017
00:40:22,980 --> 00:40:21,010
is a big one so I wanna make sure we

1018
00:40:25,110 --> 00:40:22,990
explained out that it's not a very very

1019
00:40:28,160 --> 00:40:25,120
big long thermometer that we shove out

1020
00:40:30,660 --> 00:40:28,170
there we have ways of using the light to

1021
00:40:33,060 --> 00:40:30,670
to actually get the information the

1022
00:40:35,340 --> 00:40:33,070
spectra it's actually what's going on in

1023
00:40:37,260 --> 00:40:35,350
those in those gases and in those ions

1024
00:40:38,670 --> 00:40:37,270
to that let's go that's right and and

1025
00:40:39,930 --> 00:40:38,680
these ions each live at different

1026
00:40:42,390 --> 00:40:39,940
temperatures so that's the short answer

1027
00:40:44,400 --> 00:40:42,400
is that this one lives and approximately

1028
00:40:48,060 --> 00:40:44,410
10,000 Kelvin but it's certainly not a

1029
00:40:49,980 --> 00:40:48,070
very precise broke it could be eight

1030
00:40:50,640 --> 00:40:49,990
thousand ten thousand somewhere in that

1031
00:40:53,310 --> 00:40:50,650
ballpark

1032
00:40:55,140 --> 00:40:53,320
thank you red-hot bagel that was good

1033
00:40:57,650 --> 00:40:55,150
question very good question

1034
00:41:01,440 --> 00:40:57,660
so we touched on this briefly earlier

1035
00:41:03,210 --> 00:41:01,450
and I want to follow up with your

1036
00:41:04,980 --> 00:41:03,220
looking at other quasars I want to talk

1037
00:41:08,370 --> 00:41:04,990
about what's next what's the future here

1038
00:41:10,320 --> 00:41:08,380

what do you have up coming up for us in

1039
00:41:13,170 --> 00:41:10,330
terms of learning more about these Fermi

1040
00:41:15,600 --> 00:41:13,180
bubbles do you have anything planned so

1041
00:41:17,400 --> 00:41:15,610
we do we have the other quasars as I

1042
00:41:19,260 --> 00:41:17,410
mentioned there's about 20 of them that

1043
00:41:21,180 --> 00:41:19,270
we have we've we've got the data it's

1044
00:41:23,880 --> 00:41:21,190
just a question of measure analyzing all

1045
00:41:28,290 --> 00:41:23,890
these lines okay and and modeling the

1046
00:41:30,030 --> 00:41:28,300
outflow we also have some stars so it

1047
00:41:33,390 --> 00:41:30,040
turns out that the Milky Way is

1048
00:41:34,770 --> 00:41:33,400
cooperating and it gives us some similar

1049
00:41:37,140 --> 00:41:34,780
stars which are some of them actually

1050
00:41:38,430 --> 00:41:37,150
are in the Fermi bubbles and this is

1051
00:41:40,800 --> 00:41:38,440
really interesting because you think of

1052
00:41:43,560 --> 00:41:40,810
these Fermi bubbles is very energetic

1053
00:41:45,420 --> 00:41:43,570
places but there are these single stars

1054
00:41:47,910 --> 00:41:45,430
that happen to live in the halo of the

1055
00:41:49,470 --> 00:41:47,920
galaxy not in a disk but up there and we

1056
00:41:51,660 --> 00:41:49,480
know how far away they are these are

1057
00:41:53,250 --> 00:41:51,670
just errant stars that happen to be up

1058
00:41:54,480 --> 00:41:53,260
above the plane of the galaxy yep

1059
00:41:56,070 --> 00:41:54,490
they're just wayward and they've

1060
00:41:59,250 --> 00:41:56,080
wandered up there however that their

1061
00:42:01,050 --> 00:41:59,260
history did that to them but we can use

1062
00:42:03,120 --> 00:42:01,060
them and do the same experiment but now

1063
00:42:04,350 --> 00:42:03,130

the difference with these stars is that

1064
00:42:06,120 --> 00:42:04,360
because they're in the Fermi bubble

1065
00:42:07,530 --> 00:42:06,130
you're only seeing half of the outflow

1066
00:42:09,870 --> 00:42:07,540
you're only seeing a part of it which is

1067
00:42:11,310 --> 00:42:09,880
on the near side right whereas when we

1068
00:42:12,540 --> 00:42:11,320
do the quasar experiment that we've

1069
00:42:14,820 --> 00:42:12,550
already done you can see all the way

1070
00:42:16,110 --> 00:42:14,830
through the full path of the outflows

1071
00:42:20,010 --> 00:42:16,120
you can see the front side of it and you

1072
00:42:21,300 --> 00:42:20,020
can see the back side of it but still

1073
00:42:23,190 --> 00:42:21,310
that's better than nothing right that's

1074
00:42:27,630 --> 00:42:23,200
more information than we didn't have

1075
00:42:29,430 --> 00:42:27,640
that we have and there are one or two

1076
00:42:31,140 --> 00:42:29,440
cases where we have a full Brown star

1077
00:42:33,990 --> 00:42:31,150
which is it would believers in the Fermi

1078
00:42:35,850 --> 00:42:34,000
bubbles and a background quasar which is

1079
00:42:40,230 --> 00:42:35,860
very close to it on the sky so we can

1080
00:42:42,300 --> 00:42:40,240
compare the absorption spectrum and so

1081
00:42:44,700 --> 00:42:42,310
we can say something about well if we

1082
00:42:46,110 --> 00:42:44,710
see this feature in one side line and we

1083
00:42:49,020 --> 00:42:46,120
don't see it in the other one that gives

1084
00:42:52,710 --> 00:42:49,030
us some information about where it is in

1085
00:42:53,970 --> 00:42:52,720
turn so when you get not not that I want

1086
00:42:55,770 --> 00:42:53,980
to push you or anything but were you

1087
00:42:58,560 --> 00:42:55,780
gonna get all this done and come back

1088
00:43:01,830 --> 00:42:58,570

and tell us how it what you found out is

1089
00:43:04,110 --> 00:43:01,840
there a timeline I am confident that we

1090
00:43:06,570 --> 00:43:04,120
can make some good progress on that

1091
00:43:08,250 --> 00:43:06,580
within this year and I've got a great

1092
00:43:11,000 --> 00:43:08,260
team of people working with me on this

1093
00:43:13,770 --> 00:43:11,010
on this project people focusing on

1094
00:43:16,860 --> 00:43:13,780
modeling we've also got some some radio

1095
00:43:19,500 --> 00:43:16,870
data which which gives us a new a new

1096
00:43:21,000 --> 00:43:19,510
set of observations on how much neutral

1097
00:43:24,450 --> 00:43:21,010
gas there is that goes along with this

1098
00:43:26,520 --> 00:43:24,460
ionized stuff radio data from Alma this

1099
00:43:28,710 --> 00:43:26,530
is actually from the Green Bank

1100
00:43:31,380 --> 00:43:28,720
telescope which is in West Virginia okay

1101
00:43:34,020 --> 00:43:31,390
the old that's all school it is it's

1102
00:43:37,170 --> 00:43:34,030
cool but it's a fantastic facility it's

1103
00:43:41,040 --> 00:43:37,180
it's it's been around a long time well

1104
00:43:44,490 --> 00:43:41,050
this is a huge single dish telescope and

1105
00:43:46,530 --> 00:43:44,500
it provides very very deep observations

1106
00:43:48,660 --> 00:43:46,540
so for what we needed to do it's as good

1107
00:43:50,550 --> 00:43:48,670
as we could get when my friends went to

1108
00:43:53,490 --> 00:43:50,560
UVA and she she was working out there

1109
00:43:55,890 --> 00:43:53,500
and say no cellphones own don't bring

1110
00:43:57,930 --> 00:43:55,900
anything like that right that's a big

1111
00:43:59,970 --> 00:43:57,940
thing to think about because when when

1112
00:44:02,160 --> 00:43:59,980
we're talking about these wavelengths of

1113
00:44:04,170 --> 00:44:02,170

light that's what's going on with our

1114
00:44:06,090 --> 00:44:04,180
everyday gadgets is that that is light

1115
00:44:08,190 --> 00:44:06,100
and it's going to be interfering so this

1116
00:44:10,440 --> 00:44:08,200
place in Virginia you have it's

1117
00:44:13,380 --> 00:44:10,450
completely when you're talking about

1118
00:44:15,150 --> 00:44:13,390
light preservation is first dark skies

1119
00:44:17,100 --> 00:44:15,160
well we have to do the same thing with

1120
00:44:19,290 --> 00:44:17,110
these types of telescopes to make sure

1121
00:44:21,600 --> 00:44:19,300
there's no interference from these

1122
00:44:23,280 --> 00:44:21,610
longer wavelengths of light as well it's

1123
00:44:24,990 --> 00:44:23,290
the radio equivalent of shining a

1124
00:44:30,000 --> 00:44:25,000
flashlight down the tube

1125
00:44:31,589 --> 00:44:30,010
right okay so I Scott I do you have I

1126
00:44:33,870 --> 00:44:31,599
missed any any is there any Twitter

1127
00:44:35,820 --> 00:44:33,880
things there's a budget there's a bunch

1128
00:44:39,330 --> 00:44:35,830
of tweets a lot of retweets going on

1129
00:44:41,160 --> 00:44:39,340
there is escrow gingersnap also notice a

1130
00:44:44,130 --> 00:44:41,170
me lens like I think my head might

1131
00:44:46,440 --> 00:44:44,140
explode right now from awesome space

1132
00:44:49,710 --> 00:44:46,450
news today on Rosetta and the Hubble

1133
00:44:55,109 --> 00:44:49,720
hangout and Vesta so we are adding to

1134
00:44:57,780 --> 00:44:55,119
her Minds lotion of all great and and

1135
00:44:59,700 --> 00:44:57,790
Francis ready also shared out the the

1136
00:45:01,800 --> 00:44:59,710
NASA video release which I have put into

1137
00:45:04,410 --> 00:45:01,810
the Google+ event page so I have link to

1138
00:45:05,940 --> 00:45:04,420

that and it's really good it's a really

1139
00:45:09,690 --> 00:45:05,950
good animation showing the Fermi

1140
00:45:11,849 --> 00:45:09,700
spacecraft and also the the animation

1141
00:45:14,970 --> 00:45:11,859
going on - as far as explaining what's

1142
00:45:18,330 --> 00:45:14,980
going on with the with these Fermi

1143
00:45:21,960 --> 00:45:18,340
levels excellent yeah I have a question

1144
00:45:24,450 --> 00:45:21,970
so in principle if you were given Hubble

1145
00:45:26,640 --> 00:45:24,460
Space Telescope you could do a whole

1146
00:45:28,280 --> 00:45:26,650
bunch of sightlines then all over the

1147
00:45:30,329 --> 00:45:28,290
place and then you'd want to repeat that

1148
00:45:32,070 --> 00:45:30,339
periodically just to see what the

1149
00:45:34,079 --> 00:45:32,080
changes are right so you can map the

1150
00:45:36,960 --> 00:45:34,089
whole thing and then see how it changes

1151
00:45:39,870 --> 00:45:36,970
is that right don't get that in

1152
00:45:43,410 --> 00:45:39,880
principle the problem is actually the

1153
00:45:45,150 --> 00:45:43,420
timescales you would need so if if I all

1154
00:45:47,280 --> 00:45:45,160
my colleagues could lift her like two

1155
00:45:48,839 --> 00:45:47,290
million years then yes this at a time we

1156
00:45:51,599 --> 00:45:48,849
think we would need to see these things

1157
00:45:56,130 --> 00:45:51,609
actually change on this but you could do

1158
00:45:59,910 --> 00:45:56,140
different sight lines you could you

1159
00:46:02,370 --> 00:45:59,920
would look for other quasars that happen

1160
00:46:03,990 --> 00:46:02,380
to lie close to the galactic center and

1161
00:46:06,329 --> 00:46:04,000
do the same thing we got really lucky

1162
00:46:09,480 --> 00:46:06,339
with this one quasar because there's a

1163
00:46:12,030 --> 00:46:09,490

lot of dust what we call dust is like

1164
00:46:16,020 --> 00:46:12,040
interstellar particles they block the

1165
00:46:16,980 --> 00:46:16,030
light from background quasars especially

1166
00:46:19,260 --> 00:46:16,990
when you get close to the galactic

1167
00:46:21,810 --> 00:46:19,270
center it just happens there's like a

1168
00:46:24,030 --> 00:46:21,820
little window through through the the

1169
00:46:26,820 --> 00:46:24,040
low halo of the galaxy and this quasar

1170
00:46:28,620 --> 00:46:26,830
is in that window but other places

1171
00:46:30,089 --> 00:46:28,630
nearby have so much dust that the light

1172
00:46:32,400 --> 00:46:30,099
doesn't get through which means you

1173
00:46:35,160 --> 00:46:32,410
can't find the quasars you need to do

1174
00:46:37,230 --> 00:46:35,170
this type of experiment so it's hard but

1175
00:46:38,940 --> 00:46:37,240
we had to really push down and find very

1176
00:46:40,470 --> 00:46:38,950
faint sources to do this

1177
00:46:41,960 --> 00:46:40,480
take a lot of time a lot of observing

1178
00:46:44,430 --> 00:46:41,970
time on the telescope to get this done

1179
00:46:47,250 --> 00:46:44,440
pesky dust we gotta get a vacuum cleaner

1180
00:46:49,770 --> 00:46:47,260
out there and cleared out of the way all

1181
00:46:51,270 --> 00:46:49,780
right well so dr. Andy Fox I want to

1182
00:46:53,339 --> 00:46:51,280
thank you very much for joining us on

1183
00:46:55,079 --> 00:46:53,349
our hangout is you are you will you come

1184
00:46:58,410 --> 00:46:55,089
back later once you've got more more

1185
00:47:00,060 --> 00:46:58,420
data sure yeah awesome good look for

1186
00:47:03,210 --> 00:47:00,070
anybody I want to want to follow up on

1187
00:47:04,560 --> 00:47:03,220
this and look here's a final slide I did

1188
00:47:06,000 --> 00:47:04,570

it also put the link out there and bout

1189
00:47:08,010 --> 00:47:06,010
to put up on Twitter here in a bit but

1190
00:47:10,079 --> 00:47:08,020
if you want to read more about the paper

1191
00:47:11,970 --> 00:47:10,089
that goes on here I have linked it into

1192
00:47:13,710 --> 00:47:11,980
the google event page I'll make sure it

1193
00:47:15,810 --> 00:47:13,720
gets put up onto YouTube and I'm just

1194
00:47:19,230 --> 00:47:15,820
about to tweet it out the you can go to

1195
00:47:21,050 --> 00:47:19,240
to archive and take a look at that paper

1196
00:47:24,060 --> 00:47:21,060
as well if you want to do a little bit

1197
00:47:26,880 --> 00:47:24,070
deeper digging into to the science

1198
00:47:28,319 --> 00:47:26,890
that's there good yes thanks for ya

1199
00:47:29,730 --> 00:47:28,329
thanks for reminding me about that so

1200
00:47:31,200 --> 00:47:29,740
deaf or them if you want to read the

1201
00:47:33,270 --> 00:47:31,210
actual paper there's a link to it as

1202
00:47:34,530 --> 00:47:33,280
well as the link to the press release on

1203
00:47:37,890 --> 00:47:34,540
Hubble site org

1204
00:47:40,230 --> 00:47:37,900
to learn more as well so that's it for

1205
00:47:42,390 --> 00:47:40,240
this week everybody next week Carol

1206
00:47:45,329 --> 00:47:42,400
Scott and I will be meeting with we have

1207
00:47:47,849 --> 00:47:45,339
another in our series of Hubble 25

1208
00:47:49,470 --> 00:47:47,859
hangouts to celebrate the 25th

1209
00:47:50,700 --> 00:47:49,480
anniversary of Hubble we'll have Carolyn

1210
00:47:54,390 --> 00:47:50,710
Collins peterson with us to talk more

1211
00:47:56,700 --> 00:47:54,400
about the illustrious history of Hubble

1212
00:47:58,020 --> 00:47:56,710
and as we as we said the last time we

1213
00:48:00,240 --> 00:47:58,030

did a history of Hubble hangout we're

1214
00:48:02,579 --> 00:48:00,250
gonna be doing many of these so because

1215
00:48:04,170 --> 00:48:02,589
25 years is a long time a lot of stuff

1216
00:48:06,599 --> 00:48:04,180
happens so we'll have her next week we

1217
00:48:10,130 --> 00:48:06,609
hope you'll tune in and and check us out

1218
00:48:17,250 --> 00:48:10,140
I'll create the events tomorrow and I

1219
00:48:19,650 --> 00:48:17,260
keep getting animals that isn't alright

1220
00:48:32,370 --> 00:48:19,660
are you going to the danger zone

1221
00:48:35,120 --> 00:48:32,380
yeah but you you probably you always

1222
00:48:38,069 --> 00:48:35,130
have a fun day with that ringtone yeah

1223
00:48:39,359 --> 00:48:38,079
danger zone okay everybody thank you

1224
00:48:42,809 --> 00:48:39,369
guys for watching we'll see you guys