PUBLIC LECTURE SERIES

Supermassive Black Holes in the Centers of Galaxies

Featuring Guest Speaker:

Darshan Kakkad

1
00:00:08,470 --> 00:00:05,690
welcome to the Space Telescope public

2
00:00:11,390 --> 00:00:08,480
lecture series tonight's lecture

3
00:00:14,690 --> 00:00:11,400
supermassive black holes in the centers

4
00:00:17,330 --> 00:00:14,700
of galaxies by darshan kakad

5
00:00:19,130 --> 00:00:17,340
I am your host Dr Frank Summers of the

6
00:00:23,029 --> 00:00:19,140
Office of Public Outreach here at the

7
00:00:25,009 --> 00:00:23,039
Space Telescope Science Institute and as

8
00:00:26,990 --> 00:00:25,019
always I want to thank the wonderful

9
00:00:30,170 --> 00:00:27,000
tech team Thomas marufu and Grant

10
00:00:33,110 --> 00:00:30,180
Justice who work behind the scenes to be

11
00:00:35,870 --> 00:00:33,120
able to help us present all of this to

12
00:00:36,830 --> 00:00:35,880
you and get it out to everybody on

13
00:00:39,229 --> 00:00:36,840

YouTube

14
00:00:40,910 --> 00:00:39,239
I also want to note that the Space

15
00:00:43,490 --> 00:00:40,920
Telescope public lecture series will

16
00:00:46,970 --> 00:00:43,500
continue to be online only for the rest

17
00:00:53,150 --> 00:00:51,049
coming lectures on March 7th we have a

18
00:00:55,790 --> 00:00:53,160
lecture on active galaxies I'm not

19
00:00:57,950 --> 00:00:55,800
exactly sure what aspect of active

20
00:01:00,470 --> 00:00:57,960
galaxies Travis Fisher is going to talk

21
00:01:02,930 --> 00:01:00,480
about but uh he has promised to be an

22
00:01:05,270 --> 00:01:02,940
abstract in the coming weeks so we'll

23
00:01:08,390 --> 00:01:05,280
find out but some aspect of aspect Act

24
00:01:13,429 --> 00:01:08,400
of galaxies Travis Fisher of here from

25
00:01:15,289 --> 00:01:13,439
sdsci on April 4th uh Catherine Bennett

26
00:01:18,850 --> 00:01:15,299
will be talking about understanding

27
00:01:21,649 --> 00:01:18,860
planetary habitability using exoplanet

28
00:01:23,570 --> 00:01:21,659
atmospheres looking at atmospheres

29
00:01:27,050 --> 00:01:23,580
around other planets and seeing hey

30
00:01:30,410 --> 00:01:27,060
could they be habitable uh on May we

31
00:01:32,690 --> 00:01:30,420
often even more indeterminate lecture uh

32
00:01:34,609 --> 00:01:32,700
Amanda pagul has said that she's going

33
00:01:36,170 --> 00:01:34,619
to give a lecture but she has two

34
00:01:39,170 --> 00:01:36,180
different topics and she hasn't decided

35
00:01:40,969 --> 00:01:39,180
which one but again I will push her this

36
00:01:43,910 --> 00:01:40,979
month to try and give me at least a

37
00:01:46,490 --> 00:01:43,920
topic by uh really just to talk next

38
00:01:48,830 --> 00:01:46,500

month and if you want to find out when I

39
00:01:55,149 --> 00:01:48,840
after she does give me a topic what that

40
00:02:01,069 --> 00:01:58,910
www.stsci.edu public hyphen lectures

41
00:02:06,170 --> 00:02:01,079
you'll get to our public lecture series

42
00:02:10,430 --> 00:02:06,180
uh talk page and on the lower left you

43
00:02:12,770 --> 00:02:10,440
can see the link to our webcasts uh the

44
00:02:18,110 --> 00:02:12,780
we have got recorded webcasts on YouTube

45
00:02:20,510 --> 00:02:18,120
back to about uh 2015 and we have a

46
00:02:22,270 --> 00:02:20,520
webcast archive at Space Telescope I

47
00:02:25,970 --> 00:02:22,280
think that goes all the way back to like

48
00:02:29,750 --> 00:02:25,980
2005 okay so if you want more public

49
00:02:32,869 --> 00:02:29,760
lecture series we gotcha

50
00:02:34,610 --> 00:02:32,879
covered right also in the lower right

51
00:02:36,350 --> 00:02:34,620
you can see the easiest way to get

52
00:02:38,449 --> 00:02:36,360
reminders of it

53
00:02:40,790 --> 00:02:38,459
um sign just put your email address hit

54
00:02:43,550 --> 00:02:40,800
that subscribe button and you'll get two

55
00:02:45,410 --> 00:02:43,560
or three emails a month reminding all of

56
00:02:47,690 --> 00:02:45,420
the upcoming lectures and letting you

57
00:02:49,130 --> 00:02:47,700
know when the webcasts have been uh

58
00:02:51,589 --> 00:02:49,140
posted

59
00:02:54,470 --> 00:02:51,599
also on the website are the list of our

60
00:02:56,869 --> 00:02:54,480
upcoming lectures and if you click on

61
00:02:59,869 --> 00:02:56,879
any of those lectures you will get the

62
00:03:02,270 --> 00:02:59,879
details uh including the speaker in the

63
00:03:05,330 --> 00:03:02,280

description as well as after it has been

64
00:03:09,009 --> 00:03:05,340
broadcast links to the sdsci webcast as

65
00:03:12,170 --> 00:03:09,019
well as the YouTube broadcast

66
00:03:14,030 --> 00:03:12,180
uh for email as I said announcements

67
00:03:16,729 --> 00:03:14,040
says sign up at the webs at the website

68
00:03:19,610 --> 00:03:16,739
you can also subscribe to our YouTube

69
00:03:22,850 --> 00:03:19,620
channel youtube.com Hubble Space

70
00:03:25,250 --> 00:03:22,860
Telescope that will give you notices of

71
00:03:28,009 --> 00:03:25,260
new videos and reminders of Live Events

72
00:03:30,470 --> 00:03:28,019
such as this one and finally if you have

73
00:03:36,949 --> 00:03:30,480
comments or questions you can send them

74
00:03:42,110 --> 00:03:40,250
our social media at Space Telescope does

75
00:03:44,509 --> 00:03:42,120
for the Hubble Space Telescope for the

76
00:03:47,149 --> 00:03:44,519
web Space Telescope and for our

77
00:03:49,190 --> 00:03:47,159
Institute on Facebook Twitter Youtube

78
00:03:51,289 --> 00:03:49,200
and Instagram you can see them pictured

79
00:03:55,309 --> 00:03:51,299
there I

80
00:04:01,550 --> 00:03:55,319
as always say I do a tiny amount of uh

81
00:04:07,430 --> 00:04:03,949
and now our news from the universe for

82
00:04:10,610 --> 00:04:07,440
February 2023.

83
00:04:14,210 --> 00:04:10,620
our first story tonight the weight loss

84
00:04:16,250 --> 00:04:14,220
plan of cluster galaxies and you say

85
00:04:18,170 --> 00:04:16,260
Frank you're just being silly and I say

86
00:04:20,870 --> 00:04:18,180
yes I am actually being a little bit

87
00:04:23,390 --> 00:04:20,880
silly but I think it means that you're

88
00:04:25,370 --> 00:04:23,400

going to remember it okay so first of

89
00:04:28,310 --> 00:04:25,380
all let's talk about cluster galaxies

90
00:04:30,830 --> 00:04:28,320
there are these giant clusters of

91
00:04:32,810 --> 00:04:30,840
galaxies hundreds to thousands of

92
00:04:36,469 --> 00:04:32,820
galaxies that are all orbiting around

93
00:04:38,749 --> 00:04:36,479
one another okay and as these galaxies

94
00:04:40,730 --> 00:04:38,759
agglomerate the galaxies will pass

95
00:04:42,530 --> 00:04:40,740
through the through the cluster and

96
00:04:45,350 --> 00:04:42,540
around the cluster and they orbit

97
00:04:47,689 --> 00:04:45,360
together within this cluster now when

98
00:04:50,090 --> 00:04:47,699
that happens all right they actually

99
00:04:53,330 --> 00:04:50,100
encounter something called Ram pressure

100
00:04:56,270 --> 00:04:53,340
stripping I'll say that again Ram

101
00:04:58,189 --> 00:04:56,280
pressure stripping okay that that means

102
00:05:01,610 --> 00:04:58,199
is the Galaxy going through the cluster

103
00:05:03,530 --> 00:05:01,620
hits the intracluster gas and sometimes

104
00:05:05,749 --> 00:05:03,540
some of that gas will sometimes bleed

105
00:05:09,170 --> 00:05:05,759
out material it'll strip out material

106
00:05:12,050 --> 00:05:09,180
all right and so this galaxy see here is

107
00:05:13,969 --> 00:05:12,060
called a jellyfish Galaxy not because

108
00:05:16,330 --> 00:05:13,979
it's swimming in the ocean but because

109
00:05:19,790 --> 00:05:16,340
it has these tentacles

110
00:05:21,650 --> 00:05:19,800
streaming off from it and that isn't a

111
00:05:24,170 --> 00:05:21,660
result of ram pressure stripping you can

112
00:05:26,749 --> 00:05:24,180
see these blue stars these streams of

113
00:05:29,390 --> 00:05:26,759

blue stars uh moving all in the same

114
00:05:32,210 --> 00:05:29,400
direction all right and if you actually

115
00:05:33,710 --> 00:05:32,220
pull back from this galaxy

116
00:05:36,170 --> 00:05:33,720
um

117
00:05:39,230 --> 00:05:36,180
you can and you look at it in x-ray

118
00:05:41,870 --> 00:05:39,240
light the X-ray light shows you this big

119
00:05:44,270 --> 00:05:41,880
gas streamer of material that's being

120
00:05:46,490 --> 00:05:44,280
pulled off this galaxy as it's moving

121
00:05:50,270 --> 00:05:46,500
through this intra cluster medium okay

122
00:05:52,370 --> 00:05:50,280
so this is an example of how the

123
00:05:55,490 --> 00:05:52,380
material in a Galaxy can get stripped

124
00:05:58,670 --> 00:05:55,500
out of that Galaxy and become part of

125
00:06:01,070 --> 00:05:58,680
the cluster itself all right and so if

126
00:06:05,330 --> 00:06:01,080
you've got a large cluster such as this

127
00:06:09,110 --> 00:06:05,340
one this is a Galaxy cluster Abel s1063

128
00:06:10,850 --> 00:06:09,120
it's a large Galaxy cluster and if you

129
00:06:14,210 --> 00:06:10,860
look really really really really really

130
00:06:17,689 --> 00:06:14,220
really closely with Hubble you can

131
00:06:19,790 --> 00:06:17,699
actually tell how much light there is in

132
00:06:22,550 --> 00:06:19,800
the cluster that's not due to any Galaxy

133
00:06:26,150 --> 00:06:22,560
but is due to all this stripped material

134
00:06:30,050 --> 00:06:26,160
okay this intracluster light and so

135
00:06:33,110 --> 00:06:30,060
Hubble measured it for S 1063 and here

136
00:06:38,029 --> 00:06:33,120
is a map of that intra cluster light in

137
00:06:40,610 --> 00:06:38,039
intense 63 okay so galaxies lose

138
00:06:41,809 --> 00:06:40,620

material as they go through clusters but

139
00:06:47,210 --> 00:06:41,819
the question that we're going to address

140
00:06:51,230 --> 00:06:47,220
today is which diet plan do they use is

141
00:06:52,969 --> 00:06:51,240
it a quick weight loss plan I.E does the

142
00:06:54,950 --> 00:06:52,979
Galaxy cluster have to develop to a

143
00:06:57,650 --> 00:06:54,960
certain size and the inter-cluster gas

144
00:06:59,990 --> 00:06:57,660
have to be certain density before this

145
00:07:02,090 --> 00:07:00,000
Ram pressure stripping is effective at

146
00:07:04,249 --> 00:07:02,100
pulling stuff out of it and if that's

147
00:07:06,770 --> 00:07:04,259
true well then the inter-cluster light

148
00:07:08,270 --> 00:07:06,780
should only appear recently in the

149
00:07:11,689 --> 00:07:08,280
history of the universe

150
00:07:14,689 --> 00:07:11,699
however if it's a slow burn weight loss

151
00:07:16,430 --> 00:07:14,699
plan that means the idea being that the

152
00:07:18,830 --> 00:07:16,440
ram pressure stripping of course and

153
00:07:20,570 --> 00:07:18,840
some other things like Galaxy merging is

154
00:07:22,610 --> 00:07:20,580
effective in removing material from

155
00:07:24,650 --> 00:07:22,620
galaxies right from the beginning as you

156
00:07:26,809 --> 00:07:24,660
know as the cluster is forming to begin

157
00:07:29,629 --> 00:07:26,819
with well then that intra cluster light

158
00:07:32,629 --> 00:07:29,639
will appear gradually over the course of

159
00:07:34,309 --> 00:07:32,639
of of of over time

160
00:07:36,350 --> 00:07:34,319
so

161
00:07:39,050 --> 00:07:36,360
what they did with this program is they

162
00:07:40,610 --> 00:07:39,060
looked at 10 Galaxy clusters at

163
00:07:42,830 --> 00:07:40,620

different distances out into the

164
00:07:45,830 --> 00:07:42,840
universe to see whether or not this

165
00:07:47,990 --> 00:07:45,840
inter-cluster light was there early late

166
00:07:50,210 --> 00:07:48,000
in the universe or mid in the universe

167
00:07:53,689 --> 00:07:50,220
or very early in the universe okay and

168
00:07:56,210 --> 00:07:53,699
so here are two of those clusters that

169
00:07:58,550 --> 00:07:56,220
have a serious phone number catalog

170
00:08:01,490 --> 00:07:58,560
numbers there and you can see they map

171
00:08:03,770 --> 00:08:01,500
the intracluster light from them we call

172
00:08:06,170 --> 00:08:03,780
them ghost light Galaxy clusters because

173
00:08:08,570 --> 00:08:06,180
you know you're looking really down into

174
00:08:10,370 --> 00:08:08,580
the the depth of the of the light here I

175
00:08:13,430 --> 00:08:10,380
mean this intracluster light is like one

176
00:08:15,830 --> 00:08:13,440
ten thousandth the light of the galaxies

177
00:08:18,050 --> 00:08:15,840
okay the galaxies are 10 000 times

178
00:08:19,909 --> 00:08:18,060
brighter than this intracluster light so

179
00:08:22,730 --> 00:08:19,919
you're really looking at a very faint

180
00:08:26,150 --> 00:08:22,740
signal but hey this is Hubble Hubble can

181
00:08:28,450 --> 00:08:26,160
do this and what they found is that it's

182
00:08:31,909 --> 00:08:28,460
actually this slow burn weight loss plan

183
00:08:34,250 --> 00:08:31,919
that the intra cluster light is there

184
00:08:36,230 --> 00:08:34,260
proportionately all the way back to the

185
00:08:40,730 --> 00:08:36,240
galaxies that they see

186
00:08:42,110 --> 00:08:40,740
so why we're not exactly sure you know

187
00:08:43,550 --> 00:08:42,120
it's Ram pressure stripping there's

188
00:08:45,889 --> 00:08:43,560

mergers and other things that can pull

189
00:08:48,590 --> 00:08:45,899
things out of galaxies but in

190
00:08:49,790 --> 00:08:48,600
understanding how galaxies form into

191
00:08:52,610 --> 00:08:49,800
clusters

192
00:08:56,150 --> 00:08:52,620
there has got to be some process that

193
00:08:58,130 --> 00:08:56,160
removes stars from these galaxies that

194
00:09:00,230 --> 00:08:58,140
happens all the way along through the

195
00:09:01,970 --> 00:09:00,240
history of the universe gradually it's

196
00:09:04,370 --> 00:09:01,980
not one big thing happening at all at

197
00:09:05,990 --> 00:09:04,380
once it's a gradual process all along

198
00:09:08,210 --> 00:09:06,000
the history of the earth and that

199
00:09:12,050 --> 00:09:08,220
teaches us something about the formation

200
00:09:20,030 --> 00:09:15,710
our second story for you tonight is the

201
00:09:21,550 --> 00:09:20,040
many portraits of NGC 346 ah yes you're

202
00:09:26,329 --> 00:09:21,560
thinking oh good old

203
00:09:29,150 --> 00:09:26,339
ngc346. what is ng346 well this is the

204
00:09:31,610 --> 00:09:29,160
small magellanic Cloud which is one of

205
00:09:33,410 --> 00:09:31,620
the two dwarf major dwarf galaxies

206
00:09:35,690 --> 00:09:33,420
orbiting around our Milky Way galaxy

207
00:09:37,370 --> 00:09:35,700
it's a large Magellan cloud and the

208
00:09:38,810 --> 00:09:37,380
small magellanic Cloud yeah we we

209
00:09:40,910 --> 00:09:38,820
spawners we call them as we see them

210
00:09:44,030 --> 00:09:40,920
right large small

211
00:09:47,509 --> 00:09:44,040
okay and in the small magellanic Cloud

212
00:09:51,829 --> 00:09:47,519
it only has one significant star-foring

213
00:09:53,930 --> 00:09:51,839

region and that is ngc346 okay and this

214
00:09:56,150 --> 00:09:53,940
is a valuable star from Marine region to

215
00:09:59,389 --> 00:09:56,160
look at because all of these stars are

216
00:10:00,829 --> 00:09:59,399
about 210 000 light years away so

217
00:10:02,570 --> 00:10:00,839
they're all at the same distance that

218
00:10:03,170 --> 00:10:02,580
gives us a good

219
00:10:06,050 --> 00:10:03,180
um

220
00:10:08,509 --> 00:10:06,060
measuring stick to be able to judge all

221
00:10:09,949 --> 00:10:08,519
the all the stars in there together all

222
00:10:14,030 --> 00:10:09,959
right so we've looked at it several

223
00:10:17,870 --> 00:10:14,040
times and Hubble back in 2005 released

224
00:10:22,490 --> 00:10:17,880
this image of ngc346 this beautiful blue

225
00:10:25,009 --> 00:10:22,500
image and then also in 2005 really only

226
00:10:28,730 --> 00:10:25,019
10 months later we've released this

227
00:10:31,190 --> 00:10:28,740
beautiful red image of ngc346

228
00:10:33,410 --> 00:10:31,200
um I was here in 2005 and I remember

229
00:10:36,410 --> 00:10:33,420
that we did these two images in the same

230
00:10:39,949 --> 00:10:36,420
year but I'm still to this day I'm not

231
00:10:42,590 --> 00:10:39,959
sure why we did them but also after

232
00:10:44,930 --> 00:10:42,600
doing this red image we also in that

233
00:10:49,790 --> 00:10:44,940
same press release released this black

234
00:10:52,610 --> 00:10:49,800
and white image of 346. so Hubble on its

235
00:10:55,850 --> 00:10:52,620
own really from one major observing

236
00:10:59,509 --> 00:10:55,860
program was able to get three count them

237
00:11:00,829 --> 00:10:59,519
three portraits of NGC 346 that

238
00:11:04,430 --> 00:11:00,839

highlight just slightly different

239
00:11:06,829 --> 00:11:04,440
aspects in each one of them well you can

240
00:11:09,530 --> 00:11:06,839
guess where this is heading we now have

241
00:11:11,990 --> 00:11:09,540
the web Space Telescope so now we're

242
00:11:16,370 --> 00:11:12,000
going to get the ultimate infrared

243
00:11:20,990 --> 00:11:16,380
portrait of ngc346 and here is Webb's

244
00:11:24,050 --> 00:11:21,000
portrait of ngc346 and it is really

245
00:11:27,050 --> 00:11:24,060
really cool okay I mean this is actually

246
00:11:29,449 --> 00:11:27,060
what is it it's it's like a hundred and

247
00:11:31,970 --> 00:11:29,459
forty thousand forty million pixels okay

248
00:11:34,250 --> 00:11:31,980
it there's a serious number of pixels

249
00:11:36,829 --> 00:11:34,260
here there's a lot of cool detail here

250
00:11:39,230 --> 00:11:36,839
but what I'd like to do for you is show

251
00:11:41,990 --> 00:11:39,240
you some contrast between the Hubble and

252
00:11:43,850 --> 00:11:42,000
web images so you can understand why we

253
00:11:46,610 --> 00:11:43,860
have more than one Space Telescope up

254
00:11:48,710 --> 00:11:46,620
there okay so on the left is the Hubble

255
00:11:50,030 --> 00:11:48,720
image and on the right is the web image

256
00:11:52,910 --> 00:11:50,040
and you can see that there are

257
00:11:55,970 --> 00:11:52,920
significantly different in particular

258
00:11:58,009 --> 00:11:55,980
take a look at this region here all that

259
00:12:01,850 --> 00:11:58,019
gas and dust that appears in the web

260
00:12:04,310 --> 00:12:01,860
image is barely barely visible in the

261
00:12:05,990 --> 00:12:04,320
Hubble image and at the bottom of that

262
00:12:07,370 --> 00:12:06,000
region there's sort of a in the Hubble

263
00:12:08,930 --> 00:12:07,380

image you can see there's a cluster of

264
00:12:11,509 --> 00:12:08,940
stars we're going to zoom in on that

265
00:12:13,790 --> 00:12:11,519
okay all right and so in the Hubble

266
00:12:16,430 --> 00:12:13,800
image you can see that cluster of stars

267
00:12:19,009 --> 00:12:16,440
but in the web image you don't really

268
00:12:22,430 --> 00:12:19,019
see the cluster of stars so much as you

269
00:12:26,210 --> 00:12:22,440
see the gas that it's embedded in this

270
00:12:29,630 --> 00:12:26,220
is the warm gas that the near infrared

271
00:12:32,449 --> 00:12:29,640
picks up so well if we go to the main

272
00:12:35,030 --> 00:12:32,459
cluster in the center of the image you

273
00:12:36,670 --> 00:12:35,040
can see how picking up this a really

274
00:12:40,970 --> 00:12:36,680
cool just

275
00:12:43,970 --> 00:12:40,980
unbelievably bright cluster of stars

276
00:12:46,190 --> 00:12:43,980
um but the exact web same web image

277
00:12:49,250 --> 00:12:46,200
doesn't really feature the Stars again

278
00:12:50,990 --> 00:12:49,260
it features the cool gas and dust and

279
00:12:53,030 --> 00:12:51,000
this is just a lot of fun I I spent I

280
00:12:55,009 --> 00:12:53,040
went blink back and forth like a dozen

281
00:12:56,449 --> 00:12:55,019
times as soon as I I pulled this put

282
00:12:58,069 --> 00:12:56,459
this together this afternoon it's like

283
00:13:02,329 --> 00:12:58,079
okay there's Hubble

284
00:13:05,569 --> 00:13:02,339
and there's Webb okay yeah Hubble

285
00:13:07,550 --> 00:13:05,579
and web all right so you see the two

286
00:13:09,230 --> 00:13:07,560
brightest stars in the infrared here

287
00:13:11,750 --> 00:13:09,240
okay

288
00:13:14,690 --> 00:13:11,760

um do you see those in the Hubble image

289
00:13:17,090 --> 00:13:14,700
yeah they're probably there but I they

290
00:13:19,129 --> 00:13:17,100
don't stand out at all whereas the

291
00:13:21,050 --> 00:13:19,139
brightest star in the Hubble image if

292
00:13:23,590 --> 00:13:21,060
you go look at it in the web well it's

293
00:13:26,269 --> 00:13:23,600
there but it's not particularly you know

294
00:13:28,790 --> 00:13:26,279
excessively bright as it is and this

295
00:13:30,710 --> 00:13:28,800
this this Ridge of gas and dust up here

296
00:13:31,730 --> 00:13:30,720
okay this this stuff in here in the

297
00:13:34,490 --> 00:13:31,740
center

298
00:13:36,410 --> 00:13:34,500
um that's all drowned out by the by the

299
00:13:38,090 --> 00:13:36,420
star cluster you don't see it whereas

300
00:13:41,030 --> 00:13:38,100
the ridge down here that you see a bit

301
00:13:43,910 --> 00:13:41,040
in Hubble all right comes across in

302
00:13:48,410 --> 00:13:43,920
gangbusters with the web Space Telescope

303
00:13:50,750 --> 00:13:48,420
okay so uh this is a fantastic example

304
00:13:54,230 --> 00:13:50,760
of why we have both visible light

305
00:13:56,629 --> 00:13:54,240
telescopes and infrared space telescopes

306
00:13:59,389 --> 00:13:56,639
so that we have two different views that

307
00:14:01,910 --> 00:13:59,399
show us two different sets of conditions

308
00:14:04,129 --> 00:14:01,920
and teaches that much more about what's

309
00:14:05,030 --> 00:14:04,139
going on in the universe all right some

310
00:14:06,650 --> 00:14:05,040
people

311
00:14:08,690 --> 00:14:06,660
um mistakenly say that the web has

312
00:14:10,910 --> 00:14:08,700
replaced Hubble and I hope that this

313
00:14:14,269 --> 00:14:10,920

shows you that web doesn't replace

314
00:14:17,269 --> 00:14:14,279
Hubble web complements Hubble and web

315
00:14:19,850 --> 00:14:17,279
provides an alternate view that gives us

316
00:14:25,009 --> 00:14:19,860
different physics and different science

317
00:14:33,829 --> 00:14:29,810
all right so our speaker tonight

318
00:14:36,650 --> 00:14:33,839
um darshan kakad uh welcome darshan uh

319
00:14:38,870 --> 00:14:36,660
he is only been with us at the Space

320
00:14:42,850 --> 00:14:38,880
Telescope Science Institute for a little

321
00:14:45,410 --> 00:14:42,860
over a year he joined in January 2022

322
00:14:48,590 --> 00:14:45,420
and actually Darcy do you have an office

323
00:14:50,569 --> 00:14:48,600
at the in in the building okay you do

324
00:14:53,629 --> 00:14:50,579
all right because some people who joined

325
00:14:55,490 --> 00:14:53,639
during the pandemic have never actually

326
00:14:57,230 --> 00:14:55,500
been in I've never actually been inside

327
00:14:59,710 --> 00:14:57,240
the building when they gave a public

328
00:15:04,069 --> 00:14:59,720
lecture great all right

329
00:15:08,150 --> 00:15:04,079
great I only come in once a week so uh

330
00:15:10,250 --> 00:15:08,160
darshan got his uh PhD in Munich and

331
00:15:13,250 --> 00:15:10,260
then traveled around the world he went

332
00:15:17,870 --> 00:15:13,260
to the European Southern observatory in

333
00:15:19,670 --> 00:15:17,880
Chile before going to Oxford England to

334
00:15:21,650 --> 00:15:19,680
do studies there

335
00:15:25,069 --> 00:15:21,660
um and then he ended up here at Space

336
00:15:27,710 --> 00:15:25,079
Telescope Science Institute last year

337
00:15:30,230 --> 00:15:27,720
that's actually you know one of the

338
00:15:32,030 --> 00:15:30,240

times after you get your PhD and you do

339
00:15:34,370 --> 00:15:32,040
postdocs and you transfer around till

340
00:15:36,710 --> 00:15:34,380
you finally find your permanent job uh

341
00:15:38,689 --> 00:15:36,720
is one of the more exciting times in

342
00:15:40,009 --> 00:15:38,699
astronomy because you know you have the

343
00:15:41,810 --> 00:15:40,019
opportunity to travel the world and

344
00:15:43,490 --> 00:15:41,820
Antarctica it's great that you've taken

345
00:15:44,689 --> 00:15:43,500
advantage of it

346
00:15:46,970 --> 00:15:44,699
um to

347
00:15:49,069 --> 00:15:46,980
present a little bit more about him uh

348
00:15:50,870 --> 00:15:49,079
he told me that he likes to do outdoor

349
00:15:54,290 --> 00:15:50,880
activities in particular running and

350
00:15:57,290 --> 00:15:54,300
hiking and that he also likes cooking

351
00:16:00,170 --> 00:15:57,300
especially uh proud of some of the cakes

352
00:16:04,550 --> 00:16:00,180
that he's made so ladies and gentlemen

353
00:16:04,560 --> 00:16:16,430
it's a lot of Frank

354
00:16:20,750 --> 00:16:19,670
and I suppose see all of you can see my

355
00:16:25,490 --> 00:16:20,760
slides

356
00:16:28,430 --> 00:16:25,500
can hear me well as well correct

357
00:16:30,530 --> 00:16:28,440
yes great okay thank you

358
00:16:33,230 --> 00:16:30,540
so good morning good afternoon good

359
00:16:36,170 --> 00:16:33,240
evening everyone uh wherever you're

360
00:16:38,629 --> 00:16:36,180
joining from uh thank you very much for

361
00:16:40,129 --> 00:16:38,639
joining this public lecture series on

362
00:16:43,189 --> 00:16:40,139
supermassive black holes at the center

363
00:16:45,050 --> 00:16:43,199

of galaxies my name is darshan kakat and

364
00:16:47,470 --> 00:16:45,060
I'm a postdoctoral researcher here at

365
00:16:51,170 --> 00:16:47,480
the Space Telescope Science Institute

366
00:16:53,150 --> 00:16:51,180
often when I hear the word uh or often

367
00:16:55,310 --> 00:16:53,160
whenever I say the word black hole

368
00:16:56,810 --> 00:16:55,320
people often think about these Sci-Fi

369
00:16:58,730 --> 00:16:56,820
movies and especially the movie

370
00:16:59,509 --> 00:16:58,740
Interstellar that came out a few years

371
00:17:02,030 --> 00:16:59,519
back

372
00:17:05,689 --> 00:17:02,040
uh these black holes are really powerful

373
00:17:08,809 --> 00:17:05,699
objects so uh how do we know that they

374
00:17:10,970 --> 00:17:08,819
exist how do they form whether do do

375
00:17:13,850 --> 00:17:10,980
these black holes have any relevance in

376
00:17:15,110 --> 00:17:13,860
our daily lives here on Earth so these

377
00:17:18,530 --> 00:17:15,120
are some of the things that I will touch

378
00:17:20,750 --> 00:17:18,540
upon uh during this talk today and I

379
00:17:24,110 --> 00:17:20,760
hope that I'm able to convey how

380
00:17:26,630 --> 00:17:24,120
fascinating these objects are

381
00:17:29,870 --> 00:17:26,640
so now before we dive into the world of

382
00:17:31,970 --> 00:17:29,880
black holes uh we need to understand uh

383
00:17:34,669 --> 00:17:31,980
at what point during the timeline of the

384
00:17:37,130 --> 00:17:34,679
universe did they become relevant so the

385
00:17:39,169 --> 00:17:37,140
video that I'm about to play here uh

386
00:17:41,289 --> 00:17:39,179
shows you how the universe began from

387
00:17:44,210 --> 00:17:41,299
big bang and how it evolved from there

388
00:17:47,270 --> 00:17:44,220

uh so yeah I hope that this place yeah

389
00:17:49,250 --> 00:17:47,280
good so that was a big thing right and

390
00:17:52,310 --> 00:17:49,260
soon after the big bang the size of the

391
00:17:54,770 --> 00:17:52,320
universe increased dramatically uh which

392
00:17:57,169 --> 00:17:54,780
we popularly call as the inflation of

393
00:18:00,529 --> 00:17:57,179
the universe and after this inflation

394
00:18:03,590 --> 00:18:00,539
period the increase in the size slowed

395
00:18:06,049 --> 00:18:03,600
down and the universe became dark uh we

396
00:18:08,330 --> 00:18:06,059
call this phase as the Dark Ages uh or

397
00:18:11,150 --> 00:18:08,340
in cosmology and the reason that we say

398
00:18:14,210 --> 00:18:11,160
that it's dark is because uh there was

399
00:18:16,430 --> 00:18:14,220
just gas over there there was no source

400
00:18:19,250 --> 00:18:16,440
of light there were no stars there were

401
00:18:22,310 --> 00:18:19,260
no galaxies nothing except for the gas

402
00:18:25,250 --> 00:18:22,320
and this all changed roughly about 400

403
00:18:27,830 --> 00:18:25,260
million years after the big bang uh 400

404
00:18:29,870 --> 00:18:27,840
million years might sound uh like a lot

405
00:18:31,970 --> 00:18:29,880
of years for us but then in terms of the

406
00:18:33,409 --> 00:18:31,980
cosmological time scales it's it's it's

407
00:18:36,110 --> 00:18:33,419
really small

408
00:18:38,690 --> 00:18:36,120
uh so yeah right roughly about 400

409
00:18:41,870 --> 00:18:38,700
million years after uh after the big

410
00:18:45,529 --> 00:18:41,880
bang uh when all the gas then clumped

411
00:18:47,270 --> 00:18:45,539
together and formed the first Stars uh

412
00:18:49,190 --> 00:18:47,280
and these Stars Then grouped together to

413
00:18:51,650 --> 00:18:49,200

form the first galaxies that we know in

414
00:18:53,990 --> 00:18:51,660
the universe and these stars and

415
00:18:55,789 --> 00:18:54,000
galaxies then evolved and ultimately

416
00:18:58,370 --> 00:18:55,799
gave rise to the familiar looking

417
00:19:00,470 --> 00:18:58,380
galaxies that we see today including our

418
00:19:03,169 --> 00:19:00,480
own Milky Way similar to the Galaxy that

419
00:19:05,690 --> 00:19:03,179
you see on the screen right now

420
00:19:07,789 --> 00:19:05,700
so this slide here shows you a picture

421
00:19:09,710 --> 00:19:07,799
format of what you just saw in the video

422
00:19:12,350 --> 00:19:09,720
so the timeline in this picture

423
00:19:14,029 --> 00:19:12,360
increases from left to the right and the

424
00:19:15,650 --> 00:19:14,039
size of the universe is depicted in this

425
00:19:18,770 --> 00:19:15,660
vertical scale here

426
00:19:20,289 --> 00:19:18,780
so we start off from this very very tiny

427
00:19:23,330 --> 00:19:20,299
point right here

428
00:19:26,390 --> 00:19:23,340
uh uh so that that's that's the point of

429
00:19:28,789 --> 00:19:26,400
the point of the Big Bang uh and then

430
00:19:31,010 --> 00:19:28,799
the universe expanded very rapidly uh

431
00:19:33,590 --> 00:19:31,020
followed by the Dark Ages and right

432
00:19:35,990 --> 00:19:33,600
about like 400 million years after the

433
00:19:38,930 --> 00:19:36,000
big bang we had our first Stars the

434
00:19:41,570 --> 00:19:38,940
first galaxies uh and as I will show you

435
00:19:43,430 --> 00:19:41,580
over the next next one hour it is

436
00:19:45,529 --> 00:19:43,440
exactly during these times when it is

437
00:19:47,690 --> 00:19:45,539
believed that some of the first black

438
00:19:52,909 --> 00:19:47,700

holes came into existence in the

439
00:19:55,549 --> 00:19:52,919
universe uh and we are here roughly 13.7

440
00:19:57,770 --> 00:19:55,559
billion years later and it is through

441
00:19:59,510 --> 00:19:57,780
the technology that we have developed uh

442
00:20:01,549 --> 00:19:59,520
and our understanding of the physics

443
00:20:04,250 --> 00:20:01,559
over the last few hundred or even

444
00:20:06,890 --> 00:20:04,260
thousand years or so that has allowed us

445
00:20:08,810 --> 00:20:06,900
to make this kind of a picture uh that

446
00:20:12,710 --> 00:20:08,820
you see in front of you

447
00:20:15,490 --> 00:20:12,720
so uh in order to understand how black

448
00:20:17,990 --> 00:20:15,500
holes form we need to understand Stars

449
00:20:20,570 --> 00:20:18,000
uh because as I will show you later

450
00:20:23,690 --> 00:20:20,580
black holes are basically formed after

451
00:20:27,169 --> 00:20:23,700
Stars die so first of all how do stars

452
00:20:30,289 --> 00:20:27,179
form so we start off with this uh with

453
00:20:34,190 --> 00:20:30,299
this uh with this sort of dark

454
00:20:36,650 --> 00:20:34,200
Cloud uh so this Dark Cloud consists of

455
00:20:39,289 --> 00:20:36,660
atoms molecules and dust and so on and

456
00:20:42,650 --> 00:20:39,299
so forth and due to gravity the cloud

457
00:20:44,150 --> 00:20:42,660
then compresses and starts forming these

458
00:20:46,850 --> 00:20:44,160
kind of clumps

459
00:20:49,070 --> 00:20:46,860
uh when this cloud is about say 10 000

460
00:20:52,250 --> 00:20:49,080
times the distance or between the Earth

461
00:20:54,590 --> 00:20:52,260
and and Sun so that that kind of size we

462
00:20:56,330 --> 00:20:54,600
start calling this a pre-stellar course

463
00:20:57,650 --> 00:20:56,340

it's pre-source code is something like

464
00:21:00,230 --> 00:20:57,660
you know which is dense in the right

465
00:21:03,350 --> 00:21:00,240
center and their density then falls off

466
00:21:07,490 --> 00:21:03,360
as you go outwards uh Stellar means

467
00:21:09,710 --> 00:21:07,500
Stars pre means before so that means

468
00:21:14,110 --> 00:21:09,720
that this particular Cloud that you see

469
00:21:17,810 --> 00:21:14,120
is now in the process of forming a star

470
00:21:21,890 --> 00:21:17,820
uh so at some point uh the pressure in

471
00:21:25,669 --> 00:21:21,900
inside this this this Cloud uh becomes

472
00:21:27,529 --> 00:21:25,679
uh becomes quite large uh and large to

473
00:21:29,690 --> 00:21:27,539
such an extent that the atoms inside

474
00:21:32,149 --> 00:21:29,700
these clouds then start fusing into each

475
00:21:35,450 --> 00:21:32,159
other and they produce a large amount of

476
00:21:38,330 --> 00:21:35,460
nuclear fusion energy and this energy is

477
00:21:41,330 --> 00:21:38,340
then visible in the form of a form of

478
00:21:42,770 --> 00:21:41,340
light and during these stages like you

479
00:21:45,649 --> 00:21:42,780
know when when the nuclear fusion

480
00:21:48,470 --> 00:21:45,659
happens and the cast cloud is there uh

481
00:21:52,070 --> 00:21:48,480
all the any excess uh excess gas and

482
00:21:53,930 --> 00:21:52,080
dust is just ejected along the poles uh

483
00:21:57,470 --> 00:21:53,940
and it leads to the ultimate formation

484
00:22:00,710 --> 00:21:57,480
of a near flat disc so in C D and E here

485
00:22:02,930 --> 00:22:00,720
that is exactly what you see uh that uh

486
00:22:05,210 --> 00:22:02,940
any uh so so the light from the Star

487
00:22:07,610 --> 00:22:05,220
basically just just removes that's just

488
00:22:09,710 --> 00:22:07,620

it just ejects all of these gas and does

489
00:22:12,470 --> 00:22:09,720
along the perpendicular Direction and

490
00:22:14,750 --> 00:22:12,480
then you're left with this disc uh along

491
00:22:17,450 --> 00:22:14,760
the equatorial Direction

492
00:22:19,669 --> 00:22:17,460
and so what happens is that uh the star

493
00:22:21,710 --> 00:22:19,679
still ski it still keeps growing uh from

494
00:22:23,330 --> 00:22:21,720
from the material that that it takes in

495
00:22:25,430 --> 00:22:23,340
from the disc but then there's also

496
00:22:27,710 --> 00:22:25,440
ejection taking place at this uh at the

497
00:22:30,890 --> 00:22:27,720
same time and depending on what stages

498
00:22:33,110 --> 00:22:30,900
uh the starter uh star is you would call

499
00:22:34,610 --> 00:22:33,120
it a protostar T20 Stars premium in

500
00:22:37,850 --> 00:22:34,620
sequence stars and so on and so forth

501
00:22:39,590 --> 00:22:37,860
but the final result uh is the star

502
00:22:41,810 --> 00:22:39,600
right in the center so it's called the

503
00:22:43,130 --> 00:22:41,820
premium sequence star uh where you have

504
00:22:46,669 --> 00:22:43,140
a start in the center and then there are

505
00:22:48,409 --> 00:22:46,679
planets uh surrounding that uh now let

506
00:22:50,690 --> 00:22:48,419
me tell you that this whole process

507
00:22:52,490 --> 00:22:50,700
takes about tens of thousands of years

508
00:22:55,370 --> 00:22:52,500
certainly we are not going to live that

509
00:22:57,950 --> 00:22:55,380
long I mean I I mean we will all be uh

510
00:23:01,250 --> 00:22:57,960
uh gone within the next 100 100 years or

511
00:23:03,350 --> 00:23:01,260
so so we individual human beings are

512
00:23:05,330 --> 00:23:03,360
never going to be around to see this

513
00:23:08,029 --> 00:23:05,340

entire whole process happening one by

514
00:23:10,190 --> 00:23:08,039
one so what we do is we take pictures of

515
00:23:12,710 --> 00:23:10,200
multiple objects and try and piece them

516
00:23:14,390 --> 00:23:12,720
together to get a complete picture so

517
00:23:16,310 --> 00:23:14,400
over the next few slides I will show you

518
00:23:19,130 --> 00:23:16,320
this chairs that we've taken from

519
00:23:19,909 --> 00:23:19,140
telescope both on the ground and in

520
00:23:22,610 --> 00:23:19,919
space

521
00:23:24,950 --> 00:23:22,620
so here I'm showing you an example of

522
00:23:26,830 --> 00:23:24,960
the clouds from which stars form so this

523
00:23:29,029 --> 00:23:26,840
is quite a quite a famous picture from

524
00:23:32,270 --> 00:23:29,039
Hubble Space Telescope that was already

525
00:23:33,409 --> 00:23:32,280
taken back in 1995 so roughly about 28

526
00:23:36,350 --> 00:23:33,419
years ago

527
00:23:38,510 --> 00:23:36,360
uh so the structure is called Pillars of

528
00:23:41,390 --> 00:23:38,520
Creation and shows these multiple

529
00:23:44,750 --> 00:23:41,400
elephant trunks and the reason that we

530
00:23:48,350 --> 00:23:44,760
call that this as Pillars of Creation is

531
00:23:50,330 --> 00:23:48,360
because the gas that you see here uh is

532
00:23:52,850 --> 00:23:50,340
in the in the process of creating new

533
00:23:55,970 --> 00:23:52,860
stars but at the same time some of these

534
00:23:58,669 --> 00:23:55,980
gases are also being eroded by recently

535
00:24:00,770 --> 00:23:58,679
formed Stars at the time when Hubble

536
00:24:03,529 --> 00:24:00,780
took this image it really started

537
00:24:05,409 --> 00:24:03,539
shaping the way we see how stars form

538
00:24:08,510 --> 00:24:05,419

over millions of years

539
00:24:11,510 --> 00:24:08,520
uh so then of course like recently we've

540
00:24:13,490 --> 00:24:11,520
had uh the web Space Telescope and we

541
00:24:16,490 --> 00:24:13,500
went back and took an image of this of

542
00:24:18,289 --> 00:24:16,500
the same gas cloud and voila we actually

543
00:24:21,770 --> 00:24:18,299
started seeing just as well in between

544
00:24:24,289 --> 00:24:21,780
those molecular gas clouds Now dust is a

545
00:24:26,750 --> 00:24:24,299
major ingredient of star formation and

546
00:24:31,730 --> 00:24:26,760
what we're seeing at different places uh

547
00:24:33,529 --> 00:24:31,740
uh are the lava-like regions uh uh which

548
00:24:35,990 --> 00:24:33,539
capture periodic injections from the

549
00:24:38,930 --> 00:24:36,000
Star stars as they form

550
00:24:41,590 --> 00:24:38,940
uh so this was basically the formation

551
00:24:44,149 --> 00:24:41,600
of stars from the from the dark clouds

552
00:24:46,310 --> 00:24:44,159
uh but then here's another example of

553
00:24:48,649 --> 00:24:46,320
the next stages of star formation a

554
00:24:51,470 --> 00:24:48,659
protostars that again who have Space

555
00:24:54,470 --> 00:24:51,480
Telescope captured very recently so the

556
00:24:56,630 --> 00:24:54,480
star right in the center uh makes a

557
00:24:59,630 --> 00:24:56,640
theory hourglass uh shape in its

558
00:25:02,630 --> 00:24:59,640
Infinity so basically at this point the

559
00:25:05,270 --> 00:25:02,640
the star here is clearing out all the

560
00:25:08,270 --> 00:25:05,280
gas from its polar regions as we saw in

561
00:25:10,430 --> 00:25:08,280
this cartoon picture here uh and this

562
00:25:11,830 --> 00:25:10,440
this entire system is actually on its

563
00:25:15,649 --> 00:25:11,840

way to becoming a star

564
00:25:17,690 --> 00:25:15,659
now remember that since it is ejecting

565
00:25:19,850 --> 00:25:17,700
out material so you know you you see

566
00:25:22,610 --> 00:25:19,860
this kind of a kind of a jet of streams

567
00:25:24,529 --> 00:25:22,620
like streams of particles coming out so

568
00:25:26,570 --> 00:25:24,539
it's not just forming stars but it's

569
00:25:29,450 --> 00:25:26,580
also preventing formation of new stars

570
00:25:32,510 --> 00:25:29,460
there so in a way uh what's happening is

571
00:25:34,490 --> 00:25:32,520
that it's clearing out any gas so the

572
00:25:36,710 --> 00:25:34,500
star is kind of marking its territory

573
00:25:39,529 --> 00:25:36,720
right here so in the end the Pluto star

574
00:25:41,450 --> 00:25:39,539
has all the gas around in these regions

575
00:25:43,310 --> 00:25:41,460
uh and the dust materials just for

576
00:25:46,250 --> 00:25:43,320
itself and it doesn't really have to

577
00:25:47,990 --> 00:25:46,260
share it with other stars

578
00:25:51,289 --> 00:25:48,000
and so as I said like in the final

579
00:25:53,269 --> 00:25:51,299
stages what we get is sort of a solar

580
00:25:55,909 --> 00:25:53,279
system so a star right in the center

581
00:25:57,230 --> 00:25:55,919
with a system of planets around it so

582
00:25:59,390 --> 00:25:57,240
there's a very familiar looking picture

583
00:26:02,330 --> 00:25:59,400
that we know uh from our own solar

584
00:26:04,310 --> 00:26:02,340
system uh uh so systems like assistants

585
00:26:07,310 --> 00:26:04,320
like these exist throughout our own

586
00:26:08,990 --> 00:26:07,320
Galaxy uh so like even in the Milky Way

587
00:26:11,149 --> 00:26:09,000
or in the galaxies around the universe

588
00:26:13,730 --> 00:26:11,159

there must be millions and millions or

589
00:26:15,529 --> 00:26:13,740
even billions of uh solar systems and

590
00:26:19,549 --> 00:26:15,539
the laws of physics are the same no

591
00:26:21,890 --> 00:26:19,559
matter whichever Galaxy uh we reside in

592
00:26:23,990 --> 00:26:21,900
so here's a video of uh which kind of

593
00:26:26,090 --> 00:26:24,000
shows you uh the formation of stars from

594
00:26:30,529 --> 00:26:26,100
the gas clouds and how they all come

595
00:26:35,029 --> 00:26:32,330
so what you can see is that there are

596
00:26:36,769 --> 00:26:35,039
these streams of gas there's these sort

597
00:26:38,810 --> 00:26:36,779
of like these fireworks that goes on in

598
00:26:40,490 --> 00:26:38,820
the in this video These fireworks are

599
00:26:43,970 --> 00:26:40,500
basically very new stars which is which

600
00:26:46,130 --> 00:26:43,980
are being formed and these uh these

601
00:26:49,149 --> 00:26:46,140
stores then come together and sort of

602
00:26:52,730 --> 00:26:49,159
make these kind of Galaxy kind of shape

603
00:26:55,730 --> 00:26:52,740
uh uh that you know from from uh from

604
00:26:57,430 --> 00:26:55,740
from many many astronomical images uh in

605
00:27:00,830 --> 00:26:57,440
the media as well

606
00:27:03,049 --> 00:27:00,840
uh so at least now you get a rough idea

607
00:27:05,149 --> 00:27:03,059
of like how stars form uh the beginning

608
00:27:06,529 --> 00:27:05,159
of the star life but then obviously we

609
00:27:08,390 --> 00:27:06,539
are here to study black holes but I'll

610
00:27:10,970 --> 00:27:08,400
soon come to that but we want to know

611
00:27:13,430 --> 00:27:10,980
like uh how a star evolves then so we

612
00:27:16,490 --> 00:27:13,440
just saw how an average star forms from

613
00:27:19,190 --> 00:27:16,500

a molecular gas cloud uh

614
00:27:21,049 --> 00:27:19,200
and now most of these stars have their

615
00:27:23,690 --> 00:27:21,059
fuel as the hydrogen atoms they are

616
00:27:25,850 --> 00:27:23,700
fusing into each other right now what

617
00:27:27,769 --> 00:27:25,860
happens if say the star runs out of this

618
00:27:30,049 --> 00:27:27,779
field at some point this can happen

619
00:27:31,909 --> 00:27:30,059
right that there is nothing left to fuse

620
00:27:35,210 --> 00:27:31,919
fuse into each other

621
00:27:37,250 --> 00:27:35,220
uh so that's when the red giant phase of

622
00:27:40,130 --> 00:27:37,260
the star comes up so this happens when

623
00:27:43,669 --> 00:27:40,140
the entire fuel for Star formation is

624
00:27:46,250 --> 00:27:43,679
consumed uh and the outer and uh the

625
00:27:49,070 --> 00:27:46,260
outer envelope uh expands and the reason

626
00:27:50,630 --> 00:27:49,080
that we call this is a red giant uh is

627
00:27:54,529 --> 00:27:50,640
because the star appears redder during

628
00:27:57,230 --> 00:27:54,539
this phase and it's really really big uh

629
00:27:59,210 --> 00:27:57,240
and uh really big to the extent that if

630
00:28:01,549 --> 00:27:59,220
Sun were to become Red Giant and it will

631
00:28:04,250 --> 00:28:01,559
become red giant not if it's a question

632
00:28:06,049 --> 00:28:04,260
of like when the sun becomes a red giant

633
00:28:09,110 --> 00:28:06,059
it will become so big that it will

634
00:28:12,049 --> 00:28:09,120
actually swallow Earth Mars and part of

635
00:28:13,850 --> 00:28:12,059
the asteroid belt as well uh so just

636
00:28:15,169 --> 00:28:13,860
imagine the size of Sun at that point I

637
00:28:17,570 --> 00:28:15,179
mean Earth Earth would just completely

638
00:28:20,149 --> 00:28:17,580

Disappear by that point uh fortunately

639
00:28:22,370 --> 00:28:20,159
that's certainly not going to happen uh

640
00:28:24,950 --> 00:28:22,380
at least uh all of the people who are

641
00:28:27,289 --> 00:28:24,960
watching this video are live uh so yeah

642
00:28:29,810 --> 00:28:27,299
so yeah the star becomes a red giant and

643
00:28:32,870 --> 00:28:29,820
then what's what's next so the outer

644
00:28:35,090 --> 00:28:32,880
envelope just keeps expanding and in the

645
00:28:37,430 --> 00:28:35,100
center the the star keeps getting

646
00:28:39,350 --> 00:28:37,440
Compact and Compact and it radiates

647
00:28:42,289 --> 00:28:39,360
ultraviolet and it keeps radiating

648
00:28:44,029 --> 00:28:42,299
ultraviolet right remember remember we

649
00:28:47,029 --> 00:28:44,039
all apply these sunscreen lotions that's

650
00:28:48,710 --> 00:28:47,039
basically to protect ourselves from the

651
00:28:50,149 --> 00:28:48,720
UV radiation from the Sun so the

652
00:28:52,970 --> 00:28:50,159
ultraviolet radiation from the stars

653
00:28:55,549 --> 00:28:52,980
that keeps keeps coming on and it lights

654
00:28:58,730 --> 00:28:55,559
up this envelope that is expanding uh on

655
00:29:00,890 --> 00:28:58,740
the outside and the result is one of the

656
00:29:02,390 --> 00:29:00,900
most beautiful phenomenon and the one of

657
00:29:05,269 --> 00:29:02,400
the most beautiful pictures that you can

658
00:29:07,909 --> 00:29:05,279
ever obtain in the universe and that is

659
00:29:10,669 --> 00:29:07,919
a planetary nebula look at that

660
00:29:12,470 --> 00:29:10,679
a small Star right in the center and

661
00:29:14,450 --> 00:29:12,480
that lights up all the gas that you have

662
00:29:17,090 --> 00:29:14,460
from the Stars atmosphere

663
00:29:19,370 --> 00:29:17,100

actually the the name planetary nebula

664
00:29:21,409 --> 00:29:19,380
is kind of a misnomer because it has

665
00:29:24,830 --> 00:29:21,419
nothing to do with planets it got its

666
00:29:26,210 --> 00:29:24,840
name because uh these were round uh like

667
00:29:29,029 --> 00:29:26,220
a shape like planets when the

668
00:29:31,789 --> 00:29:29,039
astronomers observed these things like

669
00:29:34,190 --> 00:29:31,799
with the early telescope so in this

670
00:29:37,909 --> 00:29:34,200
particular image you can see like uh the

671
00:29:40,310 --> 00:29:37,919
the web Space Telescope uh images of

672
00:29:42,830 --> 00:29:40,320
Southern Ring Nebula uh captured

673
00:29:45,230 --> 00:29:42,840
captured by the telescope quite recently

674
00:29:47,570 --> 00:29:45,240
and then once these envelope disappears

675
00:29:50,330 --> 00:29:47,580
all your left width is a small white

676
00:29:52,430 --> 00:29:50,340
dwarf and that is the end stage of this

677
00:29:53,510 --> 00:29:52,440
particular star a particular set of

678
00:29:56,210 --> 00:29:53,520
stars

679
00:29:57,590 --> 00:29:56,220
now uh I'm not here to tell you exactly

680
00:29:58,730 --> 00:29:57,600
about stars as I said like you know we

681
00:30:01,549 --> 00:29:58,740
are getting there towards the black

682
00:30:03,470 --> 00:30:01,559
holes now so uh and the good things

683
00:30:06,470 --> 00:30:03,480
gonna come at the end of course uh so

684
00:30:09,350 --> 00:30:06,480
what if this initial star was much much

685
00:30:11,269 --> 00:30:09,360
heavier so what if the star was say 10

686
00:30:14,149 --> 00:30:11,279
times the mass of the sun

687
00:30:16,490 --> 00:30:14,159
uh then the first two stages essentially

688
00:30:18,590 --> 00:30:16,500

remain the same that is we still get

689
00:30:20,149 --> 00:30:18,600
that star we still have the red giant

690
00:30:22,130 --> 00:30:20,159
phase only except this time there's

691
00:30:23,570 --> 00:30:22,140
going to be a red super giant phase

692
00:30:27,830 --> 00:30:23,580
because you know things are bigger now

693
00:30:30,590 --> 00:30:27,840
we have a much heavier star uh but

694
00:30:32,630 --> 00:30:30,600
instead of a planetary nebula because

695
00:30:36,350 --> 00:30:32,640
the star is so heavy and big this time

696
00:30:39,350 --> 00:30:36,360
we end up with a supernovae explosion so

697
00:30:42,230 --> 00:30:39,360
a supernova exam explosion basically is

698
00:30:44,269 --> 00:30:42,240
visible uh from the earth like even if

699
00:30:46,909 --> 00:30:44,279
it happens then like uh galaxies other

700
00:30:49,730 --> 00:30:46,919
than the Milky Way uh and after the

701
00:30:52,130 --> 00:30:49,740
supernovae explosion is over over we're

702
00:30:55,970 --> 00:30:52,140
left with two possibilities and one of

703
00:30:58,970 --> 00:30:55,980
those possibilities is a neutron star

704
00:31:01,269 --> 00:30:58,980
uh so here I'm I'm basically showing you

705
00:31:04,549 --> 00:31:01,279
a blinking picture of these two images

706
00:31:07,970 --> 00:31:04,559
uh one taken before the supernovae uh

707
00:31:10,310 --> 00:31:07,980
event and one taken after so let me keep

708
00:31:12,590 --> 00:31:10,320
this for a few seconds over here so can

709
00:31:14,450 --> 00:31:12,600
you tell uh where exactly is this

710
00:31:17,269 --> 00:31:14,460
explosion

711
00:31:19,490 --> 00:31:17,279
it's right here

712
00:31:21,529 --> 00:31:19,500
so this is what the astronomers do most

713
00:31:23,149 --> 00:31:21,539

of the time to detect a supernovi in

714
00:31:24,769 --> 00:31:23,159
order to see a supernova explosion we

715
00:31:27,110 --> 00:31:24,779
take multiple images of these galaxies

716
00:31:29,810 --> 00:31:27,120
and at some point we see this kind of a

717
00:31:32,330 --> 00:31:29,820
boom like you know uh a burst of light

718
00:31:35,269 --> 00:31:32,340
that comes from one particular point in

719
00:31:37,549 --> 00:31:35,279
uh in the galaxy

720
00:31:39,409 --> 00:31:37,559
so uh after the things have cooled down

721
00:31:41,210 --> 00:31:39,419
with respect to the supernovae we end up

722
00:31:44,029 --> 00:31:41,220
with this neutron star which is so

723
00:31:47,210 --> 00:31:44,039
Neutron is a is a some atomic particle

724
00:31:49,370 --> 00:31:47,220
uh within the nucleus of a of a uh

725
00:31:52,130 --> 00:31:49,380
within the nucleus we have protons and

726
00:31:53,990 --> 00:31:52,140
neutrons and in neutron star uh the the

727
00:31:56,450 --> 00:31:54,000
particles the neutrons there's just Pat

728
00:31:58,970 --> 00:31:56,460
themselves so densely they don't emit

729
00:32:01,010 --> 00:31:58,980
light but the this kind of a star spins

730
00:32:03,049 --> 00:32:01,020
and they have a very strong intense

731
00:32:04,549 --> 00:32:03,059
magnetic field and so if there are

732
00:32:05,930 --> 00:32:04,559
charged particles they get trapped in

733
00:32:07,610 --> 00:32:05,940
this magnetic field and they start

734
00:32:10,130 --> 00:32:07,620
emitting light and you can basically

735
00:32:12,590 --> 00:32:10,140
detect these light in the form of these

736
00:32:14,269 --> 00:32:12,600
rotate these periodic patterns very

737
00:32:17,570 --> 00:32:14,279
similar to the lighthouse that you have

738
00:32:22,070 --> 00:32:17,580

uh in the seashores

739
00:32:24,529 --> 00:32:22,080
now if finally uh if the initial mass of

740
00:32:28,010 --> 00:32:24,539
the star so the massive star was say

741
00:32:30,529 --> 00:32:28,020
roughly 25 to 30 or 15 times the mass of

742
00:32:32,029 --> 00:32:30,539
the Sun then we don't get a neutron star

743
00:32:35,870 --> 00:32:32,039
because you know the packing has to be

744
00:32:37,310 --> 00:32:35,880
even more dense now so uh the star still

745
00:32:40,250 --> 00:32:37,320
goes to a supernova stage and everything

746
00:32:42,769 --> 00:32:40,260
like that but now it leads to the

747
00:32:45,409 --> 00:32:42,779
formation of a black hole not a neutron

748
00:32:49,549 --> 00:32:45,419
star not a white dwarf but a black hole

749
00:32:51,590 --> 00:32:49,559
so finally after whatever what we've

750
00:32:54,169 --> 00:32:51,600
seen so far for the past 15 minutes how

751
00:32:56,750 --> 00:32:54,179
stars form how they evolve

752
00:32:58,789 --> 00:32:56,760
I hope you know how black hole actually

753
00:33:00,409 --> 00:32:58,799
forms at the end

754
00:33:02,750 --> 00:33:00,419
so let me tell you a bit of a history

755
00:33:04,970 --> 00:33:02,760
about black holes first the concept of

756
00:33:07,669 --> 00:33:04,980
black holes was already introduced by

757
00:33:10,250 --> 00:33:07,679
John Michelle back in 1783.

758
00:33:13,250 --> 00:33:10,260
so as it was postulated he was thinking

759
00:33:15,529 --> 00:33:13,260
of a method to determine the mass of a

760
00:33:17,509 --> 00:33:15,539
star and he accepted the Newton's theory

761
00:33:20,690 --> 00:33:17,519
of uh that light consists of small

762
00:33:23,090 --> 00:33:20,700
particles uh now imagine that you're

763
00:33:24,970 --> 00:33:23,100

throwing a ball up into the air while

764
00:33:27,950 --> 00:33:24,980
you're on your while you're on Earth

765
00:33:30,169 --> 00:33:27,960
obviously the ball speed will be maximum

766
00:33:32,149 --> 00:33:30,179
when you're throwing it it goes up to a

767
00:33:34,310 --> 00:33:32,159
certain height it slows down it stops

768
00:33:36,769 --> 00:33:34,320
and then it falls back again

769
00:33:38,990 --> 00:33:36,779
uh by that time people knew that light

770
00:33:41,750 --> 00:33:39,000
was extremely fast and if life was also

771
00:33:43,370 --> 00:33:41,760
a particle then it should kind of behave

772
00:33:45,769 --> 00:33:43,380
like what I just told you about the ball

773
00:33:47,930 --> 00:33:45,779
right now so John Michelle said that

774
00:33:50,990 --> 00:33:47,940
there could be a case where there is a

775
00:33:53,509 --> 00:33:51,000
star basically and it's so massive that

776
00:33:54,470 --> 00:33:53,519
even the light cannot Escape that star's

777
00:33:56,269 --> 00:33:54,480
gravity

778
00:33:57,789 --> 00:33:56,279
so that star must be illvisible because

779
00:34:00,230 --> 00:33:57,799
you know there is no light reaching us

780
00:34:01,789 --> 00:34:00,240
uh at that point there's no light

781
00:34:03,769 --> 00:34:01,799
escaping that star

782
00:34:06,889 --> 00:34:03,779
of course this was just a concept at

783
00:34:08,869 --> 00:34:06,899
that time and the term black hole itself

784
00:34:12,349 --> 00:34:08,879
did not exist until then no one really

785
00:34:14,690 --> 00:34:12,359
used the term black hole at that time

786
00:34:17,149 --> 00:34:14,700
the real foundations of this concept of

787
00:34:18,950 --> 00:34:17,159
a black hole started after when I Albert

788
00:34:22,490 --> 00:34:18,960

Einstein developed the general theory of

789
00:34:24,829 --> 00:34:22,500
relativity in 1915. Einstein developed a

790
00:34:27,349 --> 00:34:24,839
new paradigm that defines how gravity

791
00:34:29,570 --> 00:34:27,359
works and his entire theory is based

792
00:34:31,970 --> 00:34:29,580
upon tensor calculus in the words of

793
00:34:34,609 --> 00:34:31,980
John Wheeler and since Theory can be

794
00:34:37,490 --> 00:34:34,619
summarize as follows space-time tells

795
00:34:38,690 --> 00:34:37,500
Mata how to move Mata tells space-time

796
00:34:41,149 --> 00:34:38,700
how to cope

797
00:34:44,149 --> 00:34:41,159
now remember we're talking about 1915 a

798
00:34:45,649 --> 00:34:44,159
time of War cause schwartzel was was in

799
00:34:47,710 --> 00:34:45,659
Germany like he was a German physicist

800
00:34:50,510 --> 00:34:47,720
and an astronomer and soon after

801
00:34:53,389 --> 00:34:50,520
learning about einchan's Theory it

802
00:34:56,650 --> 00:34:53,399
develops Solutions uh to Einstein's

803
00:35:01,370 --> 00:34:56,660
equations and one of the features of

804
00:35:04,190 --> 00:35:01,380
uh's uh solution is that for very

805
00:35:05,990 --> 00:35:04,200
compact high density Stars so they were

806
00:35:08,030 --> 00:35:06,000
still calling stars at that point

807
00:35:10,370 --> 00:35:08,040
remember that because black holes still

808
00:35:11,569 --> 00:35:10,380
did not exist I'll come to I'll come to

809
00:35:14,510 --> 00:35:11,579
the point when we started calling them

810
00:35:17,329 --> 00:35:14,520
black holes uh but there could be these

811
00:35:19,670 --> 00:35:17,339
high density Stars uh that it could

812
00:35:22,010 --> 00:35:19,680
become much harder to escape the

813
00:35:23,750 --> 00:35:22,020

gravitational field of that star that

814
00:35:26,089 --> 00:35:23,760
even the light cannot Escape through it

815
00:35:27,950 --> 00:35:26,099
at the Event Horizon which is basically

816
00:35:30,530 --> 00:35:27,960
The Point Of No Escape escape from the

817
00:35:32,510 --> 00:35:30,540
black hole time slows to a complete

818
00:35:34,609 --> 00:35:32,520
stand still it's very similar to the

819
00:35:36,829 --> 00:35:34,619
concept of like Interstellar movie when

820
00:35:40,069 --> 00:35:36,839
Matthew and McConaughey approaches the

821
00:35:41,750 --> 00:35:40,079
black hole and so physical exist at that

822
00:35:43,569 --> 00:35:41,760
time basically because of this concept

823
00:35:46,010 --> 00:35:43,579
that you know the time stands still

824
00:35:49,250 --> 00:35:46,020
around the Event Horizon so the

825
00:35:52,069 --> 00:35:49,260
physicist called these bizarre objects

826
00:35:55,609 --> 00:35:52,079
Frozen Stars

827
00:35:58,010 --> 00:35:55,619
so the general relatives uh principle is

828
00:36:01,450 --> 00:35:58,020
sort of depicted here so basically we

829
00:36:04,370 --> 00:36:01,460
are living amidst a space-time fabric

830
00:36:06,530 --> 00:36:04,380
and in the presence of Mars uh the

831
00:36:08,569 --> 00:36:06,540
space-time curves it's quite similar to

832
00:36:10,370 --> 00:36:08,579
like if you have a rubber sheet or like

833
00:36:12,710 --> 00:36:10,380
a piece of cloth that you would spread

834
00:36:16,730 --> 00:36:12,720
out and stretch out and if you put some

835
00:36:20,089 --> 00:36:16,740
some Mass on them so the heavier the

836
00:36:22,370 --> 00:36:20,099
mass the greater is the bend and so if a

837
00:36:23,870 --> 00:36:22,380
light particle travels through this uh

838
00:36:25,430 --> 00:36:23,880

not for like particle but like light

839
00:36:27,589 --> 00:36:25,440
waves or particles whatever it doesn't

840
00:36:30,710 --> 00:36:27,599
matter at that point because light has

841
00:36:33,109 --> 00:36:30,720
this Duality so if uh light travels

842
00:36:36,829 --> 00:36:33,119
through this fabric it bends and then it

843
00:36:39,589 --> 00:36:36,839
changes Direction uh so the more uh the

844
00:36:42,829 --> 00:36:39,599
more heavier the masses uh the light

845
00:36:44,329 --> 00:36:42,839
curves further and if this curvature is

846
00:36:46,430 --> 00:36:44,339
too intense like in the case of black

847
00:36:49,609 --> 00:36:46,440
hole even the light cannot really come

848
00:36:51,050 --> 00:36:49,619
out of that uh that particular Hole uh

849
00:36:53,810 --> 00:36:51,060
at the end of it it can't really escape

850
00:36:56,390 --> 00:36:53,820
from that ultimately

851
00:36:59,270 --> 00:36:56,400
so the term black hole actually was

852
00:37:01,370 --> 00:36:59,280
popularized by John Wheeler uh during a

853
00:37:02,870 --> 00:37:01,380
lecture he gave in uh I gave at Nasa

854
00:37:06,349 --> 00:37:02,880
Goddard Institute of Space Sciences here

855
00:37:08,870 --> 00:37:06,359
in New York back in 1967 and as we know

856
00:37:11,050 --> 00:37:08,880
it the term black hole is if you use so

857
00:37:14,150 --> 00:37:11,060
frequently uh when we talk about space

858
00:37:16,609 --> 00:37:14,160
in science fiction fiction movies etc

859
00:37:19,010 --> 00:37:16,619
etc oh well at least in my life I use

860
00:37:21,890 --> 00:37:19,020
this term quite regularly now uh almost

861
00:37:24,170 --> 00:37:21,900
on a daily basis uh so remember like we

862
00:37:26,870 --> 00:37:24,180
are talking uh this about like back in

863
00:37:29,329 --> 00:37:26,880

1960s we still did not have a detection

864
00:37:31,849 --> 00:37:29,339
of black hole this was a concept a very

865
00:37:34,370 --> 00:37:31,859
strong one at that but but still we

866
00:37:36,170 --> 00:37:34,380
needed to develop methods of detecting

867
00:37:38,750 --> 00:37:36,180
these black holes

868
00:37:41,630 --> 00:37:38,760
Ten Years After Einstein Einstein's

869
00:37:44,329 --> 00:37:41,640
death Roger Penrose now at Oxford

870
00:37:46,250 --> 00:37:44,339
University in the UK he proposed

871
00:37:48,530 --> 00:37:46,260
critical mathematical tools to describe

872
00:37:49,910 --> 00:37:48,540
black holes he showed that Einstein's

873
00:37:52,430 --> 00:37:49,920
theory meant that black hole formation

874
00:37:54,410 --> 00:37:52,440
must be seen as a natural process in the

875
00:37:56,210 --> 00:37:54,420
development of the universe and for this

876
00:37:58,970 --> 00:37:56,220
project Penrose was given a Nobel Prize

877
00:38:00,770 --> 00:37:58,980
in physics just two years ago along with

878
00:38:03,050 --> 00:38:00,780
two other astronomers who I will

879
00:38:05,569 --> 00:38:03,060
describe in a few minutes so by the time

880
00:38:08,990 --> 00:38:05,579
it was 1960s it was pretty much clear

881
00:38:10,550 --> 00:38:09,000
that black holes should exist we had a

882
00:38:12,950 --> 00:38:10,560
very strong theoretical foundation for

883
00:38:14,810 --> 00:38:12,960
it I have of course not described the

884
00:38:16,730 --> 00:38:14,820
Gory details of the history but then

885
00:38:19,310 --> 00:38:16,740
just to give you an idea of like how

886
00:38:22,550 --> 00:38:19,320
things progressed over the last 100 or

887
00:38:25,670 --> 00:38:22,560
200 or even 300 years or so

888
00:38:27,530 --> 00:38:25,680

uh so now what was left test we had a

889
00:38:29,450 --> 00:38:27,540
theory that black holes should exist we

890
00:38:31,490 --> 00:38:29,460
needed to build telescopes develop

891
00:38:34,250 --> 00:38:31,500
state-of-the-art instruments that would

892
00:38:36,470 --> 00:38:34,260
help help us conclusively say that black

893
00:38:39,290 --> 00:38:36,480
holes do exist

894
00:38:40,790 --> 00:38:39,300
so uh over the next part of the talk I

895
00:38:43,069 --> 00:38:40,800
will show you what we have been trying

896
00:38:45,650 --> 00:38:43,079
to do to detect these black holes with

897
00:38:47,930 --> 00:38:45,660
observations uh and using these

898
00:38:51,109 --> 00:38:47,940
observations we have been confidently uh

899
00:38:53,630 --> 00:38:51,119
be able to say uh that uh what a black

900
00:38:55,190 --> 00:38:53,640
hole should look uh what the area around

901
00:38:58,370 --> 00:38:55,200
the black hole should look and so on and

902
00:39:01,310 --> 00:38:58,380
so forth so this uh picture basically

903
00:39:04,730 --> 00:39:01,320
shows you a cartoon model or a schematic

904
00:39:07,750 --> 00:39:04,740
model of uh how a black hole and a

905
00:39:10,849 --> 00:39:07,760
region around the black hole looks like

906
00:39:13,910 --> 00:39:10,859
so right at the center you have the

907
00:39:17,089 --> 00:39:13,920
singularity uh the edge of this black

908
00:39:18,950 --> 00:39:17,099
area is called The Event Horizon and the

909
00:39:21,470 --> 00:39:18,960
black holes also have these discs around

910
00:39:23,750 --> 00:39:21,480
it so through that disc it eats up the

911
00:39:26,089 --> 00:39:23,760
material uh from the interstellar medium

912
00:39:28,730 --> 00:39:26,099
and at some uh and in some cases you

913
00:39:31,130 --> 00:39:28,740

would also have a jet that comes out of

914
00:39:33,950 --> 00:39:31,140
these black holes as well

915
00:39:37,609 --> 00:39:33,960
so uh the black holes can come in like

916
00:39:41,810 --> 00:39:37,619
three Mass ranges one is still a black

917
00:39:45,829 --> 00:39:41,820
hole uh uh so their masters are anywhere

918
00:39:47,630 --> 00:39:45,839
between about uh 10 solar masses to

919
00:39:49,790 --> 00:39:47,640
about a hundred times the mass of the

920
00:39:53,270 --> 00:39:49,800
Sun then we have an intermediate Mass

921
00:39:56,150 --> 00:39:53,280
black hole which is anywhere between uh

922
00:39:57,950 --> 00:39:56,160
200 times the mass of the Sun to about a

923
00:40:00,470 --> 00:39:57,960
million or less than a million like a

924
00:40:02,569 --> 00:40:00,480
hundred thousand uh times the mass of

925
00:40:04,790 --> 00:40:02,579
the mass of the Sun Also and then we

926
00:40:06,170 --> 00:40:04,800
have the supermassive black hole so what

927
00:40:08,750 --> 00:40:06,180
I would do is like I would do this in

928
00:40:11,630 --> 00:40:08,760
stages uh I will show you how we detect

929
00:40:13,250 --> 00:40:11,640
uh uh Stellar black holes uh how we

930
00:40:15,069 --> 00:40:13,260
detect intermediate Mass black holes and

931
00:40:17,930 --> 00:40:15,079
how we detect supermass or black holes

932
00:40:20,270 --> 00:40:17,940
uh and remember

933
00:40:22,130 --> 00:40:20,280
detecting these different kinds of black

934
00:40:24,050 --> 00:40:22,140
holes require completely different

935
00:40:25,430 --> 00:40:24,060
techniques or maybe similar techniques

936
00:40:28,010 --> 00:40:25,440
as well but then different techniques as

937
00:40:30,109 --> 00:40:28,020
well so imagine that you wanted to weigh

938
00:40:33,050 --> 00:40:30,119

baking powder in your kitchen you would

939
00:40:35,690 --> 00:40:33,060
not really go to to your scale in in the

940
00:40:38,450 --> 00:40:35,700
bathroom and then use that scale to

941
00:40:39,890 --> 00:40:38,460
measure say one gram of baking powder or

942
00:40:43,250 --> 00:40:39,900
something like that you would obviously

943
00:40:46,310 --> 00:40:43,260
use a kitchen scale so as a similar

944
00:40:49,250 --> 00:40:46,320
analogy the the ways uh the the method

945
00:40:50,990 --> 00:40:49,260
of weighing these Stellar black holes or

946
00:40:53,329 --> 00:40:51,000
supermassive black holes they differ

947
00:40:54,650 --> 00:40:53,339
depending on what kind of object we are

948
00:40:56,870 --> 00:40:54,660
looking at

949
00:40:59,210 --> 00:40:56,880
so let's come to Stella Mars black holes

950
00:41:01,609 --> 00:40:59,220
uh Stella Mars black holes as I said

951
00:41:04,550 --> 00:41:01,619
that they are anywhere between say 10 or

952
00:41:05,990 --> 00:41:04,560
uh but pretty much less than 100 times

953
00:41:08,750 --> 00:41:06,000
the mass of the sun

954
00:41:10,849 --> 00:41:08,760
now let me tell you in our own Milky Way

955
00:41:12,710 --> 00:41:10,859
it's postulated that there could be

956
00:41:15,410 --> 00:41:12,720
about a hundred million black holes or

957
00:41:16,910 --> 00:41:15,420
so the problem is it's difficult to

958
00:41:18,770 --> 00:41:16,920
detect them because they're black holes

959
00:41:20,390 --> 00:41:18,780
at the end of the day we can't see them

960
00:41:22,550 --> 00:41:20,400
they are they're I mean you know the

961
00:41:24,170 --> 00:41:22,560
space is dark and then in between you're

962
00:41:25,910 --> 00:41:24,180
trying to find this uh find this black

963
00:41:29,870 --> 00:41:25,920

object over there

964
00:41:34,010 --> 00:41:29,880
so one of the ways that we can find

965
00:41:37,310 --> 00:41:34,020
black holes in the Milky Way is is using

966
00:41:41,270 --> 00:41:39,230
so this is again going back to the

967
00:41:43,609 --> 00:41:41,280
space-time fabric of uh Einstein's

968
00:41:44,870 --> 00:41:43,619
gender relativity that we that we saw a

969
00:41:48,530 --> 00:41:44,880
few slides back

970
00:41:51,290 --> 00:41:48,540
so here I'm showing you say two very

971
00:41:53,870 --> 00:41:51,300
compact objects they are circling around

972
00:41:57,290 --> 00:41:53,880
each other and in this process what they

973
00:42:00,650 --> 00:41:57,300
do is they sent out this Ripple of waves

974
00:42:02,270 --> 00:42:00,660
uh for a completely outward uh in the

975
00:42:04,970 --> 00:42:02,280
outward Direction

976
00:42:09,410 --> 00:42:04,980
and it is possible to detect these

977
00:42:13,010 --> 00:42:09,420
ripples uh on Earth and that is using uh

978
00:42:14,750 --> 00:42:13,020
the ligo interferometer so uh here I'm

979
00:42:18,410 --> 00:42:14,760
going to show you a video like how ligo

980
00:42:20,569 --> 00:42:18,420
works so what happens is that there is a

981
00:42:23,390 --> 00:42:20,579
beam of light that goes and hits against

982
00:42:26,990 --> 00:42:23,400
a a mirror which then splits the light

983
00:42:29,829 --> 00:42:27,000
into two arms so you'll see that the one

984
00:42:36,370 --> 00:42:29,839
of the light goes in One Direction

985
00:42:42,589 --> 00:42:39,109
and comes back and combines with the

986
00:42:46,550 --> 00:42:42,599
other light Ray and then we see how it

987
00:42:49,069 --> 00:42:46,560
looks now if the path between this

988
00:42:51,050 --> 00:42:49,079

mirror and this mirror this mirror and

989
00:42:53,450 --> 00:42:51,060
this rear mirror was exactly the same

990
00:42:55,790 --> 00:42:53,460
then what we would get is a combined

991
00:42:57,410 --> 00:42:55,800
light what that means a bright spot

992
00:43:00,530 --> 00:42:57,420
but then in the presence of gravitation

993
00:43:02,809 --> 00:43:00,540
waves what happens is that so let me go

994
00:43:04,130 --> 00:43:02,819
back a bit yeah let me pause right here

995
00:43:07,609 --> 00:43:04,140
maybe

996
00:43:10,609 --> 00:43:07,619
there we go so if these two paths were

997
00:43:13,670 --> 00:43:10,619
uh parts were the same then the

998
00:43:16,010 --> 00:43:13,680
combination would be would lead to a

999
00:43:18,470 --> 00:43:16,020
bright uh bright spot here in the

1000
00:43:21,230 --> 00:43:18,480
detector but then because of the

1001
00:43:24,530 --> 00:43:21,240
gravitation waves uh the relative parts

1002
00:43:27,890 --> 00:43:24,540
of this arm and this arm would differ

1003
00:43:29,690 --> 00:43:27,900
and due to which we'll see a change in

1004
00:43:32,390 --> 00:43:29,700
the intensity of the light pattern on

1005
00:43:34,550 --> 00:43:32,400
the detector over here so when we see

1006
00:43:37,010 --> 00:43:34,560
the change in the intensity you see like

1007
00:43:39,890 --> 00:43:37,020
you can see the intensity changing using

1008
00:43:42,050 --> 00:43:39,900
that we can detect uh that okay there is

1009
00:43:46,609 --> 00:43:42,060
a gravitation wave that we just observed

1010
00:43:48,410 --> 00:43:46,619
and using uh how much time it took for

1011
00:43:50,930 --> 00:43:48,420
these waves to change these shapes and

1012
00:43:53,510 --> 00:43:50,940
so on and so forth you can determine the

1013
00:43:55,190 --> 00:43:53,520

mass of the of the black holes which are

1014
00:43:56,630 --> 00:43:55,200
then ultimately combining or circling

1015
00:43:59,270 --> 00:43:56,640
around each other

1016
00:44:01,849 --> 00:43:59,280
so here's an example of like the the

1017
00:44:03,589 --> 00:44:01,859
masses that we've measured so far using

1018
00:44:05,870 --> 00:44:03,599
gravitational waves so you can see that

1019
00:44:08,690 --> 00:44:05,880
you know it's anywhere uh say up to 100

1020
00:44:13,010 --> 00:44:08,700
or even 200 or so uh all the way down to

1021
00:44:15,230 --> 00:44:13,020
even 1.5 uh or two uh times the mass of

1022
00:44:17,990 --> 00:44:15,240
the sun

1023
00:44:20,210 --> 00:44:18,000
uh so coming uh to the next stage which

1024
00:44:22,069 --> 00:44:20,220
is the intermediate Mass black holes uh

1025
00:44:23,450 --> 00:44:22,079
which are much much heavier than the

1026
00:44:25,309 --> 00:44:23,460
Stellar Mass black holes but much much

1027
00:44:28,730 --> 00:44:25,319
lighter than the supermaster black holes

1028
00:44:31,970 --> 00:44:28,740
uh and this is the big question right

1029
00:44:34,130 --> 00:44:31,980
now that how do we detect intermediate

1030
00:44:36,650 --> 00:44:34,140
Mass black holes even astronomers are

1031
00:44:38,990 --> 00:44:36,660
struggling right now and this is a major

1032
00:44:40,430 --> 00:44:39,000
challenge because we want to know where

1033
00:44:43,609 --> 00:44:40,440
we can find these intermediate Mouse

1034
00:44:45,109 --> 00:44:43,619
black holes so uh it is postulated that

1035
00:44:47,089 --> 00:44:45,119
there are these globular clusters

1036
00:44:51,170 --> 00:44:47,099
globular clusters are these clusters of

1037
00:44:53,210 --> 00:44:51,180
stars uh and uh clusters of stars and in

1038
00:44:56,030 --> 00:44:53,220

between these intermediate Mass black

1039
00:44:57,890 --> 00:44:56,040
holes can be lurking around uh and we

1040
00:45:00,650 --> 00:44:57,900
might also find intermediate Mouse black

1041
00:45:02,470 --> 00:45:00,660
holes in small galaxies right in their

1042
00:45:06,829 --> 00:45:02,480
Center

1043
00:45:08,930 --> 00:45:06,839
so uh as we saw like the Intermediate

1044
00:45:11,930 --> 00:45:08,940
Mass black holes can be determined using

1045
00:45:14,630 --> 00:45:11,940
uh the intimated months

1046
00:45:16,849 --> 00:45:14,640
which are uh which I'll come to in a in

1047
00:45:18,410 --> 00:45:16,859
a short while and the last way we can

1048
00:45:20,809 --> 00:45:18,420
detect is through tidal disruption

1049
00:45:23,870 --> 00:45:20,819
events so title disruption events is

1050
00:45:27,109 --> 00:45:23,880
when a star is completely ripped apart

1051
00:45:29,329 --> 00:45:27,119
uh by a black hole uh I will show you a

1052
00:45:31,970 --> 00:45:29,339
video in a while but then this is what

1053
00:45:33,950 --> 00:45:31,980
happens so there is a star because of

1054
00:45:35,990 --> 00:45:33,960
the presence of a black hole somewhere

1055
00:45:38,089 --> 00:45:36,000
it encounters that black hole and the

1056
00:45:40,250 --> 00:45:38,099
stars are basically ripped apart

1057
00:45:43,010 --> 00:45:40,260
start image slide right so if you can

1058
00:45:45,530 --> 00:45:43,020
trace that light path we know that there

1059
00:45:48,109 --> 00:45:45,540
is a black hole over there so this is

1060
00:45:50,630 --> 00:45:48,119
quite incredible uh and uh it's kind of

1061
00:45:52,010 --> 00:45:50,640
it's very rare to even detect these kind

1062
00:45:54,230 --> 00:45:52,020
of events

1063
00:45:55,670 --> 00:45:54,240

so now finally moving on to the

1064
00:45:57,589 --> 00:45:55,680
supermassive black holes right at the

1065
00:46:00,109 --> 00:45:57,599
center of the galaxies so when I say

1066
00:46:03,609 --> 00:46:00,119
supermassive how massive are they

1067
00:46:07,309 --> 00:46:03,619
these supermassive black holes can be as

1068
00:46:09,470 --> 00:46:07,319
heavy as 1 million to 10 billion times

1069
00:46:11,510 --> 00:46:09,480
the masses of the Sun so just think

1070
00:46:14,150 --> 00:46:11,520
about it for a bit 10 billion times the

1071
00:46:18,530 --> 00:46:14,160
mass of the sun it's extremely heavy and

1072
00:46:20,210 --> 00:46:18,540
you can imagine how uh how powerful this

1073
00:46:22,730 --> 00:46:20,220
kind of a system can be

1074
00:46:25,490 --> 00:46:22,740
so the question arises is that how did

1075
00:46:28,130 --> 00:46:25,500
they end up getting so heavy how is it

1076
00:46:30,589 --> 00:46:28,140
that that these black holes have become

1077
00:46:32,030 --> 00:46:30,599
this size

1078
00:46:33,770 --> 00:46:32,040
so

1079
00:46:35,569 --> 00:46:33,780
remember I told you about the title

1080
00:46:38,450 --> 00:46:35,579
disruption event so this is how it

1081
00:46:40,670 --> 00:46:38,460
happens so uh the the black holes grow

1082
00:46:43,790 --> 00:46:40,680
by taking in materials from their

1083
00:46:46,670 --> 00:46:43,800
surroundings and so here I'm showing you

1084
00:46:48,710 --> 00:46:46,680
an example that okay here's a star and

1085
00:46:51,349 --> 00:46:48,720
there's a black hole somewhere and then

1086
00:46:53,089 --> 00:46:51,359
you can see how the star is completely

1087
00:46:55,370 --> 00:46:53,099
ripped apart

1088
00:46:56,630 --> 00:46:55,380

taken in by the black hole so there's

1089
00:46:59,569 --> 00:46:56,640
this black hole right in the center

1090
00:47:01,849 --> 00:46:59,579
there is an accretion disk this disc is

1091
00:47:04,670 --> 00:47:01,859
where uh you get most of the material

1092
00:47:06,589 --> 00:47:04,680
funneling into the black hole and in

1093
00:47:08,450 --> 00:47:06,599
some cases you can also see this jets

1094
00:47:10,730 --> 00:47:08,460
that are coming right perpendicularly

1095
00:47:13,069 --> 00:47:10,740
out of the black hole

1096
00:47:15,349 --> 00:47:13,079
so this is one of the ways in which the

1097
00:47:17,030 --> 00:47:15,359
black holes grow this is one of the ways

1098
00:47:19,069 --> 00:47:17,040
in which the black hole accumulates mass

1099
00:47:21,230 --> 00:47:19,079
and this is not just limited to

1100
00:47:23,450 --> 00:47:21,240
supermassive black holes this is limited

1101
00:47:25,490 --> 00:47:23,460
to telomos black holes intermediate Mass

1102
00:47:27,950 --> 00:47:25,500
black holes as well as supermassive

1103
00:47:30,530 --> 00:47:27,960
black holes

1104
00:47:32,750 --> 00:47:30,540
and this is also another way that the

1105
00:47:35,750 --> 00:47:32,760
black holes can become supermassive by

1106
00:47:38,510 --> 00:47:35,760
combining two black holes together so we

1107
00:47:40,430 --> 00:47:38,520
often have these situations where there

1108
00:47:42,230 --> 00:47:40,440
are two black holes circling around each

1109
00:47:44,930 --> 00:47:42,240
other and you can see that because you

1110
00:47:47,990 --> 00:47:44,940
know because of the uh fabric of space

1111
00:47:49,550 --> 00:47:48,000
and time you can see like so all of

1112
00:47:52,190 --> 00:47:49,560
these uh these stars in the background

1113
00:47:53,990 --> 00:47:52,200

they start becoming fuzzy or they they

1114
00:47:56,510 --> 00:47:54,000
start moving around a bit and that's all

1115
00:48:00,290 --> 00:47:56,520
because of the space time uh space-time

1116
00:48:03,770 --> 00:48:00,300
curvature and so uh so we have just

1117
00:48:06,710 --> 00:48:03,780
explored two ways of uh there of uh

1118
00:48:09,349 --> 00:48:06,720
through which the black holes grow one

1119
00:48:11,150 --> 00:48:09,359
is by the title disruption event but

1120
00:48:13,730 --> 00:48:11,160
when basically a star is completely

1121
00:48:15,109 --> 00:48:13,740
ripped apart and one is by the

1122
00:48:17,930 --> 00:48:15,119
combination of two black holes

1123
00:48:21,770 --> 00:48:19,190
so

1124
00:48:24,230 --> 00:48:21,780
the another way of detecting black holes

1125
00:48:27,170 --> 00:48:24,240
is Through Time series observations so a

1126
00:48:29,210 --> 00:48:27,180
few slides back if you remember I I told

1127
00:48:32,150 --> 00:48:29,220
you here right here high resolution time

1128
00:48:35,270 --> 00:48:32,160
series observations of clusters

1129
00:48:38,210 --> 00:48:35,280
now this is an image of the very center

1130
00:48:42,470 --> 00:48:38,220
of our own galaxy The Milky Way

1131
00:48:44,329 --> 00:48:42,480
so over the last 20 years or so using

1132
00:48:46,370 --> 00:48:44,339
extremely high resolution observations

1133
00:48:48,589 --> 00:48:46,380
from ground-based telescopes what we've

1134
00:48:50,569 --> 00:48:48,599
done is we've kept taking pictures of

1135
00:48:53,329 --> 00:48:50,579
the center of our Milky Way

1136
00:48:56,230 --> 00:48:53,339
and what we've observed is this as you

1137
00:49:00,290 --> 00:48:56,240
can see these Stars seem to be rotating

1138
00:49:02,210 --> 00:49:00,300

around this invisible object

1139
00:49:04,190 --> 00:49:02,220
now obviously this is a perfect

1140
00:49:05,930 --> 00:49:04,200
candidate that there is a black hole

1141
00:49:07,790 --> 00:49:05,940
right there and this is the center of

1142
00:49:11,329 --> 00:49:07,800
our galaxy

1143
00:49:13,550 --> 00:49:11,339
so this was basically obtained using the

1144
00:49:15,710 --> 00:49:13,560
very large telescope uh right in the

1145
00:49:18,410 --> 00:49:15,720
middle of the Atacama Desert desert in

1146
00:49:19,970 --> 00:49:18,420
Chile uh if you ever get a chance to go

1147
00:49:22,130 --> 00:49:19,980
to this Observatory I would highly

1148
00:49:23,750 --> 00:49:22,140
recommend to do that I worked here for

1149
00:49:26,809 --> 00:49:23,760
about three years or so I spent about

1150
00:49:30,109 --> 00:49:26,819
200 nights there uh and what you do is

1151
00:49:31,970 --> 00:49:30,119
uh you uh you you you land at the

1152
00:49:34,910 --> 00:49:31,980
airport you then go right in the middle

1153
00:49:36,589 --> 00:49:34,920
of the desert there's no light uh even

1154
00:49:38,690 --> 00:49:36,599
during the night you have to drive a car

1155
00:49:40,910 --> 00:49:38,700
down from the mountain over here you're

1156
00:49:43,010 --> 00:49:40,920
not allowed to turn on the headlights

1157
00:49:45,410 --> 00:49:43,020
because even a little bit of light could

1158
00:49:48,530 --> 00:49:45,420
contaminate your astronomical data and

1159
00:49:51,349 --> 00:49:48,540
it's one of the darkest regions on Earth

1160
00:49:53,089 --> 00:49:51,359
so in the middle of the desert we have

1161
00:49:56,569 --> 00:49:53,099
developed this

1162
00:49:59,990 --> 00:49:56,579
uh uh develop this state-of-the-art

1163
00:50:01,730 --> 00:50:00,000

instrumentation uh that could help us uh

1164
00:50:04,970 --> 00:50:01,740
in obtaining these high resolution

1165
00:50:08,450 --> 00:50:04,980
images so that we can see how the stars

1166
00:50:10,910 --> 00:50:08,460
are moving around right in the center of

1167
00:50:13,910 --> 00:50:10,920
our galaxy

1168
00:50:16,370 --> 00:50:13,920
so uh how do we obtain high resolution

1169
00:50:18,230 --> 00:50:16,380
imaging uh high resolution imaging is

1170
00:50:21,650 --> 00:50:18,240
obtained using this technology called

1171
00:50:23,089 --> 00:50:21,660
adaptive objects in so I'll just uh play

1172
00:50:25,910 --> 00:50:23,099
this video here which shows you how

1173
00:50:28,069 --> 00:50:25,920
adaptive object actually works uh so

1174
00:50:30,290 --> 00:50:28,079
obviously when you have something on the

1175
00:50:32,270 --> 00:50:30,300
ground there is atmosphere it's not

1176
00:50:34,730 --> 00:50:32,280
really as dark as space you have the

1177
00:50:37,309 --> 00:50:34,740
atmospheric molecules due to which the

1178
00:50:39,710 --> 00:50:37,319
star then appears fuzzy

1179
00:50:42,290 --> 00:50:39,720
and what we want is to remove this

1180
00:50:45,290 --> 00:50:42,300
atmosphere completely so there is this

1181
00:50:47,809 --> 00:50:45,300
technology there uh where you know it

1182
00:50:50,990 --> 00:50:47,819
detects how the atmosphere is

1183
00:50:53,750 --> 00:50:51,000
and it removes the the turbulence that

1184
00:50:56,210 --> 00:50:53,760
the wind uh from different regions so so

1185
00:51:00,710 --> 00:50:56,220
for example like this Technologies is

1186
00:51:03,410 --> 00:51:00,720
detecting uh uh uh what the uh what the

1187
00:51:05,930 --> 00:51:03,420
atmosphere atmospheric disturbing look

1188
00:51:08,109 --> 00:51:05,940

looks like it replicates that and then

1189
00:51:11,150 --> 00:51:08,119
it corrects for it

1190
00:51:13,910 --> 00:51:11,160
and to do this for the center of our

1191
00:51:17,690 --> 00:51:13,920
galaxy two astronomers Andrea guess from

1192
00:51:19,849 --> 00:51:17,700
UCLA and Reinhardt genzel uh from Max

1193
00:51:22,849 --> 00:51:19,859
Planck Institute in Germany they did

1194
00:51:25,190 --> 00:51:22,859
pioneering work uh by developing these

1195
00:51:27,650 --> 00:51:25,200
Technologies uh and they shared the

1196
00:51:31,490 --> 00:51:27,660
Nobel Prize back in 2020 uh along with

1197
00:51:34,010 --> 00:51:31,500
Roger Penrose uh and their work

1198
00:51:36,589 --> 00:51:34,020
basically gave us the most convincing

1199
00:51:38,210 --> 00:51:36,599
evidence yet of a supermassive black

1200
00:51:40,130 --> 00:51:38,220
hole right in the center of the Milky

1201
00:51:41,569 --> 00:51:40,140
Way and that was the time series image

1202
00:51:44,630 --> 00:51:41,579
that I just showed you a couple of

1203
00:51:47,750 --> 00:51:44,640
slides back and here's a sort of a

1204
00:51:51,049 --> 00:51:47,760
cartoon or rather a schematic diagram of

1205
00:51:53,210 --> 00:51:51,059
what was happening uh in that uh uh in

1206
00:51:55,849 --> 00:51:53,220
that video so we have these different

1207
00:51:57,849 --> 00:51:55,859
Stars at the center of the Milky Way and

1208
00:52:01,190 --> 00:51:57,859
they are they're revolving around this

1209
00:52:04,549 --> 00:52:01,200
invisible object and this invisible

1210
00:52:06,650 --> 00:52:04,559
object is basically uh the the black

1211
00:52:09,049 --> 00:52:06,660
hole right in the center of our own

1212
00:52:12,170 --> 00:52:09,059
galaxy The Milky Way

1213
00:52:13,549 --> 00:52:12,180

now obviously uh we want to imagine the

1214
00:52:15,349 --> 00:52:13,559
black hole I mean obviously if you want

1215
00:52:17,630 --> 00:52:15,359
to get pictures of that we have pictures

1216
00:52:20,210 --> 00:52:17,640
of stars we have pictures of nebulae we

1217
00:52:22,609 --> 00:52:20,220
have pictures of those protostars from

1218
00:52:25,250 --> 00:52:22,619
uh which show these kind of nice uh

1219
00:52:26,450 --> 00:52:25,260
hourglass shapes and so on like that why

1220
00:52:27,470 --> 00:52:26,460
can't we take the picture of a black

1221
00:52:30,710 --> 00:52:27,480
hole

1222
00:52:33,290 --> 00:52:30,720
and so this is what you might have seen

1223
00:52:35,450 --> 00:52:33,300
say from the Interstellar movie where

1224
00:52:37,430 --> 00:52:35,460
there was this black hole right in the

1225
00:52:40,670 --> 00:52:37,440
center but then what do you see this

1226
00:52:42,290 --> 00:52:40,680
sort of a bright structure this bright

1227
00:52:45,650 --> 00:52:42,300
structure is basically the accretion

1228
00:52:48,829 --> 00:52:45,660
disk remember black hole's gravity is so

1229
00:52:51,109 --> 00:52:48,839
strong that it curves space and time so

1230
00:52:53,150 --> 00:52:51,119
what you see on the top here

1231
00:52:55,430 --> 00:52:53,160
is basically the accretion disc from

1232
00:52:57,470 --> 00:52:55,440
behind the black hole so it completely

1233
00:52:59,870 --> 00:52:57,480
curves the light completely curves from

1234
00:53:01,790 --> 00:52:59,880
behind the accretion desk comes towards

1235
00:53:03,650 --> 00:53:01,800
us and that's why we see this sort of a

1236
00:53:05,569 --> 00:53:03,660
symmetrical structure

1237
00:53:07,809 --> 00:53:05,579
and obviously this was a picture from

1238
00:53:11,030 --> 00:53:07,819

the movie this was a this is a picture

1239
00:53:12,890 --> 00:53:11,040
uh which is based on simulations but can

1240
00:53:14,809 --> 00:53:12,900
we actually take a real real picture

1241
00:53:17,030 --> 00:53:14,819
from our telescopes

1242
00:53:19,010 --> 00:53:17,040
and that is exactly what happened a

1243
00:53:22,430 --> 00:53:19,020
couple of years ago using the Event

1244
00:53:24,470 --> 00:53:22,440
Horizon telescope if y'all remember uh

1245
00:53:27,349 --> 00:53:24,480
this is this was a black hole uh image

1246
00:53:30,650 --> 00:53:27,359
taken from a nearby Galaxy

1247
00:53:33,530 --> 00:53:30,660
and our own Milky Way looks like this so

1248
00:53:35,809 --> 00:53:33,540
kind of like this donut shape structure

1249
00:53:41,569 --> 00:53:35,819
how did we do this

1250
00:53:43,910 --> 00:53:41,579
so in order to make uh an image uh using

1251
00:53:46,730 --> 00:53:43,920
any telescope we want the telescopes to

1252
00:53:48,890 --> 00:53:46,740
be much much larger larger the telescope

1253
00:53:50,569 --> 00:53:48,900
the more zooming in you can see it's

1254
00:53:53,150 --> 00:53:50,579
very similar to the Nikon and Canon

1255
00:53:56,329 --> 00:53:53,160
cameras that you use the larger the the

1256
00:53:58,549 --> 00:53:56,339
size size of the lens the more uh

1257
00:54:01,069 --> 00:53:58,559
clearly you can see those images

1258
00:54:04,130 --> 00:54:01,079
so what astronomers did was

1259
00:54:06,770 --> 00:54:04,140
they use the Earth itself like a like a

1260
00:54:08,630 --> 00:54:06,780
telescope so we have telescope all the

1261
00:54:11,930 --> 00:54:08,640
way down to the South Pole

1262
00:54:13,730 --> 00:54:11,940
in Chile in the U.S in Hawaii in Europe

1263
00:54:15,890 --> 00:54:13,740

and in Greenland

1264
00:54:18,290 --> 00:54:15,900
and what we did was we combined the

1265
00:54:20,930 --> 00:54:18,300
power of all of these telescope using

1266
00:54:24,349 --> 00:54:20,940
this technology called interferometry

1267
00:54:26,210 --> 00:54:24,359
so the data was recorded in hard disk in

1268
00:54:28,670 --> 00:54:26,220
all of these locations physically

1269
00:54:31,549 --> 00:54:28,680
brought together in one place to combine

1270
00:54:34,370 --> 00:54:31,559
them with the data all together uh so

1271
00:54:36,430 --> 00:54:34,380
this is this is an image of of some of

1272
00:54:39,829 --> 00:54:36,440
the telescopes that were used

1273
00:54:44,569 --> 00:54:39,839
to to make those those images

1274
00:54:47,510 --> 00:54:44,579
and so due to the the due to the fact

1275
00:54:49,730 --> 00:54:47,520
that we've been able to combine the data

1276
00:54:52,970 --> 00:54:49,740
from these telescopes we were able to

1277
00:54:56,630 --> 00:54:52,980
get these beautiful images uh uh of of

1278
00:54:58,849 --> 00:54:56,640
our own Milky Way uh using uh using the

1279
00:55:02,210 --> 00:54:58,859
data from uh from telescopes all the way

1280
00:55:03,950 --> 00:55:02,220
from the South Pole all the way to the

1281
00:55:06,410 --> 00:55:03,960
Greenland

1282
00:55:08,870 --> 00:55:06,420
now as I said like uh in the title like

1283
00:55:10,490 --> 00:55:08,880
the supermassive black holes at the

1284
00:55:13,670 --> 00:55:10,500
center of the galaxies

1285
00:55:15,170 --> 00:55:13,680
so very recently uh when I say very

1286
00:55:16,309 --> 00:55:15,180
recently recently compared to the

1287
00:55:18,890 --> 00:55:16,319
conception of the blackout the

1288
00:55:22,970 --> 00:55:18,900

conception of all of this Theory uh so

1289
00:55:26,390 --> 00:55:22,980
what we found out was that uh the mass

1290
00:55:28,490 --> 00:55:26,400
of the central bulge of the Galaxy and

1291
00:55:30,650 --> 00:55:28,500
the mass of the black hole they kind of

1292
00:55:33,049 --> 00:55:30,660
go hand in hand with each other

1293
00:55:36,530 --> 00:55:33,059
so that means if the black hole is

1294
00:55:39,170 --> 00:55:36,540
lighter the Bulge of my Galaxy is also

1295
00:55:41,930 --> 00:55:39,180
lighter the black hole is massive the

1296
00:55:44,809 --> 00:55:41,940
Bulge of my Galaxy is also massive and

1297
00:55:47,210 --> 00:55:44,819
that gave rise to the idea that maybe

1298
00:55:50,450 --> 00:55:47,220
the black hole is actually doing

1299
00:55:54,470 --> 00:55:50,460
something to our galaxy it's actually

1300
00:55:57,109 --> 00:55:54,480
impacting the way stars are forming

1301
00:56:01,490 --> 00:55:57,119
so use

1302
00:56:03,470 --> 00:56:01,500
uh here's a uh here's a a schematic or

1303
00:56:04,370 --> 00:56:03,480
rather a video of how this might be

1304
00:56:06,710 --> 00:56:04,380
happening

1305
00:56:08,210 --> 00:56:06,720
so what you see here is a black hole

1306
00:56:10,730 --> 00:56:08,220
right in the center

1307
00:56:13,430 --> 00:56:10,740
and because of the accretion disk

1308
00:56:16,430 --> 00:56:13,440
there's a lot of radiation pressure

1309
00:56:18,049 --> 00:56:16,440
and due to this radiation very fast

1310
00:56:21,470 --> 00:56:18,059
winds start coming out of these black

1311
00:56:24,710 --> 00:56:21,480
holes so what you see in yellow here is

1312
00:56:26,390 --> 00:56:24,720
basically the Fast Wind that comes from

1313
00:56:28,490 --> 00:56:26,400

these black holes and why is that

1314
00:56:29,809 --> 00:56:28,500
happening because it was it is from the

1315
00:56:31,609 --> 00:56:29,819
accretion disk there's a lot of

1316
00:56:34,549 --> 00:56:31,619
radiation pressure over there

1317
00:56:37,609 --> 00:56:34,559
and as a result of that what happens is

1318
00:56:39,950 --> 00:56:37,619
that this wind and I'm talking about

1319
00:56:42,650 --> 00:56:39,960
this uh the wind speeds of

1320
00:56:44,990 --> 00:56:42,660
thousand kilometers per second

1321
00:56:48,049 --> 00:56:45,000
it's extremely fast and only a black

1322
00:56:50,450 --> 00:56:48,059
hole can drive a wind which is that fast

1323
00:56:52,970 --> 00:56:50,460
and what it does what this wind does is

1324
00:56:55,790 --> 00:56:52,980
it just clears out the Galaxy completely

1325
00:56:58,910 --> 00:56:55,800
out of gas so basically if there is no

1326
00:57:01,370 --> 00:56:58,920
gas there would be no star formation

1327
00:57:04,970 --> 00:57:01,380
so again what the black hole is doing

1328
00:57:07,370 --> 00:57:04,980
the black hole is taking in matter

1329
00:57:10,430 --> 00:57:07,380
it is producing radiation

1330
00:57:12,589 --> 00:57:10,440
the radiation is then hitting against

1331
00:57:15,650 --> 00:57:12,599
the interstellar medium

1332
00:57:16,970 --> 00:57:15,660
and that is driving the gas out of the

1333
00:57:19,970 --> 00:57:16,980
galaxies

1334
00:57:21,470 --> 00:57:19,980
and what ultimately happens is a

1335
00:57:23,270 --> 00:57:21,480
shutdown of star formation in the

1336
00:57:24,470 --> 00:57:23,280
galaxies the galaxies basically become

1337
00:57:27,950 --> 00:57:24,480
dead

1338
00:57:30,710 --> 00:57:27,960

and it's all happening because of this

1339
00:57:32,930 --> 00:57:30,720
black hole which is taking in matter and

1340
00:57:35,809 --> 00:57:32,940
trying to grow actually

1341
00:57:37,790 --> 00:57:35,819
but at the same time so as I said right

1342
00:57:40,190 --> 00:57:37,800
now that the black hole basically

1343
00:57:42,829 --> 00:57:40,200
removed the gas from the Galaxy but at

1344
00:57:46,309 --> 00:57:42,839
the same time the black hole wins like

1345
00:57:49,309 --> 00:57:46,319
these can also trigger star formation

1346
00:57:50,750 --> 00:57:49,319
so here's a video uh of like one of the

1347
00:57:53,630 --> 00:57:50,760
results that we obtained about five

1348
00:57:55,370 --> 00:57:53,640
years ago uh so you see that there's

1349
00:57:58,010 --> 00:57:55,380
this galaxy here

1350
00:57:59,150 --> 00:57:58,020
and this is the outflow or rather these

1351
00:58:02,270 --> 00:57:59,160
are the fast winds that are coming

1352
00:58:04,790 --> 00:58:02,280
perpendicular out of the galaxies

1353
00:58:08,750 --> 00:58:04,800
and then you have these star formations

1354
00:58:10,670 --> 00:58:08,760
so uh I think you'll soon see that uh

1355
00:58:12,890 --> 00:58:10,680
within the wind itself there would be

1356
00:58:15,890 --> 00:58:12,900
star formation uh happening so this is

1357
00:58:19,849 --> 00:58:17,870
and from the equation test you have the

1358
00:58:23,150 --> 00:58:19,859
radiation

1359
00:58:25,130 --> 00:58:23,160
and uh we used basically uh the

1360
00:58:26,809 --> 00:58:25,140
telescope in Chile the one the picture

1361
00:58:29,690 --> 00:58:26,819
that I showed you very recently so you

1362
00:58:32,390 --> 00:58:29,700
can see that there are these uh these

1363
00:58:34,010 --> 00:58:32,400

fast winds they try they travel at

1364
00:58:37,010 --> 00:58:34,020
extremely high speeds of thousand or

1365
00:58:41,930 --> 00:58:37,020
even two thousand kilometers per second

1366
00:58:45,349 --> 00:58:41,940
and you see these clumps right here

1367
00:58:48,530 --> 00:58:45,359
that's basically starts forming Within

1368
00:58:51,049 --> 00:58:48,540
These winds so while these black holes

1369
00:58:53,569 --> 00:58:51,059
can shut down star formation

1370
00:58:55,910 --> 00:58:53,579
it can also create the formation of new

1371
00:58:58,430 --> 00:58:55,920
stars it can also give birth or give

1372
00:59:02,809 --> 00:58:58,440
rise to the birth of new stars uh Within

1373
00:59:07,010 --> 00:59:04,609
and obviously

1374
00:59:11,630 --> 00:59:07,020
a lot of things change on 25th of

1375
00:59:13,809 --> 00:59:11,640
December 2021 when we launched uh when

1376
00:59:17,089 --> 00:59:13,819
we launched the web Space Telescope

1377
00:59:19,490 --> 00:59:17,099
this really ushered in a new era in in

1378
00:59:22,789 --> 00:59:19,500
astronomy because now we were able to

1379
00:59:24,950 --> 00:59:22,799
obtain much clearer pictures a

1380
00:59:28,030 --> 00:59:24,960
complimentary picture but much clearer

1381
00:59:30,589 --> 00:59:28,040
pictures of these galaxies

1382
00:59:32,630 --> 00:59:30,599
to the extent that now we can zoom in

1383
00:59:36,470 --> 00:59:32,640
very close to the regions of the black

1384
00:59:38,930 --> 00:59:36,480
holes to see how they look like

1385
00:59:41,510 --> 00:59:38,940
so this this was the launch of the of

1386
00:59:44,150 --> 00:59:41,520
the of the web Space Telescope

1387
00:59:46,190 --> 00:59:44,160
and this is one of the images of the

1388
00:59:51,470 --> 00:59:46,200

nearby Galaxy and the nearby black hole

1389
00:59:57,289 --> 00:59:54,829
and what we can see is that we can now

1390
00:59:59,210 --> 00:59:57,299
peel through the dust because of the

1391
01:00:01,190 --> 00:59:59,220
fact that the web Space Telescope works

1392
01:00:03,230 --> 01:00:01,200
in the infrared

1393
01:00:06,230 --> 01:00:03,240
we can now look through the columns of

1394
01:00:08,630 --> 01:00:06,240
dust uh that would have otherwise and

1395
01:00:09,710 --> 01:00:08,640
shrouded the black holes uh making it

1396
01:00:12,349 --> 01:00:09,720
invisible

1397
01:00:15,230 --> 01:00:12,359
but not now in the infrared it shines

1398
01:00:20,870 --> 01:00:18,170
and so the Stefan quintet is one of the

1399
01:00:23,030 --> 01:00:20,880
uh galaxies uh one of the set of

1400
01:00:25,910 --> 01:00:23,040
galaxies that uh that uh the web Space

1401
01:00:29,569 --> 01:00:25,920
Telescope image and what we can see is

1402
01:00:33,049 --> 01:00:29,579
this uh this detail of gas and dust

1403
01:00:35,390 --> 01:00:33,059
interplaying with each other uh uh and

1404
01:00:37,730 --> 01:00:35,400
we can we can now see these details

1405
01:00:39,710 --> 01:00:37,740
which we could not basically even a year

1406
01:00:41,750 --> 01:00:39,720
ago or so so this is really really

1407
01:00:43,910 --> 01:00:41,760
incredible stuff uh that is now coming

1408
01:00:45,650 --> 01:00:43,920
out of gym service based telescope and

1409
01:00:48,710 --> 01:00:45,660
it's also going to improve our

1410
01:00:50,990 --> 01:00:48,720
understanding of how these black holes

1411
01:00:53,930 --> 01:00:51,000
right in the center are able to affect

1412
01:00:55,609 --> 01:00:53,940
our galaxies and uh how would they look

1413
01:00:57,530 --> 01:00:55,619

like in the future

1414
01:01:01,370 --> 01:00:57,540
but the story obviously doesn't stop

1415
01:01:04,730 --> 01:01:01,380
there uh at the end of 2020s we will

1416
01:01:07,309 --> 01:01:04,740
also have the extremely large telescope

1417
01:01:09,170 --> 01:01:07,319
the extremely large telescope as you can

1418
01:01:12,349 --> 01:01:09,180
see I mean we have a habit of naming

1419
01:01:14,690 --> 01:01:12,359
telescopes based on their uh their sizes

1420
01:01:15,890 --> 01:01:14,700
we have the very large telescope and now

1421
01:01:17,990 --> 01:01:15,900
we will have the extremely large

1422
01:01:21,470 --> 01:01:18,000
telescope and the extremely large in the

1423
01:01:24,109 --> 01:01:21,480
sense that this will be the size of one

1424
01:01:27,109 --> 01:01:24,119
of the football stadium imagine that a

1425
01:01:29,569 --> 01:01:27,119
telescope the size the telescope Dome uh

1426
01:01:31,970 --> 01:01:29,579
to be the size of a football stadium

1427
01:01:34,069 --> 01:01:31,980
so the extremely large telescope and the

1428
01:01:36,289 --> 01:01:34,079
web Space Telescope will kind of work

1429
01:01:38,089 --> 01:01:36,299
together they're not canceling each

1430
01:01:42,109 --> 01:01:38,099
other out but rather they're working

1431
01:01:43,970 --> 01:01:42,119
together uh to to uncover what lies

1432
01:01:46,970 --> 01:01:43,980
right in the center of these black holes

1433
01:01:49,190 --> 01:01:46,980
what happens to the gas as it as it

1434
01:01:51,589 --> 01:01:49,200
moves in and how exactly those fast

1435
01:01:54,770 --> 01:01:51,599
velocity winds that I had that I had

1436
01:01:57,049 --> 01:01:54,780
shown you uh is actually launched uh

1437
01:02:00,049 --> 01:01:57,059
from close to the black holes

1438
01:02:02,210 --> 01:02:00,059

so I hope that I've I have convinced you

1439
01:02:06,829 --> 01:02:02,220
that these black holes are fascinating

1440
01:02:09,230 --> 01:02:06,839
targets uh and over the next decade uh

1441
01:02:10,849 --> 01:02:09,240
over the next 10 20 years very easily

1442
01:02:13,010 --> 01:02:10,859
there's going to be exciting times

1443
01:02:14,589 --> 01:02:13,020
because we have new telescope coming up

1444
01:02:17,270 --> 01:02:14,599
even more

1445
01:02:20,030 --> 01:02:17,280
both from the space telescopes as well

1446
01:02:23,270 --> 01:02:20,040
as the ground base uh as well as from

1447
01:02:25,910 --> 01:02:23,280
ground uh based uh telescopes in Chile

1448
01:02:28,010 --> 01:02:25,920
and elsewhere around the world as well

1449
01:02:29,990 --> 01:02:28,020
uh so I would like to thank you for your

1450
01:02:33,170 --> 01:02:30,000
attention and I would be happy to take

1451
01:02:39,109 --> 01:02:35,930
all right thank you darshan that was

1452
01:02:41,390 --> 01:02:39,119
very very extensive coverage of black

1453
01:02:43,250 --> 01:02:41,400
holes from the beginning of the universe

1454
01:02:45,589 --> 01:02:43,260
to the formation of Stellar Mass black

1455
01:02:48,109 --> 01:02:45,599
holes uh getting into the intermediate

1456
01:02:50,030 --> 01:02:48,119
black hole and up to this super massive

1457
01:02:53,150 --> 01:02:50,040
black holes

1458
01:02:55,490 --> 01:02:53,160
um one of the questions that you one of

1459
01:02:59,150 --> 01:02:55,500
the points you you made is uh web being

1460
01:03:00,710 --> 01:02:59,160
able to see uh these uh active Galactic

1461
01:03:02,450 --> 01:03:00,720
nuclei

1462
01:03:04,250 --> 01:03:02,460
um uh in particular you talked about

1463
01:03:07,010 --> 01:03:04,260

Stefan's quintet now I just did a

1464
01:03:08,690 --> 01:03:07,020
visualization on Stefan's quintet and

1465
01:03:14,450 --> 01:03:08,700
the the Galaxy with the the big bright

1466
01:03:18,289 --> 01:03:14,460
AGN NGC 7319 has a honking big emission

1467
01:03:21,530 --> 01:03:18,299
that Webb sees but being a cosmology guy

1468
01:03:24,170 --> 01:03:21,540
it wasn't clear to me where is that

1469
01:03:25,970 --> 01:03:24,180
infrared emission coming from around the

1470
01:03:28,190 --> 01:03:25,980
AGN is it the outer parts of the

1471
01:03:31,069 --> 01:03:28,200
accretion disk is it the the outflow

1472
01:03:34,670 --> 01:03:31,079
material I mean for to emit in the

1473
01:03:36,829 --> 01:03:34,680
infrared you've got to be cool gas and I

1474
01:03:38,630 --> 01:03:36,839
wasn't sure and since I naturally

1475
01:03:41,210 --> 01:03:38,640
associate black holes with high energy

1476
01:03:43,130 --> 01:03:41,220
stuff and x-rays and such uh where is

1477
01:03:45,289 --> 01:03:43,140
the infrared emission coming from

1478
01:03:47,210 --> 01:03:45,299
so if you talk about the black hole

1479
01:03:49,430 --> 01:03:47,220
black hole itself so the Supermassive

1480
01:03:53,089 --> 01:03:49,440
Black Hole uh so the infrared emission

1481
01:03:55,490 --> 01:03:53,099
comes from two places uh so uh there is

1482
01:03:58,250 --> 01:03:55,500
the foreign for it uh that comes from

1483
01:03:59,930 --> 01:03:58,260
the the equatorial Direction so we have

1484
01:04:01,730 --> 01:03:59,940
like the equatorial Direction there but

1485
01:04:04,130 --> 01:04:01,740
the mid infrared emission which I think

1486
01:04:06,950 --> 01:04:04,140
the the web telescope might be seen

1487
01:04:09,289 --> 01:04:06,960
could be coming in from the uh from the

1488
01:04:12,349 --> 01:04:09,299

uh from the outflow or rather these fast

1489
01:04:14,630 --> 01:04:12,359
winds so there's this Dusty outflow uh

1490
01:04:16,849 --> 01:04:14,640
scenario that is taking place uh very

1491
01:04:20,390 --> 01:04:16,859
close uh close to these back holes and

1492
01:04:22,609 --> 01:04:20,400
we have seen that uh uh in many many

1493
01:04:24,470 --> 01:04:22,619
other galaxies as well where the

1494
01:04:27,710 --> 01:04:24,480
infrared emission basically comes very

1495
01:04:29,630 --> 01:04:27,720
perpendicular uh to uh to the galaxies

1496
01:04:32,510 --> 01:04:29,640
and what we think is that is basically

1497
01:04:34,490 --> 01:04:32,520
the dust uh from from The Polar

1498
01:04:37,130 --> 01:04:34,500
directions of the of the of of the of

1499
01:04:39,950 --> 01:04:37,140
these black holes uh which is emitting

1500
01:04:43,370 --> 01:04:39,960
yeah in in the

1501
01:04:45,770 --> 01:04:43,380
end okay cool because I I guess I had

1502
01:04:48,170 --> 01:04:45,780
naively not knowing this the subject

1503
01:04:51,289 --> 01:04:48,180
matter expected huge infrared emission

1504
01:04:53,150 --> 01:04:51,299
from from uh active Galactic nuclei

1505
01:04:54,770 --> 01:04:53,160
um uh and so it was something I was

1506
01:04:57,230 --> 01:04:54,780
trying to learn about but I was doing

1507
01:04:58,849 --> 01:04:57,240
the visualization and I didn't need to

1508
01:05:00,890 --> 01:04:58,859
know but I needed to know some of the

1509
01:05:02,870 --> 01:05:00,900
some of the material information about

1510
01:05:04,849 --> 01:05:02,880
it and I thought that was fantastic

1511
01:05:07,789 --> 01:05:04,859
all right grant justice has been

1512
01:05:10,490 --> 01:05:07,799
following the chat on our YouTube stream

1513
01:05:13,549 --> 01:05:10,500

uh Grant would you like to join us and

1514
01:05:16,130 --> 01:05:13,559
tell us if you found any cool uh

1515
01:05:18,230 --> 01:05:16,140
questions on our YouTube chat yeah

1516
01:05:19,930 --> 01:05:18,240
absolutely I actually have a really good

1517
01:05:22,970 --> 01:05:19,940
one to start us off

1518
01:05:26,510 --> 01:05:22,980
so um one of the viewers had heard that

1519
01:05:30,069 --> 01:05:26,520
the Milky Way uh supermassive black hole

1520
01:05:32,990 --> 01:05:30,079
is smaller than others or is uniquely

1521
01:05:35,150 --> 01:05:33,000
smaller than others is this true or is

1522
01:05:36,349 --> 01:05:35,160
there anything special about our black

1523
01:05:39,470 --> 01:05:36,359
hole

1524
01:05:42,470 --> 01:05:39,480
so I would say I'm sorry I would say

1525
01:05:45,069 --> 01:05:42,480
that uh the Milky Way black hole is

1526
01:05:47,150 --> 01:05:45,079
indeed smaller than many other

1527
01:05:49,970 --> 01:05:47,160
supermassive black holes that I have

1528
01:05:51,829 --> 01:05:49,980
personally studied uh so Milky Way black

1529
01:05:54,250 --> 01:05:51,839
hole is roughly around like a million

1530
01:05:57,109 --> 01:05:54,260
solar masses or so if I'm not mistaken

1531
01:06:01,250 --> 01:05:57,119
uh but then the black holes that I am

1532
01:06:04,250 --> 01:06:01,260
looking at uh are roughly about

1533
01:06:08,329 --> 01:06:04,260
100 million or thousand or or about a

1534
01:06:10,010 --> 01:06:08,339
billion uh solo masses or so so I would

1535
01:06:11,750 --> 01:06:10,020
say that it's not especially in that

1536
01:06:14,809 --> 01:06:11,760
sense because like there's always this

1537
01:06:19,190 --> 01:06:14,819
this bell curve right we'll we will

1538
01:06:21,829 --> 01:06:19,200

always have a maximum number of uh of

1539
01:06:24,170 --> 01:06:21,839
galaxies with a particular Mass bin uh

1540
01:06:26,089 --> 01:06:24,180
so yes I mean there is a black hole in

1541
01:06:28,069 --> 01:06:26,099
right in the center of the Milky Way It

1542
01:06:30,710 --> 01:06:28,079
Is inactive right now in the sense that

1543
01:06:34,370 --> 01:06:30,720
it's not as bright as a lot of other uh

1544
01:06:36,650 --> 01:06:34,380
galaxies that you see uh but it was at

1545
01:06:39,049 --> 01:06:36,660
some point right and we know that from

1546
01:06:41,930 --> 01:06:39,059
Fermi bubbles uh so if you look at in

1547
01:06:43,430 --> 01:06:41,940
the gamma rays uh uh so just as you saw

1548
01:06:45,349 --> 01:06:43,440
like in the perpendicular you have these

1549
01:06:47,690 --> 01:06:45,359
these two kind of like cone sort of

1550
01:06:50,510 --> 01:06:47,700
structures uh we can see them them in

1551
01:06:52,309 --> 01:06:50,520
gamma rays also so the Milky Way is I

1552
01:06:55,069 --> 01:06:52,319
would say is sort of a stereotypical

1553
01:06:58,549 --> 01:06:55,079
Galaxy but then yes there is black hole

1554
01:07:01,250 --> 01:06:58,559
is lighter than a lot of other galaxies

1555
01:07:03,770 --> 01:07:01,260
that we are that we see yeah but I guess

1556
01:07:06,829 --> 01:07:03,780
I guess my question uh I'm following on

1557
01:07:10,609 --> 01:07:06,839
that is is the Milky Way smaller than it

1558
01:07:12,710 --> 01:07:10,619
should be given its mass right uh we

1559
01:07:16,730 --> 01:07:12,720
have a you know a a trillion solar

1560
01:07:20,150 --> 01:07:16,740
masses in stars and dust and dark matter

1561
01:07:21,890 --> 01:07:20,160
Etc in our galaxy is the 2 million solar

1562
01:07:23,569 --> 01:07:21,900
mass black hole what we should be have

1563
01:07:26,450 --> 01:07:23,579

should have or should we have a larger

1564
01:07:27,710 --> 01:07:26,460
one and I wasn't sure the answer to that

1565
01:07:29,569 --> 01:07:27,720
yeah

1566
01:07:32,569 --> 01:07:29,579
I would say I'm not too sure about the

1567
01:07:34,910 --> 01:07:32,579
answer as well okay all right so that

1568
01:07:36,470 --> 01:07:34,920
relation you showed going from the

1569
01:07:38,809 --> 01:07:36,480
Stellar Mass black holes out to the

1570
01:07:40,010 --> 01:07:38,819
intermediate to the supermassive

1571
01:07:42,230 --> 01:07:40,020
um we're at the low end of the

1572
01:07:43,910 --> 01:07:42,240
supermassive black hole range being just

1573
01:07:46,190 --> 01:07:43,920
in a few million

1574
01:07:49,430 --> 01:07:46,200
um but you know we're also not the

1575
01:07:52,069 --> 01:07:49,440
largest of large galaxies right so

1576
01:07:54,049 --> 01:07:52,079
um I wasn't I wasn't sure whether we we

1577
01:07:55,910 --> 01:07:54,059
fit on the curve or whether we're below

1578
01:07:57,650 --> 01:07:55,920
the curve or not

1579
01:08:00,289 --> 01:07:57,660
all right well we'll have to look that

1580
01:08:03,109 --> 01:08:00,299
up and and we'll get back to we'll get

1581
01:08:10,370 --> 01:08:05,270
is there any reason that we know of that

1582
01:08:14,089 --> 01:08:11,690
I'm sorry

1583
01:08:16,610 --> 01:08:14,099
is there any reason that we know of why

1584
01:08:19,430 --> 01:08:16,620
it is um smaller or not as bright as you

1585
01:08:25,970 --> 01:08:23,269
be uh so it all depends on like how much

1586
01:08:27,890 --> 01:08:25,980
mass the Galaxy had to begin with uh how

1587
01:08:31,030 --> 01:08:27,900
much of gas and does it was able to

1588
01:08:34,010 --> 01:08:31,040

create uh during its formation

1589
01:08:36,110 --> 01:08:34,020
uh so

1590
01:08:38,570 --> 01:08:36,120
yeah I mean I don't have an answer to

1591
01:08:40,789 --> 01:08:38,580
the fact that why it's smaller right now

1592
01:08:43,370 --> 01:08:40,799
not at the top of out of the top of my

1593
01:08:45,229 --> 01:08:43,380
head you're good it's your whole study

1594
01:08:46,849 --> 01:08:45,239
like that's that's why you have a job is

1595
01:08:48,890 --> 01:08:46,859
to find out these answers so exactly

1596
01:08:49,910 --> 01:08:48,900
it's good it's something of my homework

1597
01:08:51,530 --> 01:08:49,920
then

1598
01:08:53,809 --> 01:08:51,540
that's one of the things I love about

1599
01:08:54,890 --> 01:08:53,819
working with Scientists is if like when

1600
01:08:56,329 --> 01:08:54,900
you're presented with information you

1601
01:08:59,510 --> 01:08:56,339
don't know it's just more things to

1602
01:09:00,920 --> 01:08:59,520
learn like it's beautiful the endurance

1603
01:09:04,430 --> 01:09:00,930
is job security

1604
01:09:07,370 --> 01:09:04,440
[Laughter]

1605
01:09:10,370 --> 01:09:07,380
okay so I wanted to nope there was a

1606
01:09:12,829 --> 01:09:10,380
question about the ligo results okay and

1607
01:09:15,950 --> 01:09:12,839
the implication being that ligo has

1608
01:09:17,930 --> 01:09:15,960
totally changed your field right

1609
01:09:20,570 --> 01:09:17,940
um and so

1610
01:09:22,550 --> 01:09:20,580
um if ligo results had come out a decade

1611
01:09:24,590 --> 01:09:22,560
or two decades or earlier the question

1612
01:09:26,329 --> 01:09:24,600
was how would that have changed where

1613
01:09:30,590 --> 01:09:26,339

you would be now in your career or

1614
01:09:33,410 --> 01:09:30,600
something I mean um we're the I were

1615
01:09:35,510 --> 01:09:33,420
they truly this step change and and is

1616
01:09:37,070 --> 01:09:35,520
is that you know going to be marked as a

1617
01:09:39,709 --> 01:09:37,080
point where you know this changes

1618
01:09:41,809 --> 01:09:39,719
everything yes

1619
01:09:43,490 --> 01:09:41,819
it's just completely a different way of

1620
01:09:45,289 --> 01:09:43,500
looking at the universe right I mean we

1621
01:09:47,269 --> 01:09:45,299
we started off

1622
01:09:51,470 --> 01:09:47,279
500 years ago with these optical

1623
01:09:53,209 --> 01:09:51,480
telescope and soon about just 70 years

1624
01:09:55,729 --> 01:09:53,219
ago or so we started doing these radio

1625
01:09:59,270 --> 01:09:55,739
observations and that opened up a new

1626
01:10:02,209 --> 01:09:59,280
era in astronomy and then now we have

1627
01:10:03,890 --> 01:10:02,219
these uh the we had x-ray telescopes we

1628
01:10:05,810 --> 01:10:03,900
had gamma ray telescopes and now we have

1629
01:10:07,669 --> 01:10:05,820
gravitational wave telescopes which is

1630
01:10:11,209 --> 01:10:07,679
just different in the way that it

1631
01:10:14,150 --> 01:10:11,219
operates right so obviously yes if the

1632
01:10:16,490 --> 01:10:14,160
if ligo results or rather ligo

1633
01:10:18,709 --> 01:10:16,500
operations had come out 20 years ago 30

1634
01:10:20,570 --> 01:10:18,719
years ago so my career could have been

1635
01:10:22,669 --> 01:10:20,580
different in the sense that I could have

1636
01:10:26,030 --> 01:10:22,679
been working on a completely different

1637
01:10:28,610 --> 01:10:26,040
kind of telescope right now uh and even

1638
01:10:30,050 --> 01:10:28,620

I mean if you look at it after the Lego

1639
01:10:33,649 --> 01:10:30,060
results have come out I mean we have

1640
01:10:36,290 --> 01:10:33,659
Virgo uh and ligo India as well which

1641
01:10:38,990 --> 01:10:36,300
which might come up at some point so the

1642
01:10:41,630 --> 01:10:39,000
resources are then distributed uh and

1643
01:10:44,510 --> 01:10:41,640
the job creation is or rather the the

1644
01:10:48,250 --> 01:10:44,520
priority is then to have more people

1645
01:10:50,330 --> 01:10:48,260
working on say ligo instead of say that

1646
01:10:51,950 --> 01:10:50,340
instead of say the other telescope and

1647
01:10:53,689 --> 01:10:51,960
so on and so forth but I would say at

1648
01:10:55,310 --> 01:10:53,699
this point what we are doing is that we

1649
01:10:57,350 --> 01:10:55,320
are balancing it out like there's a

1650
01:10:58,790 --> 01:10:57,360
group of people working on like a group

1651
01:10:59,930 --> 01:10:58,800
of people working on optical telescope

1652
01:11:01,970 --> 01:10:59,940
group of people working on space

1653
01:11:04,610 --> 01:11:01,980
telescopes and so on and so forth so

1654
01:11:06,890 --> 01:11:04,620
it's going to balance itself out uh say

1655
01:11:09,110 --> 01:11:06,900
in the next 20 30 years or so so in

1656
01:11:10,850 --> 01:11:09,120
short yes if like our result had come

1657
01:11:13,250 --> 01:11:10,860
out 20 30 years ago

1658
01:11:14,750 --> 01:11:13,260
there is a possibility that yes the

1659
01:11:15,950 --> 01:11:14,760
career parts of most of the astronomers

1660
01:11:17,110 --> 01:11:15,960
that we know of right now could have

1661
01:11:20,330 --> 01:11:17,120
been different

1662
01:11:22,490 --> 01:11:20,340
so a slight follow-on to that was that

1663
01:11:25,550 --> 01:11:22,500

you know I've only followed the Lego

1664
01:11:26,810 --> 01:11:25,560
results from afar and you know you

1665
01:11:28,430 --> 01:11:26,820
should you showed one of the plots about

1666
01:11:31,010 --> 01:11:28,440
all the different merger events they

1667
01:11:33,290 --> 01:11:31,020
have and I know that these runs are sort

1668
01:11:36,830 --> 01:11:33,300
of staged and things when do we think

1669
01:11:39,709 --> 01:11:36,840
we'll have enough statistics really to

1670
01:11:41,209 --> 01:11:39,719
gauge whether the expected merger rate

1671
01:11:42,830 --> 01:11:41,219
you know in order to build these

1672
01:11:46,610 --> 01:11:42,840
supermassive black holes there has to be

1673
01:11:47,810 --> 01:11:46,620
this merger rate of of of of of of black

1674
01:11:49,130 --> 01:11:47,820
holes

1675
01:11:51,229 --> 01:11:49,140
um with the expected merger rate whether

1676
01:11:53,090 --> 01:11:51,239
we what we measure actually fits with

1677
01:11:54,290 --> 01:11:53,100
the expected murder rate is that

1678
01:11:55,790 --> 01:11:54,300
something we're getting a handle on now

1679
01:11:57,590 --> 01:11:55,800
or is it going to take another decade or

1680
01:11:59,330 --> 01:11:57,600
two

1681
01:12:01,850 --> 01:11:59,340
I'm not sure if it will take another

1682
01:12:03,530 --> 01:12:01,860
decade or so but then right now yes we

1683
01:12:05,870 --> 01:12:03,540
are building up the statistics we are we

1684
01:12:07,610 --> 01:12:05,880
are right right on that curve there so

1685
01:12:09,950 --> 01:12:07,620
at some point over the next few years or

1686
01:12:11,810 --> 01:12:09,960
so we might be able to to say whether

1687
01:12:13,850 --> 01:12:11,820
it's within the expected merger rates or

1688
01:12:16,910 --> 01:12:13,860

so uh but then there's also the

1689
01:12:20,689 --> 01:12:16,920
challenge that uh these signals are so

1690
01:12:22,850 --> 01:12:20,699
weak that we are trying to isolate uh

1691
01:12:25,189 --> 01:12:22,860
those individual events within that

1692
01:12:27,470 --> 01:12:25,199
noise uh let's say the the noise that we

1693
01:12:29,990 --> 01:12:27,480
have uh so there's a possibility that

1694
01:12:34,250 --> 01:12:30,000
you know we we do have that data but

1695
01:12:37,130 --> 01:12:34,260
it's uh the the immense amount of effort

1696
01:12:40,669 --> 01:12:37,140
comes in to detect those signals to

1697
01:12:42,530 --> 01:12:40,679
isolate those uh so yeah uh overall I

1698
01:12:44,209 --> 01:12:42,540
would say that uh to to properly

1699
01:12:46,370 --> 01:12:44,219
characterize the amount of merger rates

1700
01:12:49,850 --> 01:12:46,380
and everything that we see could take a

1701
01:12:52,430 --> 01:12:49,860
few years still okay great

1702
01:12:53,930 --> 01:12:52,440
okay what else did you find Graham

1703
01:12:55,430 --> 01:12:53,940
sure

1704
01:12:58,430 --> 01:12:55,440
um with Tess

1705
01:12:59,810 --> 01:12:58,440
um Tess being a telescope for those in

1706
01:13:01,550 --> 01:12:59,820
the chat that don't already know Google

1707
01:13:03,770 --> 01:13:01,560
it it's awesome

1708
01:13:07,189 --> 01:13:03,780
um astronomers have observed a ring of

1709
01:13:09,110 --> 01:13:07,199
planetary nebula a planetary debris with

1710
01:13:13,930 --> 01:13:09,120
moon size structures in the habitable

1711
01:13:20,350 --> 01:13:16,189
wd-1054-226. how could they have

1712
01:13:28,370 --> 01:13:24,070
so it's that's an interesting question

1713
01:13:32,330 --> 01:13:28,380

uh and as a non-expert I can answer that

1714
01:13:34,490 --> 01:13:32,340
uh that it's possible that you're

1715
01:13:37,430 --> 01:13:34,500
looking at a planet which is say in the

1716
01:13:40,430 --> 01:13:37,440
outskirts or so so it's it's left

1717
01:13:43,090 --> 01:13:40,440
relatively unscathed uh during this

1718
01:13:46,490 --> 01:13:43,100
entire red red giant phase

1719
01:13:49,430 --> 01:13:46,500
uh so yeah that would be my guess uh to

1720
01:13:51,229 --> 01:13:49,440
that question that it's possible that uh

1721
01:13:54,410 --> 01:13:51,239
you're looking at a planet which is say

1722
01:13:56,149 --> 01:13:54,420
in the outskirts or so and that was that

1723
01:13:58,790 --> 01:13:56,159
was sort of protected uh well not even

1724
01:14:01,189 --> 01:13:58,800
if it's not protected uh it is survived

1725
01:14:03,229 --> 01:14:01,199
in its form

1726
01:14:05,090 --> 01:14:03,239
I just get the image of like random

1727
01:14:07,990 --> 01:14:05,100
fragmentation like it's all just chance

1728
01:14:13,189 --> 01:14:08,000
yeah further away the safer you can be

1729
01:14:15,709 --> 01:14:13,199
perhaps potentially yeah all right

1730
01:14:17,390 --> 01:14:15,719
um let me grab another one

1731
01:14:20,330 --> 01:14:17,400
uh I have one

1732
01:14:22,790 --> 01:14:20,340
go ahead so you were talking about the

1733
01:14:24,770 --> 01:14:22,800
black hole wind and be having an effect

1734
01:14:27,830 --> 01:14:24,780
on the Galaxy itself

1735
01:14:29,930 --> 01:14:27,840
um I was it just occurred to me when I

1736
01:14:31,669 --> 01:14:29,940
was watching that going to myself all

1737
01:14:33,590 --> 01:14:31,679
right so the we have a Stellar Wind and

1738
01:14:35,689 --> 01:14:33,600

that you know can create a little bit of

1739
01:14:37,430 --> 01:14:35,699
things and only during like the tea Tory

1740
01:14:39,770 --> 01:14:37,440
phases that wind's strong enough to

1741
01:14:43,070 --> 01:14:39,780
actually push gas out of the solar

1742
01:14:44,689 --> 01:14:43,080
system right so is this black hole wind

1743
01:14:53,350 --> 01:14:44,699
that

1744
01:14:55,790 --> 01:14:53,360
affect on a galactic wide scale

1745
01:14:56,930 --> 01:14:55,800
material in terms of this the first

1746
01:14:59,270 --> 01:14:56,940
pressure

1747
01:15:01,729 --> 01:14:59,280
yes I mean compared to the Stellar winds

1748
01:15:03,830 --> 01:15:01,739
I think the black hole winds are immense

1749
01:15:05,450 --> 01:15:03,840
I mean you're looking at two thousand

1750
01:15:08,930 --> 01:15:05,460
three even three thousand kilometers per

1751
01:15:12,169 --> 01:15:08,940
second sometimes uh especially at the

1752
01:15:14,209 --> 01:15:12,179
time in the universe uh when uh the

1753
01:15:17,510 --> 01:15:14,219
black hole growth rate and the star

1754
01:15:19,310 --> 01:15:17,520
formation rate was really maximum so yes

1755
01:15:22,430 --> 01:15:19,320
it is possible for these black hole

1756
01:15:25,430 --> 01:15:22,440
winds to clear to to you know affect the

1757
01:15:27,590 --> 01:15:25,440
outskirts of the Galaxy and not just you

1758
01:15:29,450 --> 01:15:27,600
know at the basically or not just at the

1759
01:15:32,870 --> 01:15:29,460
vicinity of black holes

1760
01:15:34,669 --> 01:15:32,880
yeah and does that act as some sort of a

1761
01:15:36,830 --> 01:15:34,679
limiter in terms of like if your black

1762
01:15:38,689 --> 01:15:36,840
hole gets this big it's going to blow

1763
01:15:40,490 --> 01:15:38,699

out everything in in the galaxy and your

1764
01:15:42,950 --> 01:15:40,500
Galaxy can't get any bigger that's

1765
01:15:45,169 --> 01:15:42,960
that's exactly the limiting effect yes

1766
01:15:46,729 --> 01:15:45,179
that's the limiting effect not just for

1767
01:15:47,930 --> 01:15:46,739
the Galaxy but for the black hole itself

1768
01:15:49,370 --> 01:15:47,940
because if the black hole is just

1769
01:15:51,410 --> 01:15:49,380
removing all the gas

1770
01:15:53,330 --> 01:15:51,420
it's not getting anything for itself as

1771
01:15:54,709 --> 01:15:53,340
well so you know it's a it's a lose-lose

1772
01:15:57,290 --> 01:15:54,719
situation both for the Galaxy and the

1773
01:16:00,110 --> 01:15:57,300
black hole but then hey that's how we

1774
01:16:02,870 --> 01:16:00,120
have maintained this sort of a balance

1775
01:16:08,510 --> 01:16:02,880
uh uh so to speak

1776
01:16:12,590 --> 01:16:10,790
all right what else we have Grant

1777
01:16:13,250 --> 01:16:12,600
sure

1778
01:16:15,709 --> 01:16:13,260
um

1779
01:16:19,550 --> 01:16:15,719
a little bit broader question

1780
01:16:21,350 --> 01:16:19,560
um when you refer to center of Galaxy in

1781
01:16:23,510 --> 01:16:21,360
relation to other things are you talking

1782
01:16:26,930 --> 01:16:23,520
about Center of Mass center of visible

1783
01:16:30,649 --> 01:16:26,940
visible mass or matter Center of motion

1784
01:16:35,149 --> 01:16:30,659
what does that refer to specifically

1785
01:16:36,709 --> 01:16:35,159
I would say is the center like the

1786
01:16:38,149 --> 01:16:36,719
physical Center in the sense like when

1787
01:16:40,729 --> 01:16:38,159
you look at the morphology of a galaxy

1788
01:16:44,510 --> 01:16:40,739

and I'm only talking about these nice

1789
01:16:46,370 --> 01:16:44,520
spiral looking Galaxy right uh so uh

1790
01:16:47,810 --> 01:16:46,380
yeah that's like the physical center of

1791
01:16:49,430 --> 01:16:47,820
the Galaxy which could I mean which

1792
01:16:51,950 --> 01:16:49,440
could be very similar to the center of

1793
01:16:54,050 --> 01:16:51,960
Mars as well uh if you ask me because I

1794
01:16:56,330 --> 01:16:54,060
think at the end of the day the the

1795
01:16:59,630 --> 01:16:56,340
actual morphological Center the center

1796
01:17:02,630 --> 01:16:59,640
of Mars uh they would newly coincide at

1797
01:17:04,550 --> 01:17:02,640
that same spot almost over there unless

1798
01:17:07,070 --> 01:17:04,560
you're looking at say an irregular

1799
01:17:09,229 --> 01:17:07,080
galaxy in which even I would not be able

1800
01:17:12,470 --> 01:17:09,239
to tell you what exactly the center of

1801
01:17:15,649 --> 01:17:12,480
that Galaxy until we make some dynamical

1802
01:17:19,310 --> 01:17:15,659
or kinematical analysis uh of the gas

1803
01:17:20,810 --> 01:17:19,320
around that Galaxy right so uh yeah I

1804
01:17:22,669 --> 01:17:20,820
would say that whether you're talking

1805
01:17:23,930 --> 01:17:22,679
about the uh like the galaxies that I

1806
01:17:25,910 --> 01:17:23,940
was showing uh whether you're talking

1807
01:17:27,950 --> 01:17:25,920
about morphological Center or the

1808
01:17:30,229 --> 01:17:27,960
Central Mass or so on and so forth they

1809
01:17:32,750 --> 01:17:30,239
would nearly nearly coincide with each

1810
01:17:37,189 --> 01:17:35,390
gotcha that makes more sense yeah and

1811
01:17:39,530 --> 01:17:37,199
just to for our our viewers remember

1812
01:17:41,149 --> 01:17:39,540
that the when you talk about Center of

1813
01:17:44,390 --> 01:17:41,159

mass it's not just the visible light

1814
01:17:46,010 --> 01:17:44,400
it's also the dark matter in the Galaxy

1815
01:17:48,590 --> 01:17:46,020
um and because the Dark Matter

1816
01:17:50,930 --> 01:17:48,600
determines the gravity that determines

1817
01:17:53,510 --> 01:17:50,940
the Motions the center of mass and the

1818
01:17:55,189 --> 01:17:53,520
center of motion uh as our as our uh

1819
01:17:56,990 --> 01:17:55,199
questioner put it really are going to

1820
01:18:02,330 --> 01:17:57,000
have to be the same thing okay because

1821
01:18:06,110 --> 01:18:04,430
gotcha and as you can see from the

1822
01:18:08,450 --> 01:18:06,120
questions we're on both sides of the

1823
01:18:10,490 --> 01:18:08,460
spectrum from understanding which I love

1824
01:18:13,070 --> 01:18:10,500
about this so bringing it back to

1825
01:18:15,890 --> 01:18:13,080
another general question what is it

1826
01:18:20,209 --> 01:18:15,900
about black holes that makes it so hard

1827
01:18:21,830 --> 01:18:20,219
to study photograph or capture data

1828
01:18:22,850 --> 01:18:21,840
oh I'm sorry can you repeat that

1829
01:18:24,770 --> 01:18:22,860
question

1830
01:18:27,169 --> 01:18:24,780
what is it about black holes that makes

1831
01:18:30,229 --> 01:18:27,179
it so hard to study them why can't we

1832
01:18:33,110 --> 01:18:30,239
see images or why was it such country

1833
01:18:34,729 --> 01:18:33,120
what like worldwide news when we had

1834
01:18:36,050 --> 01:18:34,739
captured an image or as close as we got

1835
01:18:37,610 --> 01:18:36,060
of a black hole right what is it about

1836
01:18:38,750 --> 01:18:37,620
them that makes them so difficult to

1837
01:18:41,169 --> 01:18:38,760
study

1838
01:18:44,510 --> 01:18:41,179

so uh

1839
01:18:47,870 --> 01:18:44,520
is a black hole right I mean so there's

1840
01:18:51,110 --> 01:18:47,880
no light coming out of it uh so for

1841
01:18:53,870 --> 01:18:51,120
example so for example like if if I'm

1842
01:18:55,729 --> 01:18:53,880
looking at uh I mean myself for example

1843
01:18:57,950 --> 01:18:55,739
the reason that you're able to see me is

1844
01:19:00,050 --> 01:18:57,960
that there is light coming out of this

1845
01:19:02,090 --> 01:19:00,060
this bulb here it hits against my skin

1846
01:19:04,070 --> 01:19:02,100
and then it reflects off onto the camera

1847
01:19:07,149 --> 01:19:04,080
that's why you're able to see me now

1848
01:19:11,209 --> 01:19:07,159
what if I switch off the slide right now

1849
01:19:13,130 --> 01:19:11,219
uh then obviously like it reduces and if

1850
01:19:15,530 --> 01:19:13,140
I switch off the other light as well

1851
01:19:18,050 --> 01:19:15,540
obviously like I'll get darker and so on

1852
01:19:20,570 --> 01:19:18,060
and so forth so in order to capture

1853
01:19:23,030 --> 01:19:20,580
an image you need the light coming out

1854
01:19:24,530 --> 01:19:23,040
of that object and in a black hole if

1855
01:19:27,290 --> 01:19:24,540
the light itself is not able to escape

1856
01:19:28,430 --> 01:19:27,300
the gravitation potential then what are

1857
01:19:31,370 --> 01:19:28,440
we going to capture we are basically

1858
01:19:34,490 --> 01:19:31,380
going to capture something which is dark

1859
01:19:36,709 --> 01:19:34,500
so that's why it has been difficult to

1860
01:19:38,750 --> 01:19:36,719
detect black holes because there is no

1861
01:19:40,370 --> 01:19:38,760
light coming out of them and even if

1862
01:19:42,530 --> 01:19:40,380
there is light coming out of them that's

1863
01:19:44,510 --> 01:19:42,540

from these accretion disks and we have

1864
01:19:47,810 --> 01:19:44,520
to wait for the appropriate opportunity

1865
01:19:50,510 --> 01:19:47,820
when that accretion disk forms and that

1866
01:19:52,550 --> 01:19:50,520
emanates light or when when a star is

1867
01:19:55,010 --> 01:19:52,560
ripped apart basically we need to wait

1868
01:19:57,709 --> 01:19:55,020
for those kind of moments or you make

1869
01:19:59,149 --> 01:19:57,719
these observations for 10 15 years and

1870
01:20:00,890 --> 01:19:59,159
then you see how the stars are on the

1871
01:20:04,550 --> 01:20:00,900
are on the center of the Milky Way move

1872
01:20:06,770 --> 01:20:04,560
so yeah I mean uh definitely it's a it's

1873
01:20:09,130 --> 01:20:06,780
a hard job because of that

1874
01:20:13,010 --> 01:20:09,140
kind of like a

1875
01:20:15,649 --> 01:20:13,020
the what they use for exoplanets where

1876
01:20:18,950 --> 01:20:15,659
the the transit happens but the opposite

1877
01:20:22,189 --> 01:20:18,960
instead of blocking the light it's

1878
01:20:25,450 --> 01:20:22,199
it's diverting the light so it's the

1879
01:20:28,070 --> 01:20:25,460
opposite effect on study I would imagine

1880
01:20:30,050 --> 01:20:28,080
because one is the absence of light or

1881
01:20:31,790 --> 01:20:30,060
the other is the

1882
01:20:34,550 --> 01:20:31,800
the brightness and we're seeing words

1883
01:20:35,930 --> 01:20:34,560
yeah I mean it's great you're great I

1884
01:20:38,090 --> 01:20:35,940
think you've got an analogy there in

1885
01:20:40,070 --> 01:20:38,100
terms of the exoplanet the transiting

1886
01:20:42,470 --> 01:20:40,080
exoplanet versus like micro lensing

1887
01:20:44,149 --> 01:20:42,480
right the words aren't there but I'm

1888
01:20:46,010 --> 01:20:44,159

trying yeah yeah no but I'm saying

1889
01:20:47,630 --> 01:20:46,020
microlensing the black hole passes in

1890
01:20:51,169 --> 01:20:47,640
front of a star and it amplifies the

1891
01:20:54,770 --> 01:20:51,179
star it changes the the star of due to

1892
01:20:56,990 --> 01:20:54,780
lensing and such so that that that's

1893
01:20:59,870 --> 01:20:57,000
an analogy I hadn't used before but I

1894
01:21:02,149 --> 01:20:59,880
think that that might work all right so

1895
01:21:05,270 --> 01:21:02,159
I want to actually question another

1896
01:21:07,790 --> 01:21:05,280
thing that I don't know is the um census

1897
01:21:10,370 --> 01:21:07,800
of intermediate Mass black holes because

1898
01:21:13,729 --> 01:21:10,380
I remember when we first announced um

1899
01:21:15,890 --> 01:21:13,739
you know a decade or so ago uh the

1900
01:21:17,209 --> 01:21:15,900
detection of intermediate Mass black

1901
01:21:20,930 --> 01:21:17,219
holes

1902
01:21:22,850 --> 01:21:20,940
um so like the merger rates do we have a

1903
01:21:24,770 --> 01:21:22,860
good census of how many intermediate

1904
01:21:27,410 --> 01:21:24,780
Mass black holes there are because I

1905
01:21:29,030 --> 01:21:27,420
don't hear many discoveries of these

1906
01:21:32,090 --> 01:21:29,040
intermediate Mass spectacles I still

1907
01:21:34,430 --> 01:21:32,100
feel like that's a big unknown in our

1908
01:21:36,050 --> 01:21:34,440
knowledge correct that's correct I mean

1909
01:21:37,970 --> 01:21:36,060
we know about supermassive black holes

1910
01:21:39,110 --> 01:21:37,980
we have just started detecting Stellar

1911
01:21:40,490 --> 01:21:39,120
Mass black holes as well using

1912
01:21:42,830 --> 01:21:40,500
gravitational waves and so on and so

1913
01:21:45,050 --> 01:21:42,840

forth but intermediate Mars black holes

1914
01:21:47,090 --> 01:21:45,060
as this big unknown I mean for example

1915
01:21:49,729 --> 01:21:47,100
detecting say a thousand times the mass

1916
01:21:50,870 --> 01:21:49,739
of the song uh like yeah do you think of

1917
01:21:52,669 --> 01:21:50,880
black hole with thousand times the mass

1918
01:21:55,430 --> 01:21:52,679
of the Sun that's something that has not

1919
01:21:57,770 --> 01:21:55,440
happened for example uh or even if that

1920
01:22:00,709 --> 01:21:57,780
has I mean uh so that's something we are

1921
01:22:03,649 --> 01:22:00,719
not able to detect right now uh and so

1922
01:22:05,450 --> 01:22:03,659
one of the so the gravitational waves

1923
01:22:06,709 --> 01:22:05,460
could be one of the ways to detect

1924
01:22:08,990 --> 01:22:06,719
intermediate Mouse black holes

1925
01:22:10,330 --> 01:22:09,000
especially if you have 200 300 solar

1926
01:22:13,370 --> 01:22:10,340
masses or so on

1927
01:22:15,050 --> 01:22:13,380
uh but then other ways is actually what

1928
01:22:16,490 --> 01:22:15,060
we did with the center of the Milky Way

1929
01:22:20,209 --> 01:22:16,500
That We

1930
01:22:22,790 --> 01:22:20,219
track the Stars motion uh every few

1931
01:22:26,030 --> 01:22:22,800
months or every few years or so and then

1932
01:22:28,430 --> 01:22:26,040
we see how they move around and uh for

1933
01:22:30,169 --> 01:22:28,440
globular clusters for example if you do

1934
01:22:33,890 --> 01:22:30,179
the same thing you can look at you know

1935
01:22:36,470 --> 01:22:33,900
the the way the dynamic works uh

1936
01:22:39,110 --> 01:22:36,480
so that's the way of detecting them but

1937
01:22:42,050 --> 01:22:39,120
then the senses wise yeah it's it's a

1938
01:22:44,810 --> 01:22:42,060

big unknown there we don't know when we

1939
01:22:48,110 --> 01:22:44,820
will be able to detect uh intermediate

1940
01:22:51,110 --> 01:22:48,120
my almost black holes in large numbers

1941
01:22:53,149 --> 01:22:51,120
all right great all right grant uh do we

1942
01:22:55,910 --> 01:22:53,159
have like one more question

1943
01:22:57,470 --> 01:22:55,920
um yeah yeah I've got a couple more if

1944
01:22:58,669 --> 01:22:57,480
we've got time but I might I think we

1945
01:23:01,130 --> 01:22:58,679
have time for two more

1946
01:23:04,610 --> 01:23:01,140
okay two more sounds good

1947
01:23:08,390 --> 01:23:04,620
um What In your experience has been the

1948
01:23:10,729 --> 01:23:08,400
spread of sizes of black holes like what

1949
01:23:12,169 --> 01:23:10,739
is the smallest what is the largest what

1950
01:23:14,330 --> 01:23:12,179
notable ones have you seen that you

1951
01:23:15,950 --> 01:23:14,340
would like to discuss there's always

1952
01:23:18,590 --> 01:23:15,960
something that jumps out in the data to

1953
01:23:21,649 --> 01:23:18,600
people yeah so I think like the smallest

1954
01:23:24,110 --> 01:23:21,659
black holes that we've seen uh like uh

1955
01:23:26,750 --> 01:23:24,120
at least detected uh so far was with the

1956
01:23:28,070 --> 01:23:26,760
gravitational waves like you know 1.52

1957
01:23:30,709 --> 01:23:28,080
syllable months or something like that

1958
01:23:33,770 --> 01:23:30,719
uh the heaviest that we have seen is in

1959
01:23:37,790 --> 01:23:33,780
the early Universe uh where we have

1960
01:23:40,430 --> 01:23:37,800
detected uh up to say 10 billion solar

1961
01:23:42,350 --> 01:23:40,440
masses or so so that's the rough range

1962
01:23:44,390 --> 01:23:42,360
that we are looking at all the way down

1963
01:23:48,470 --> 01:23:44,400

from like two solar masses

1964
01:23:49,850 --> 01:23:48,480
uh to about 10 billion or so but I do

1965
01:23:52,790 --> 01:23:49,860
believe that there are there could be

1966
01:23:56,390 --> 01:23:52,800
even smaller black holes uh than than

1967
01:23:58,850 --> 01:23:56,400
what you've detected so far uh or maybe

1968
01:24:00,590 --> 01:23:58,860
heavier ones as well uh but then yeah

1969
01:24:05,030 --> 01:24:00,600
that's that's the limit that we have had

1970
01:24:08,930 --> 01:24:07,729
and on these Stellar Mass black hole

1971
01:24:11,570 --> 01:24:08,940
scale

1972
01:24:13,610 --> 01:24:11,580
um we've detected a couple hundred solar

1973
01:24:16,490 --> 01:24:13,620
masses I know we've checked 150 Solar

1974
01:24:18,950 --> 01:24:16,500
masses with ligo and Virgo and such how

1975
01:24:21,050 --> 01:24:18,960
how how how large have we detected

1976
01:24:22,430 --> 01:24:21,060
on the solar the Stellar Mass black hole

1977
01:24:26,090 --> 01:24:22,440
scale

1978
01:24:28,729 --> 01:24:26,100
so I think it's up to just below 200 I

1979
01:24:32,570 --> 01:24:28,739
think okay and was this expected to get

1980
01:24:34,669 --> 01:24:32,580
200 solar mass black holes because I'm

1981
01:24:36,350 --> 01:24:34,679
not an expert I I I sort of hadn't

1982
01:24:39,649 --> 01:24:36,360
expected that large

1983
01:24:41,689 --> 01:24:39,659
uh yeah I I mean uh again not working on

1984
01:24:48,890 --> 01:24:41,699
ligo but I would say that this could

1985
01:24:52,970 --> 01:24:51,649
okay next question

1986
01:24:56,930 --> 01:24:52,980
sure

1987
01:24:57,490 --> 01:24:56,940
um and we'll we'll finish up on this one

1988
01:24:59,689 --> 01:24:57,500

um

1989
01:25:01,729 --> 01:24:59,699
I like this

1990
01:25:05,750 --> 01:25:01,739
um which came first the star of the

1991
01:25:11,810 --> 01:25:10,250
uh uh I would like to say Stars so you

1992
01:25:15,590 --> 01:25:11,820
know I mean we always had the gas right

1993
01:25:18,350 --> 01:25:15,600
I mean uh after the gas came the Stars

1994
01:25:20,750 --> 01:25:18,360
stars of the stars came probably black

1995
01:25:23,030 --> 01:25:20,760
holes or galaxies so yeah I think I

1996
01:25:25,790 --> 01:25:23,040
would I would I would follow that

1997
01:25:28,550 --> 01:25:25,800
succession there okay all right so so

1998
01:25:31,370 --> 01:25:28,560
this is corollary to that is how quickly

1999
01:25:33,410 --> 01:25:31,380
does the supermassive black hole form as

2000
01:25:35,270 --> 01:25:33,420
a Galaxy forms

2001
01:25:38,750 --> 01:25:35,280
um if we looked in the early universe

2002
01:25:41,209 --> 01:25:38,760
and we saw you know a a billion solar

2003
01:25:42,950 --> 01:25:41,219
mass Galaxy right would it have the

2004
01:25:45,649 --> 01:25:42,960
proportional supermassive black hole

2005
01:25:49,669 --> 01:25:45,659
even early on or is that going to take

2006
01:25:51,470 --> 01:25:49,679
longer how do they grow

2007
01:25:53,689 --> 01:25:51,480
um at the same same rate the galaxies

2008
01:25:56,209 --> 01:25:53,699
grow so that's interesting because like

2009
01:25:58,490 --> 01:25:56,219
I think uh

2010
01:26:00,050 --> 01:25:58,500
right now we are already debating like

2011
01:26:03,770 --> 01:26:00,060
when the first galaxies and stars came

2012
01:26:05,689 --> 01:26:03,780
in and so how early on the black holes

2013
01:26:08,209 --> 01:26:05,699

or rather supermaster black holes came

2014
01:26:10,850 --> 01:26:08,219
in is is yes it's it's a question right

2015
01:26:13,189 --> 01:26:10,860
now which uh I don't think we have we

2016
01:26:15,530 --> 01:26:13,199
have an answer to uh but then I think

2017
01:26:17,330 --> 01:26:15,540
with the web as well we are starting to

2018
01:26:20,390 --> 01:26:17,340
challenge when the first Galaxy started

2019
01:26:22,550 --> 01:26:20,400
coming in uh with the theory so I think

2020
01:26:25,910 --> 01:26:22,560
that's going to be quite interesting

2021
01:26:27,830 --> 01:26:25,920
uh we very recently have the tools to do

2022
01:26:30,530 --> 01:26:27,840
something about this exactly and then

2023
01:26:32,750 --> 01:26:30,540
over the next years or so we're going to

2024
01:26:34,430 --> 01:26:32,760
keep getting tools to push the

2025
01:26:37,070 --> 01:26:34,440
boundaries there

2026
01:26:40,070 --> 01:26:37,080
all right I think a look to the future

2027
01:26:41,689 --> 01:26:40,080
is always a good place to stop uh thank

2028
01:26:45,290 --> 01:26:41,699
you very much for all this wonderful

2029
01:26:47,149 --> 01:26:45,300
discussion and um next month on March

2030
01:26:49,669 --> 01:26:47,159
7th we will have Travis Fisher

2031
01:26:53,450 --> 01:26:49,679
presenting his take on active galaxies