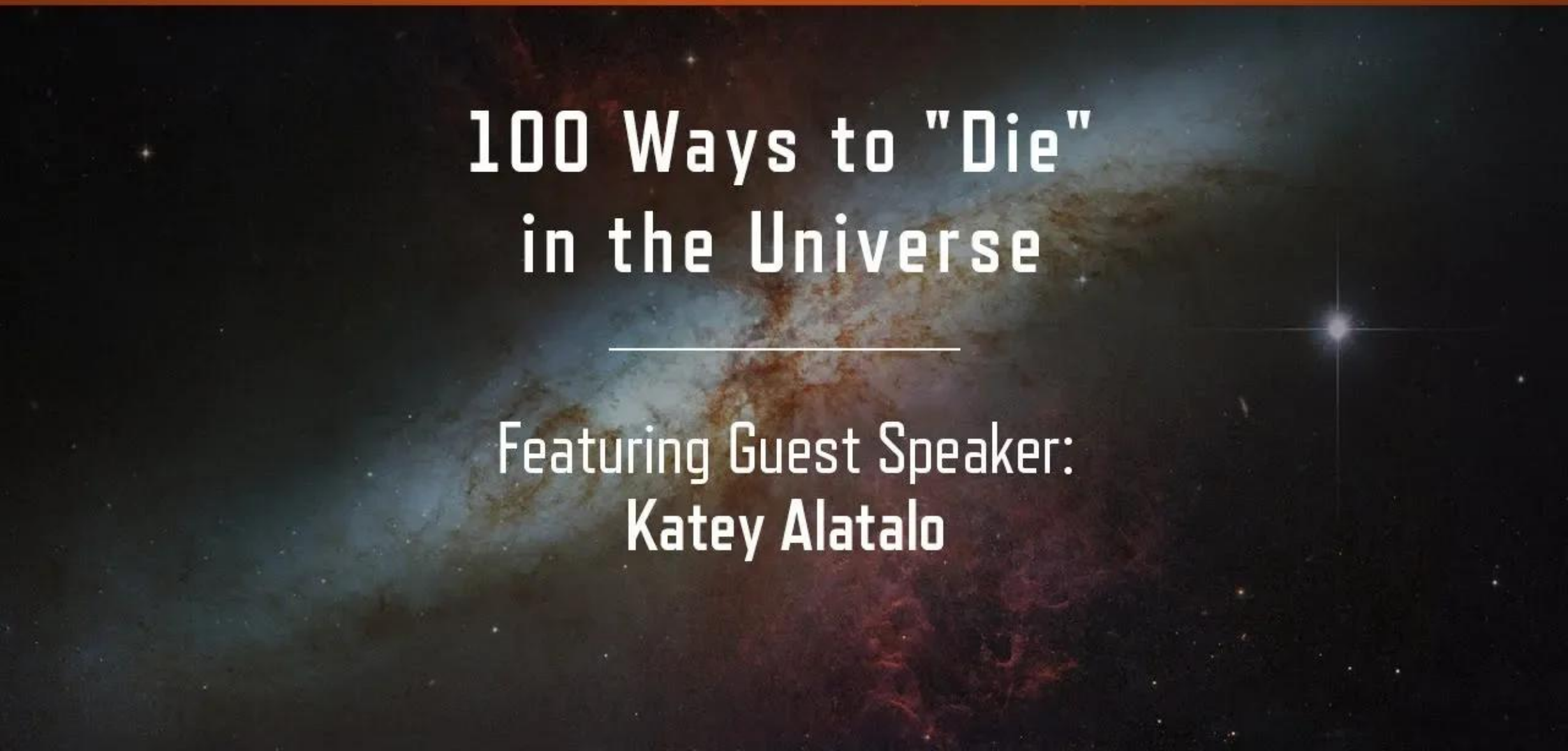
PUBLIC LECTURE SERIES



100 Ways to "Die" in the Universe

Featuring Guest Speaker:
Katey Alatalo

1
00:00:04,460 --> 00:00:02,090
and and welcome to the Space Telescope

2
00:00:06,769 --> 00:00:04,470
Science Institute public lecture series

3
00:00:09,110 --> 00:00:06,779
it is my pleasure to be your host

4
00:00:12,140 --> 00:00:09,120
I am dr. Frank summers of the office of

5
00:00:14,180 --> 00:00:12,150
public outreach as you come in as these

6
00:00:17,000 --> 00:00:14,190
gentlemen just are right now there are

7
00:00:19,370 --> 00:00:17,010
lithographs on the table that you can

8
00:00:24,019 --> 00:00:19,380
grab and take home tonight's lithograph

9
00:00:25,730 --> 00:00:24,029
is of interacting galaxies ARP 273 our

10
00:00:26,900 --> 00:00:25,740
speaker will be talking on the

11
00:00:29,660 --> 00:00:26,910
development of galaxies in the universe

12
00:00:31,250 --> 00:00:29,670
and this is a very interesting pair if

13
00:00:33,350 --> 00:00:31,260

you would like to know more about it

14
00:00:35,630 --> 00:00:33,360
turn over on the back and we have a few

15
00:00:38,810 --> 00:00:35,640
paragraphs telling you about the state

16
00:00:43,700 --> 00:00:38,820
of ARP 273 and where you can go to get

17
00:00:47,779 --> 00:00:43,710
more information our speaker tonight kvl

18
00:00:51,200 --> 00:00:47,789
Italo is talking about 100 ways to die

19
00:00:54,430 --> 00:00:51,210
in the universe okay she promises death

20
00:00:56,360 --> 00:00:54,440
and destruction here tonight okay

21
00:00:58,630 --> 00:00:56,370
astronomy usually doesn't have that much

22
00:01:00,139 --> 00:00:58,640
action but we're gonna have it tonight

23
00:01:02,810 --> 00:01:00,149
next month

24
00:01:05,719 --> 00:01:02,820
chasing supernovae with Kepler the

25
00:01:08,929 --> 00:01:05,729
Kepler satellite was out there to find

26
00:01:11,020 --> 00:01:08,939
planets but you can also use it because

27
00:01:13,880 --> 00:01:11,030
it can monitor the brightnesses of stars

28
00:01:16,820 --> 00:01:13,890
extremely carefully you can also use it

29
00:01:18,710 --> 00:01:16,830
to find supernovae and Gotham Narayan

30
00:01:23,270 --> 00:01:18,720
will be telling us about that on October

31
00:01:25,670 --> 00:01:23,280
2nd November and because Election Day is

32
00:01:28,940 --> 00:01:25,680
the first Tuesday we will be skipping to

33
00:01:31,429 --> 00:01:28,950
the second Tuesday November 13th and

34
00:01:35,149 --> 00:01:31,439
we'll talk about exoplanet atmospheres G

35
00:01:37,280 --> 00:01:35,159
Giovanni Bruno now I got an email last

36
00:01:41,090 --> 00:01:37,290
week saying he might not be able to make

37
00:01:43,670 --> 00:01:41,100
that so this is gonna become a TBD

38
00:01:46,580 --> 00:01:43,680

probably next week as soon as I get in

39
00:01:48,679 --> 00:01:46,590
contact with him again so I guess some

40
00:01:50,990 --> 00:01:48,689
work to do as you can tell because

41
00:01:54,830 --> 00:01:51,000
December is listed as some intriguing

42
00:01:57,020 --> 00:01:54,840
topic by some amazing speaker so it's

43
00:01:58,160 --> 00:01:57,030
difficult to get astronomers to commit

44
00:02:00,380 --> 00:01:58,170
over the summer so I wait until

45
00:02:02,179 --> 00:02:00,390
September to get them to commit and so

46
00:02:04,999 --> 00:02:02,189
yes I'll be sending that email out this

47
00:02:07,639 --> 00:02:05,009
this week are next okay don't worry I

48
00:02:09,380 --> 00:02:07,649
always fill up the schedule alright and

49
00:02:11,180 --> 00:02:09,390
you want to find out what these speakers

50
00:02:13,040 --> 00:02:11,190
are when I do fill up that schedule you

51
00:02:13,880 --> 00:02:13,050
go to our website go to your favorite

52
00:02:16,040 --> 00:02:13,890
search engine

53
00:02:20,060 --> 00:02:16,050
typing Hubble public talks you'll find

54
00:02:22,670 --> 00:02:20,070
us or we have this go cuddle site or go

55
00:02:25,580 --> 00:02:22,680
Toxteth to find us we have our list of

56
00:02:27,920 --> 00:02:25,590
the upcoming lectures we have the links

57
00:02:31,630 --> 00:02:27,930
to the live webcasting and YouTube

58
00:02:34,780 --> 00:02:31,640
events we also have our archives back to

59
00:02:39,050 --> 00:02:34,790
2014 on YouTube and all the way back to

60
00:02:41,420 --> 00:02:39,060
2005 in the webcast archive so our guys

61
00:02:44,480 --> 00:02:41,430
in the pack have been doing this for

62
00:02:46,699 --> 00:02:44,490
what is this now 13 years all right this

63
00:02:53,900 --> 00:02:46,709

is amazing stuff yeah yeah my hat my hat

64
00:02:56,870 --> 00:02:53,910
they deserve it so on our website you

65
00:02:58,640 --> 00:02:56,880
can sign up for our email list which is

66
00:03:00,620 --> 00:02:58,650
basically just reminders of the talks

67
00:03:04,310 --> 00:03:00,630
and telling you when the webcasts are

68
00:03:05,870 --> 00:03:04,320
posted on YouTube okay so yeah that's

69
00:03:08,330 --> 00:03:05,880
the announcements sign up the website if

70
00:03:10,220 --> 00:03:08,340
you don't like signing up on the website

71
00:03:11,750 --> 00:03:10,230
you can always just write your email

72
00:03:14,000 --> 00:03:11,760
address on a piece of paper and hand it

73
00:03:16,100 --> 00:03:14,010
to me at the end of the lecture if you

74
00:03:19,550 --> 00:03:16,110
have comments or questions we have an

75
00:03:22,970 --> 00:03:19,560
email set up public lecture at stsci edu

76
00:03:24,740 --> 00:03:22,980
and you can sent use that our social

77
00:03:26,680 --> 00:03:24,750
media for those who do it we've got

78
00:03:29,300 --> 00:03:26,690
Facebook Twitter YouTube and Instagram

79
00:03:32,090 --> 00:03:29,310
not just for the Hubble telescope not

80
00:03:34,670 --> 00:03:32,100
just for the Webb telescope also for the

81
00:03:36,890 --> 00:03:34,680
Space Telescope Science Institute so

82
00:03:39,500 --> 00:03:36,900
we've got three different brands that we

83
00:03:41,300 --> 00:03:39,510
are marketing here and we get it we

84
00:03:42,740 --> 00:03:41,310
actually you know these the folks who do

85
00:03:45,320 --> 00:03:42,750
this do a really good job of getting it

86
00:03:48,289 --> 00:03:45,330
an interesting mix of things across the

87
00:03:50,240 --> 00:03:48,299
various channels I do not however do an

88
00:03:53,590 --> 00:03:50,250

interesting mix of things I rarely post

89
00:03:55,670 --> 00:03:53,600
online something I should do more of but

90
00:03:57,650 --> 00:03:55,680
frankly there's just too much cool

91
00:04:00,530 --> 00:03:57,660
things to do to spend all my time on

92
00:04:03,860 --> 00:04:00,540
social media so you can follow me but I

93
00:04:07,250 --> 00:04:03,870
will not be I will not not be on there

94
00:04:09,830 --> 00:04:07,260
all the time the weather is finally

95
00:04:12,289 --> 00:04:09,840
permitting I got the email from araignee

96
00:04:15,020 --> 00:04:12,299
today and yes the observatory will be

97
00:04:17,719 --> 00:04:15,030
open after the lecture okay so the

98
00:04:20,030 --> 00:04:17,729
Maryland Space Grant Observatory arena

99
00:04:21,349 --> 00:04:20,040
will come here toward the end of the

100
00:04:24,320 --> 00:04:21,359
lecture she's probably watching this on

101
00:04:26,930 --> 00:04:24,330
YouTube right now when the questions

102
00:04:27,300 --> 00:04:26,940
start at Starcom and if you would like

103
00:04:29,250 --> 00:04:27,310
to go

104
00:04:31,830 --> 00:04:29,260
to the telescope to look through the

105
00:04:34,350 --> 00:04:31,840
telescope tonight it may be warm but

106
00:04:38,129 --> 00:04:34,360
we'll meet down here in the front at the

107
00:04:41,060 --> 00:04:38,139
end of the lecture okay alright and now

108
00:04:42,860 --> 00:04:41,070
the news from the universe for September

109
00:04:47,060 --> 00:04:42,870
2018

110
00:04:50,700 --> 00:04:47,070
our first story tonight ultra large

111
00:04:54,450 --> 00:04:50,710
ultra deep ultraviolet

112
00:04:56,220 --> 00:04:54,460
yes Hubble is going altra here now what

113
00:04:58,770 --> 00:04:56,230

am I talking about I'm actually talking

114
00:05:02,210 --> 00:04:58,780
about the legacy of Hubble's deep fields

115
00:05:05,490 --> 00:05:02,220
and the first deep field was released in

116
00:05:07,680 --> 00:05:05,500
1996 this was done with wide field

117
00:05:11,990 --> 00:05:07,690
planetary camera 2 hence it has the

118
00:05:15,960 --> 00:05:12,000
chevron shape to it and it was a

119
00:05:18,180 --> 00:05:15,970
magnificent step in cosmology because we

120
00:05:19,530 --> 00:05:18,190
really didn't know what we would see

121
00:05:22,950 --> 00:05:19,540
when we looked at the universe this

122
00:05:25,650 --> 00:05:22,960
deeply when we use Hubble to expose for

123
00:05:27,510 --> 00:05:25,660
a week's worth of exposure time there

124
00:05:29,400 --> 00:05:27,520
were arguments amongst the cosmologists

125
00:05:31,620 --> 00:05:29,410
as whether this is a total waste of

126
00:05:34,050 --> 00:05:31,630
Hubble or hey we're gonna find out

127
00:05:35,969 --> 00:05:34,060
something really cool fortunately is the

128
00:05:38,700 --> 00:05:35,979
second one we did find out something

129
00:05:43,170 --> 00:05:38,710
really cool we found 3,000 galaxies in a

130
00:05:45,000 --> 00:05:43,180
tiny tiny tiny patch of sky and so what

131
00:05:46,920 --> 00:05:45,010
these art we're seeing galaxies all the

132
00:05:48,779 --> 00:05:46,930
way across the universe compressed into

133
00:05:50,700 --> 00:05:48,789
a single image we're seeing galaxies

134
00:05:53,040 --> 00:05:50,710
deeper and further into the universe

135
00:05:54,719 --> 00:05:53,050
than we had ever seen before so of

136
00:05:58,290 --> 00:05:54,729
course when we got a new instrument in

137
00:06:01,050 --> 00:05:58,300
2004 the advanced camera for surveys we

138
00:06:02,940 --> 00:06:01,060

started doing some surveys and one of

139
00:06:06,540 --> 00:06:02,950
the surveys we did in 2000 and I'm sorry

140
00:06:09,770 --> 00:06:06,550
the cameras in 2002 in 2003 the Great

141
00:06:14,820 --> 00:06:09,780
observatories origins deep survey in

142
00:06:18,029 --> 00:06:14,830
2003 this was fifteen pointings of

143
00:06:20,430 --> 00:06:18,039
Hubble Accra and with a detector that's

144
00:06:22,320 --> 00:06:20,440
twice the size of whispering - so 30

145
00:06:25,110 --> 00:06:22,330
times the area on the sky of the

146
00:06:27,810 --> 00:06:25,120
original Hubble Deep Field well when you

147
00:06:30,540 --> 00:06:27,820
do that large of a region you can't go

148
00:06:33,659 --> 00:06:30,550
extremely deep so they chose a special

149
00:06:37,290 --> 00:06:33,669
region in here in which they really

150
00:06:39,350 --> 00:06:37,300
really been in and they million seconds

151
00:06:43,100 --> 00:06:39,360
of exposure time on it

152
00:06:45,469 --> 00:06:43,110
was the Hubble ultra-deep field in 2004

153
00:06:48,230 --> 00:06:45,479
the deepest visible light exposure of

154
00:06:50,029 --> 00:06:48,240
the universe taken to that time and

155
00:06:52,459 --> 00:06:50,039
remains to this day really because the

156
00:06:55,429 --> 00:06:52,469
only thing deeper are updates to the

157
00:06:57,589 --> 00:06:55,439
Ultra Deep Field and so this had 10,000

158
00:07:00,559 --> 00:06:57,599
galaxies and really started letting us

159
00:07:03,920 --> 00:07:00,569
look out towards the the edge of the

160
00:07:06,080 --> 00:07:03,930
cosmos well in 2009 we had another

161
00:07:09,619 --> 00:07:06,090
servicing mission and that greatly

162
00:07:11,719 --> 00:07:09,629
improved our infrared capability so in

163
00:07:14,300 --> 00:07:11,729

this region here which is where the

164
00:07:17,600 --> 00:07:14,310
infrared detector covered we did the

165
00:07:20,089 --> 00:07:17,610
alternate field with infrared in 2009

166
00:07:21,860 --> 00:07:20,099
and infrared is extremely important for

167
00:07:24,439 --> 00:07:21,870
cosmology because the light from very

168
00:07:26,300 --> 00:07:24,449
distant galaxies is redshifted it's

169
00:07:27,920 --> 00:07:26,310
light is stretched and it goes from

170
00:07:30,649 --> 00:07:27,930
visible light even from ultraviolet

171
00:07:32,600 --> 00:07:30,659
light into the infrared so if you want

172
00:07:35,959 --> 00:07:32,610
to see the most distant galaxies you've

173
00:07:38,240 --> 00:07:35,969
got to look in the infrared well we also

174
00:07:39,950 --> 00:07:38,250
improve the ultraviolet capabilities at

175
00:07:41,420 --> 00:07:39,960
that time but we didn't get around to

176
00:07:47,570 --> 00:07:41,430
releasing and doing those observations

177
00:07:48,860 --> 00:07:47,580
on June 2014 with ultraviolet and this I

178
00:07:51,140 --> 00:07:48,870
like to call this the multi-wavelength

179
00:07:53,959 --> 00:07:51,150
deep field because it's got ultraviolet

180
00:07:56,899 --> 00:07:53,969
visible and infrared it covers the

181
00:08:00,019 --> 00:07:56,909
entire panoply of wavelengths that

182
00:08:03,469 --> 00:08:00,029
Hubble can look at and it was really an

183
00:08:07,159 --> 00:08:03,479
amazing piece but it showed us that we

184
00:08:10,129 --> 00:08:07,169
still wanted more so a bunch of

185
00:08:13,219 --> 00:08:10,139
astronomers proposed to do this but on

186
00:08:16,670 --> 00:08:13,229
the Hubble Deep altra violet legacy

187
00:08:21,290 --> 00:08:16,680
survey and we just released those a few

188
00:08:24,409 --> 00:08:21,300

weeks ago the HUD v2 fields this is the

189
00:08:26,809 --> 00:08:24,419
North field and this is the South field

190
00:08:30,529 --> 00:08:26,819
and I gotta say when you look at them

191
00:08:34,610 --> 00:08:30,539
you go okay yeah Mordy fields right yes

192
00:08:37,009 --> 00:08:34,620
and no okay because first of all the

193
00:08:38,480 --> 00:08:37,019
ultraviolet is extremely important

194
00:08:41,449 --> 00:08:38,490
because it shows us where stars are

195
00:08:43,900 --> 00:08:41,459
forming okay newborn stars the most

196
00:08:47,030 --> 00:08:43,910
massive stars shine brightly in the

197
00:08:49,760 --> 00:08:47,040
ultraviolet but they only do so for tens

198
00:08:52,309 --> 00:08:49,770
of millions of years so it's just the

199
00:08:53,060 --> 00:08:52,319
brand-new newborn stars that can be

200
00:08:56,420 --> 00:08:53,070
found

201
00:08:59,360 --> 00:08:56,430
with ultraviolet and ultraviolet can't

202
00:09:00,740 --> 00:08:59,370
be seen from the ground we can't do good

203
00:09:02,420 --> 00:09:00,750
ultraviolet astronomers no ground we

204
00:09:04,400 --> 00:09:02,430
have to do it from space so having

205
00:09:08,450 --> 00:09:04,410
Hubble do these ultraviolet fields is

206
00:09:09,920 --> 00:09:08,460
extremely important furthermore the size

207
00:09:14,120 --> 00:09:09,930
of that Hubble ultra-deep field

208
00:09:18,620 --> 00:09:14,130
ultraviolet is only that and with these

209
00:09:21,920 --> 00:09:18,630
two fields we have 14 times more surface

210
00:09:24,860 --> 00:09:21,930
area on the sky 14 times more statistics

211
00:09:27,140 --> 00:09:24,870
of the ultraviolet galaxies so what

212
00:09:28,640 --> 00:09:27,150
we're doing is we're looking at the

213
00:09:31,130 --> 00:09:28,650

ultraviolet which we can see most

214
00:09:33,440 --> 00:09:31,140
clearly in the nearby galaxies but in

215
00:09:35,270 --> 00:09:33,450
the far galaxies where the ultraviolet

216
00:09:38,060 --> 00:09:35,280
has been stretched to the visible or the

217
00:09:41,120 --> 00:09:38,070
infrared we now have a calibration data

218
00:09:43,040 --> 00:09:41,130
set of the nearby stuff took compared to

219
00:09:44,600 --> 00:09:43,050
what these objects look like in the

220
00:09:47,060 --> 00:09:44,610
visible or the infrared which is really

221
00:09:49,490 --> 00:09:47,070
the ultraviolet for them because their

222
00:09:52,820 --> 00:09:49,500
light has been stretched so we now get a

223
00:09:54,680 --> 00:09:52,830
much better comparison of what these

224
00:09:56,870 --> 00:09:54,690
distant galaxies might be looking like

225
00:09:59,560 --> 00:09:56,880
in the ultraviolet compared to this now

226
00:10:02,660 --> 00:09:59,570
this was just the announcement that the

227
00:10:05,210 --> 00:10:02,670
ultraviolet legacy Survey has completed

228
00:10:08,410 --> 00:10:05,220
their observations it's not the science

229
00:10:10,430 --> 00:10:08,420
results yet but it shows that Hubble is

230
00:10:13,550 --> 00:10:10,440
putting together what we call these

231
00:10:16,520 --> 00:10:13,560
legacy projects these important datasets

232
00:10:18,110 --> 00:10:16,530
that only Hubble can do during its last

233
00:10:20,780 --> 00:10:18,120
year's because we know Hubble you know

234
00:10:23,870 --> 00:10:20,790
hopefully it'll last a long long time

235
00:10:25,580 --> 00:10:23,880
but while we've got a problem is working

236
00:10:28,190 --> 00:10:25,590
really really well we want to make sure

237
00:10:31,040 --> 00:10:28,200
we get these legacy projects done that

238
00:10:34,730 --> 00:10:31,050

really cement I haven't read it said for

239
00:10:40,220 --> 00:10:34,740
astronomers to study in the future our

240
00:10:43,930 --> 00:10:40,230
second story the master retires there's

241
00:10:48,670 --> 00:10:43,940
been a gentleman his name is solavei and

242
00:10:51,410 --> 00:10:48,680
he has worked here for 35 years now

243
00:10:52,910 --> 00:10:51,420
those of you who do the math Hubble has

244
00:10:55,640 --> 00:10:52,920
only been around for 28 years

245
00:10:59,510 --> 00:10:55,650
okay Zolt has been working here for 35

246
00:11:02,720 --> 00:10:59,520
years for the last 25 of them he has had

247
00:11:05,960 --> 00:11:02,730
his hand in almost every single Hubble

248
00:11:06,770 --> 00:11:05,970
image you've ever seen he is I called

249
00:11:08,240 --> 00:11:06,780
him the

250
00:11:10,820 --> 00:11:08,250
sir in terms of master attire he's

251
00:11:14,480 --> 00:11:10,830
what's known his job title was master

252
00:11:17,090 --> 00:11:14,490
image processor so the look and feel of

253
00:11:21,410 --> 00:11:17,100
all the Hubble images has gone through

254
00:11:26,980 --> 00:11:21,420
his computer for the last 25 years and

255
00:11:29,960 --> 00:11:26,990
he has really put his stamp on it and he

256
00:11:33,050 --> 00:11:29,970
he's really well-loved around here but

257
00:11:36,320 --> 00:11:33,060
he retired last Friday and we had a we

258
00:11:40,580 --> 00:11:36,330
had a big party for him for me it's

259
00:11:43,280 --> 00:11:40,590
especially important because well he was

260
00:11:45,650 --> 00:11:43,290
part of our visualization team this is

261
00:11:47,960 --> 00:11:45,660
the four of us holding a piece of IMAX

262
00:11:50,930 --> 00:11:47,970
film this is the former basically

263
00:11:53,480 --> 00:11:50,940

working the IMAX film Hubble 3d and some

264
00:11:57,380 --> 00:11:53,490
of the test negatives from IMAX Hubble

265
00:11:59,360 --> 00:11:57,390
3d and Zolt was a big part of it and so

266
00:12:01,850 --> 00:11:59,370
although I've worked with him for 17

267
00:12:03,770 --> 00:12:01,860
years I worked extremely closely with

268
00:12:08,210 --> 00:12:03,780
him for about the last 10 years on our

269
00:12:11,870 --> 00:12:08,220
visualization team and it he's a

270
00:12:13,450 --> 00:12:11,880
consummate professional and will truly

271
00:12:17,540 --> 00:12:13,460
he'll truly be missed

272
00:12:19,790 --> 00:12:17,550
what's he gonna do well he also not only

273
00:12:23,030 --> 00:12:19,800
doing working with space images he also

274
00:12:25,130 --> 00:12:23,040
does nature photography this is an

275
00:12:28,160 --> 00:12:25,140
exhibit that he had in Jackson Hole

276
00:12:30,350 --> 00:12:28,170
Wyoming which then came to Baltimore

277
00:12:33,380 --> 00:12:30,360
this summer called celestial terrestrial

278
00:12:34,820 --> 00:12:33,390
convergence where he's comparing a bit

279
00:12:37,940 --> 00:12:34,830
of the Carina Nebula here

280
00:12:40,880 --> 00:12:37,950
to star trails over some rocks in Zion

281
00:12:43,160 --> 00:12:40,890
National Park and it's the combination

282
00:12:46,730 --> 00:12:43,170
of the terrestrial photography that he

283
00:12:49,070 --> 00:12:46,740
does as well as the celestial imagery

284
00:12:50,990 --> 00:12:49,080
that he has processed that's part of

285
00:12:53,300 --> 00:12:51,000
this art exhibit and he's going to spend

286
00:12:54,920 --> 00:12:53,310
a lot of his time now on the terrestrial

287
00:12:57,110 --> 00:12:54,930
part of it working was asked from

288
00:13:00,050 --> 00:12:57,120

astrophotography as I said he's been

289
00:13:04,160 --> 00:13:00,060
here for several decades and we just

290
00:13:06,080 --> 00:13:04,170
wanted to wish him well and congratulate

291
00:13:07,700 --> 00:13:06,090
him on his success in the years past and

292
00:13:14,639 --> 00:13:07,710
wish him well in the future

293
00:13:17,560 --> 00:13:14,649
[Applause]

294
00:13:22,030 --> 00:13:17,570
all right our featured speaker tonight

295
00:13:25,030 --> 00:13:22,040
is katie al italo who tells me she grew

296
00:13:26,889 --> 00:13:25,040
up in michigan and she stayed in

297
00:13:30,040 --> 00:13:26,899
michigan for her undergraduate work

298
00:13:32,050 --> 00:13:30,050
going to university of michigan oh yeah

299
00:13:33,250 --> 00:13:32,060
she has to say go blue so I'll make sure

300
00:13:36,460 --> 00:13:33,260
that the people in the webcast can hear

301
00:13:37,990 --> 00:13:36,470
that okay all right their arrival would

302
00:13:40,960 --> 00:13:38,000
be Ohio State right

303
00:13:43,509 --> 00:13:40,970
because I was at Michigan with Gus

304
00:13:46,660 --> 00:13:43,519
Everard and I was there during the week

305
00:13:48,910 --> 00:13:46,670
with the oh how I hate Ohio State you

306
00:13:51,220 --> 00:13:48,920
know going all over the place so that

307
00:13:53,170 --> 00:13:51,230
was one of the few things I remember

308
00:13:57,040 --> 00:13:53,180
from that from that week or two I spent

309
00:13:57,670 --> 00:13:57,050
there anyways Buckeye fans you know we

310
00:13:59,920 --> 00:13:57,680
love you too

311
00:14:04,480 --> 00:13:59,930
we just happen to have a Wolverine here

312
00:14:06,040 --> 00:14:04,490
tonight she did her graduate work at the

313
00:14:08,710 --> 00:14:06,050

University of California Berkeley where

314
00:14:13,540 --> 00:14:08,720
I also did my PhD although separated by

315
00:14:19,750 --> 00:14:13,550
just a few years and she came here last

316
00:14:28,920 --> 00:14:19,760
April to work in the AI NS on what's the

317
00:14:31,690 --> 00:14:28,930
acronym here nears I and I are ISS

318
00:14:33,930 --> 00:14:31,700
spectroscope yes there we go I haven't

319
00:14:37,269 --> 00:14:33,940
gotten the AJ duis to the James Webb

320
00:14:39,730 --> 00:14:37,279
acronyms fully down yet but you know

321
00:14:48,220 --> 00:14:39,740
we'll get there oh and she's here to

322
00:14:50,260 --> 00:14:48,230
talk to us tonight all right 100 ways to

323
00:14:51,840 --> 00:14:50,270
die in the universe ladies and gentlemen

324
00:14:58,819 --> 00:14:51,850
Katey Allah Tala

325
00:15:01,290 --> 00:14:58,829
[Applause]

326
00:15:03,509 --> 00:15:01,300
Frank with an intro like that I'm not

327
00:15:05,370 --> 00:15:03,519
entirely sure I'm going to need some of

328
00:15:12,060 --> 00:15:05,380
my slides thank you

329
00:15:14,370 --> 00:15:12,070
so yes I'm going to take a walk with you

330
00:15:16,350 --> 00:15:14,380
between through showdowns brawls and

331
00:15:20,009 --> 00:15:16,360
zombies and the life and death of

332
00:15:23,579 --> 00:15:20,019
galaxies so Frank has already actually

333
00:15:26,930 --> 00:15:23,589
covered this this is me born and raised

334
00:15:29,389 --> 00:15:26,940
in Michigan at Wolverine a proud one

335
00:15:32,389 --> 00:15:29,399
don't worry I do actually also

336
00:15:36,269 --> 00:15:32,399
appreciate people from Ohio State though

337
00:15:39,660 --> 00:15:36,279
there's one Saturday a year I might not

338
00:15:41,759 --> 00:15:39,670

so much but don't worry I then went to

339
00:15:44,340 --> 00:15:41,769
California and spent a long time in

340
00:15:47,220 --> 00:15:44,350
California and now here I am in the

341
00:15:50,340 --> 00:15:47,230
great state of Maryland I would call

342
00:15:52,829 --> 00:15:50,350
myself a galactic archaeologist if I

343
00:15:55,319 --> 00:15:52,839
were to put a name upon it I will say I

344
00:15:57,240 --> 00:15:55,329
have never had to go into any caves and

345
00:15:59,730 --> 00:15:57,250
like switch things and dodge boulders

346
00:16:01,620 --> 00:15:59,740
but some of the things I've had to do

347
00:16:04,860 --> 00:16:01,630
with radio telescopes we're a bit

348
00:16:07,850 --> 00:16:04,870
death-defying so you know maybe a little

349
00:16:10,560 --> 00:16:07,860
bit Indiana Jones but not completely

350
00:16:13,050 --> 00:16:10,570
so again when I say galactic

351
00:16:15,449 --> 00:16:13,060
archaeologists what I mean is I studied

352
00:16:18,210 --> 00:16:15,459
galaxies I searched for the imprints of

353
00:16:22,949 --> 00:16:18,220
their past interactions on their

354
00:16:25,500 --> 00:16:22,959
present-day cells I look for I look

355
00:16:28,139 --> 00:16:25,510
through huge datasets looking for a

356
00:16:33,269 --> 00:16:28,149
special subset of galaxies that are

357
00:16:35,370 --> 00:16:33,279
dying right now and I use the size of

358
00:16:37,170 --> 00:16:35,380
the universe as a time machine to look

359
00:16:39,540 --> 00:16:37,180
at galaxies from ten billion years ago

360
00:16:42,540 --> 00:16:39,550
and the great news about the the news

361
00:16:45,240 --> 00:16:42,550
today about the Hubble ultraviolet Ultra

362
00:16:47,309 --> 00:16:45,250
Deep Field is that that actually is one

363
00:16:49,889 --> 00:16:47,319

of the kinds of time machines I like to

364
00:16:51,960 --> 00:16:49,899
use because of the fact that when you

365
00:16:57,900 --> 00:16:51,970
are looking at distant galaxies you're

366
00:16:59,430 --> 00:16:57,910
also looking at old galaxies but I guess

367
00:17:02,639 --> 00:16:59,440
we will actually start with a history

368
00:17:05,340 --> 00:17:02,649
lesson here I start with Sheldon Messier

369
00:17:07,260 --> 00:17:05,350
in particular who was an astronomer and

370
00:17:10,110 --> 00:17:07,270
a lot of people know him as basically

371
00:17:13,470 --> 00:17:10,120
putting together a catalog of alien

372
00:17:15,900 --> 00:17:13,480
that is not failures in what they were

373
00:17:18,329 --> 00:17:15,910
because again he categorized some of the

374
00:17:21,710 --> 00:17:18,339
open star clusters globular clusters

375
00:17:24,449 --> 00:17:21,720
planetary nebula star-forming galaxies

376
00:17:26,760 --> 00:17:24,459
star-forming nebula but it was mostly

377
00:17:30,450 --> 00:17:26,770
because he was looking for comets so to

378
00:17:33,210 --> 00:17:30,460
him he got new science out of a failed

379
00:17:34,050 --> 00:17:33,220
product that failed project was finding

380
00:17:37,610 --> 00:17:34,060
more comets

381
00:17:43,020 --> 00:17:37,620
because he said look it's not a comment

382
00:17:46,200 --> 00:17:43,030
not a comment shoot not a comment but

383
00:17:47,910 --> 00:17:46,210
for us again his catalog is very

384
00:17:50,400 --> 00:17:47,920
important because of some of the near

385
00:17:53,160 --> 00:17:50,410
sky objects we can actually look at and

386
00:17:55,200 --> 00:17:53,170
see in great detail sometimes we can see

387
00:17:57,480 --> 00:17:55,210
them with our naked eye and sometimes it

388
00:18:03,060 --> 00:17:57,490

takes very little something like

389
00:18:06,900 --> 00:18:03,070
binoculars to actually see this but to

390
00:18:09,330 --> 00:18:06,910
me the actual start of understanding

391
00:18:12,300 --> 00:18:09,340
what the universe was came from this

392
00:18:14,790 --> 00:18:12,310
gentleman right here with his pipe Edwin

393
00:18:18,000 --> 00:18:14,800
Hubble I think you might have heard that

394
00:18:19,770 --> 00:18:18,010
name this gentleman was the namesake and

395
00:18:23,430 --> 00:18:19,780
I was lucky enough when I was a

396
00:18:25,860 --> 00:18:23,440
postdoctoral hubbell fellow at Carnegie

397
00:18:27,300 --> 00:18:25,870
observatories I actually got to work at

398
00:18:29,550 --> 00:18:27,310
the place where Edwin Hubble did his

399
00:18:32,280 --> 00:18:29,560
science which was pretty cool I got to

400
00:18:34,860 --> 00:18:32,290
see his office which now the director of

401
00:18:36,930 --> 00:18:34,870
Carnegie observatories uses and I

402
00:18:40,020 --> 00:18:36,940
actually got to see this which is a

403
00:18:42,390 --> 00:18:40,030
plate taken by Edwin Hubble of the

404
00:18:44,340 --> 00:18:42,400
Andromeda galaxy where that up there

405
00:18:46,710 --> 00:18:44,350
that red bar is Edwin Hubble's

406
00:18:49,800 --> 00:18:46,720
handwriting because he found a variable

407
00:18:51,960 --> 00:18:49,810
star in the Andromeda galaxy which told

408
00:18:57,180 --> 00:18:51,970
him that the universe was beyond the

409
00:18:59,670 --> 00:18:57,190
Milky Way so not only did he discover

410
00:19:02,160 --> 00:18:59,680
this he actually also put together

411
00:19:03,990 --> 00:19:02,170
something that we use today for galaxies

412
00:19:07,560 --> 00:19:04,000
which is he put together the Hubble

413
00:19:13,140 --> 00:19:07,570

sequence of galaxies so here's the paper

414
00:19:16,170 --> 00:19:13,150
from I think this was in 1923 maybe 1926

415
00:19:18,270 --> 00:19:16,180
the classification employed is based on

416
00:19:20,730 --> 00:19:18,280
the forms of the photographic images

417
00:19:21,660 --> 00:19:20,740
about 3% are irregular but the remaining

418
00:19:24,330 --> 00:19:21,670
nebula

419
00:19:26,340 --> 00:19:24,340
fall into a sequence of type forms

420
00:19:29,310 --> 00:19:26,350
characterized by rotational symmetry

421
00:19:31,650 --> 00:19:29,320
about dominating nuclei the sequence is

422
00:19:34,470 --> 00:19:31,660
composed of two sections the elliptical

423
00:19:38,100 --> 00:19:34,480
navilet and the spirals which merge into

424
00:19:40,260 --> 00:19:38,110
each other so here is what the Hubble

425
00:19:43,410 --> 00:19:40,270
sequence actually looks like in modern

426
00:19:46,080 --> 00:19:43,420
times here is a really nice version of

427
00:19:48,900 --> 00:19:46,090
it made in part but the help of the of

428
00:19:51,750 --> 00:19:48,910
the Zooniverse but let me show you what

429
00:19:58,650 --> 00:19:51,760
Edwin Hubble published in 1926 in this

430
00:20:02,370 --> 00:19:58,660
book 1926 folks I think he did a pretty

431
00:20:04,590 --> 00:20:02,380
good job now he accidentally flipped the

432
00:20:06,800 --> 00:20:04,600
order he thought that the elliptical

433
00:20:12,090 --> 00:20:06,810
galaxies were the ones that morphed into

434
00:20:15,090 --> 00:20:12,100
the spiral galaxies but that is all that

435
00:20:20,460 --> 00:20:15,100
he got wrong because as I said as I

436
00:20:27,060 --> 00:20:20,470
showed you just previously right pretty

437
00:20:28,530 --> 00:20:27,070
good so as I've once said in that

438
00:20:31,590 --> 00:20:28,540

original paper the Hubble sequence

439
00:20:34,380 --> 00:20:31,600
breaks in two types over here you have

440
00:20:37,200 --> 00:20:34,390
spirals and over here you have early

441
00:20:39,000 --> 00:20:37,210
type galaxies now again early type is an

442
00:20:40,590 --> 00:20:39,010
old-fashioned nomenclature coming

443
00:20:42,480 --> 00:20:40,600
originally from that Edwin Hubble

444
00:20:45,120 --> 00:20:42,490
mistake which we still use today

445
00:20:47,220 --> 00:20:45,130
- unfortunately confuse the public as

446
00:20:49,350 --> 00:20:47,230
well as our students but early type

447
00:20:52,590 --> 00:20:49,360
galaxies are actually the old galaxies

448
00:20:55,080 --> 00:20:52,600
so a typical spiral is disky it has

449
00:20:58,680 --> 00:20:55,090
spiral structure it's blue in color and

450
00:21:01,050 --> 00:20:58,690
it's forming stars early types actually

451
00:21:02,970 --> 00:21:01,060
break into two different types you have

452
00:21:06,180 --> 00:21:02,980
typical ellipticals and lenticular x'

453
00:21:08,520 --> 00:21:06,190
this is a lenticular galaxy this is an

454
00:21:11,190 --> 00:21:08,530
elliptical galaxy the thing that

455
00:21:13,020 --> 00:21:11,200
differentiates an elliptical or an early

456
00:21:15,450 --> 00:21:13,030
type but when an elliptical and

457
00:21:17,700 --> 00:21:15,460
lenticular slash early type galaxy from

458
00:21:22,410 --> 00:21:17,710
a spiral is actually that it lacks that

459
00:21:26,010 --> 00:21:22,420
spiral structure so in the sense the

460
00:21:29,640 --> 00:21:26,020
smooth structure is what classifies you

461
00:21:31,560 --> 00:21:29,650
as an early type galaxy lenticular ZAR

462
00:21:33,970 --> 00:21:31,570
disk a ellipticals are ellipsoidal

463
00:21:39,970 --> 00:21:33,980

they're reading color

464
00:21:42,070 --> 00:21:39,980
and their non star-forming so again we

465
00:21:43,840 --> 00:21:42,080
break it down spirals are blue

466
00:21:47,020 --> 00:21:43,850
they've destructure visible spiral

467
00:21:49,270 --> 00:21:47,030
spiral arms star forming and right now

468
00:21:52,900 --> 00:21:49,280
77 percent of the galaxies in the sky

469
00:21:56,860 --> 00:21:52,910
are spirals blue star forming again this

470
00:21:58,690 --> 00:21:56,870
is typical ellipticals are read their

471
00:22:01,539 --> 00:21:58,700
lips swollen structures with light

472
00:22:03,669 --> 00:22:01,549
distribution quiescent which basically

473
00:22:05,710 --> 00:22:03,679
just means non star forming my accent

474
00:22:07,450 --> 00:22:05,720
means quiet so if I slip into

475
00:22:09,490 --> 00:22:07,460
astronomers speak I just wanted to make

476
00:22:11,080 --> 00:22:09,500
sure when I use the word pious that you

477
00:22:16,630 --> 00:22:11,090
know what it means they tend to be more

478
00:22:18,580 --> 00:22:16,640
massive why is it that I keep saying the

479
00:22:21,430 --> 00:22:18,590
word star farming when I'm talking about

480
00:22:24,430 --> 00:22:21,440
blue and I keep saying things like quiet

481
00:22:28,000 --> 00:22:24,440
when I talk about red the colors of

482
00:22:30,520 --> 00:22:28,010
galaxies for the most part save for dust

483
00:22:33,070 --> 00:22:30,530
which is actually important come from

484
00:22:36,370 --> 00:22:33,080
the colors of the stars that the galaxy

485
00:22:38,560 --> 00:22:36,380
is comprised of so a stellar population

486
00:22:41,860 --> 00:22:38,570
a young stellar population again

487
00:22:44,980 --> 00:22:41,870
something frank said earlier is blue

488
00:22:47,440 --> 00:22:44,990

it's coming from young hot rock star

489
00:22:51,730 --> 00:22:47,450
stars that are going to live hard rock

490
00:22:53,770 --> 00:22:51,740
hard and die young because they are

491
00:22:56,020 --> 00:22:53,780
burning up their star forming fuel so

492
00:22:59,799 --> 00:22:56,030
fast they get very hot in temperature

493
00:23:03,549 --> 00:22:59,809
and that temperature makes them blue on

494
00:23:07,000 --> 00:23:03,559
the other hand older younger older

495
00:23:09,370 --> 00:23:07,010
smaller stars are red in color like that

496
00:23:11,230 --> 00:23:09,380
which is why elliptical galaxies would

497
00:23:12,850 --> 00:23:11,240
have a lot more of these stars that have

498
00:23:16,240 --> 00:23:12,860
been taking it easy their whole lives

499
00:23:20,409 --> 00:23:16,250
not really big burning their hydrogen

500
00:23:22,060 --> 00:23:20,419
sort of at a low level it's why these

501
00:23:24,430 --> 00:23:22,070
galaxies are red because they're cooler

502
00:23:27,669 --> 00:23:24,440
which means they can last longer and

503
00:23:30,310 --> 00:23:27,679
they're older the reason this works in

504
00:23:33,789 --> 00:23:30,320
the galaxies is because these blue hot

505
00:23:35,950 --> 00:23:33,799
stars are so dominant to the light in

506
00:23:39,010 --> 00:23:35,960
the galaxy that even if you have a lot

507
00:23:40,690 --> 00:23:39,020
of these older red stars in your galaxy

508
00:23:46,000 --> 00:23:40,700
the second you have blue stars or

509
00:23:48,760 --> 00:23:46,010
galaxies gonna look blue so

510
00:23:50,350 --> 00:23:48,770
when I talk about star formation I also

511
00:23:52,720 --> 00:23:50,360
kind of want to tell you what I mean

512
00:23:54,250 --> 00:23:52,730
because again we're having to get into

513
00:23:58,150 --> 00:23:54,260

the murder mysteries of what kills

514
00:24:00,220 --> 00:23:58,160
galaxies so when I observe star

515
00:24:02,440 --> 00:24:00,230
formation what you're usually looking at

516
00:24:04,840 --> 00:24:02,450
is a hot young new least form star

517
00:24:07,480 --> 00:24:04,850
cluster and around that star cluster is

518
00:24:10,539 --> 00:24:07,490
all of these clouds these parent clouds

519
00:24:13,900 --> 00:24:10,549
that created these stars and what you

520
00:24:16,510 --> 00:24:13,910
see is you see this hydrogen and this

521
00:24:19,750 --> 00:24:16,520
dust that is reradiating that hot

522
00:24:23,039 --> 00:24:19,760
ultraviolet light that hydrogen is now

523
00:24:25,810 --> 00:24:23,049
getting is now getting irradiated and is

524
00:24:26,950 --> 00:24:25,820
reradiating that's in the optical from

525
00:24:29,289 --> 00:24:26,960
h2 regions

526
00:24:32,500 --> 00:24:29,299
h2 roman numeral rather than h2

527
00:24:34,600 --> 00:24:32,510
subscript and the dust grains where

528
00:24:36,789 --> 00:24:34,610
again this they're absorbing this

529
00:24:39,850 --> 00:24:36,799
ultraviolet light from these new hot

530
00:24:44,200 --> 00:24:39,860
young stars is getting reradiating in

531
00:24:46,299 --> 00:24:44,210
the infrared so when you think about how

532
00:24:48,310 --> 00:24:46,309
to tell if a galaxy is forming stars you

533
00:24:49,450 --> 00:24:48,320
now know that they're blue in color but

534
00:24:51,400 --> 00:24:49,460
you also now know that there might be

535
00:24:54,039 --> 00:24:51,410
some other signatures for instance you

536
00:24:58,090 --> 00:24:54,049
might see these hydrogen lines or you

537
00:24:59,799 --> 00:24:58,100
might see dust and on top of that you

538
00:25:05,860 --> 00:24:59,809

want to look for things like this that's

539
00:25:09,360 --> 00:25:05,870
h2 gas so when we look up in the sky we

540
00:25:11,710 --> 00:25:09,370
see this well I should point out from

541
00:25:14,470 --> 00:25:11,720
Maryland for a while unfortunately we

542
00:25:16,390 --> 00:25:14,480
haven't been seeing this we've been

543
00:25:19,120 --> 00:25:16,400
seeing a lot of clouds getting a little

544
00:25:21,820 --> 00:25:19,130
rain in our faces in Los Angeles where

545
00:25:23,590 --> 00:25:21,830
usually it is pretty dry I will say we

546
00:25:27,340 --> 00:25:23,600
did not see this we saw a lot of city

547
00:25:29,020 --> 00:25:27,350
lights but if we're very lucky and we go

548
00:25:30,970 --> 00:25:29,030
out into the desert when we go to a

549
00:25:33,460 --> 00:25:30,980
place that's low light we could

550
00:25:35,110 --> 00:25:33,470
potentially see this my favorite place

551
00:25:36,940 --> 00:25:35,120
to see this is probably the Chilean

552
00:25:38,440 --> 00:25:36,950
desert but you don't need to get to the

553
00:25:40,720 --> 00:25:38,450
Chilean desert to see it you could see

554
00:25:45,630 --> 00:25:40,730
this in Wyoming and on particularly dark

555
00:25:48,220 --> 00:25:45,640
nights in Michigan but that's not what

556
00:25:50,409 --> 00:25:48,230
everything everyone sees when they look

557
00:25:52,060 --> 00:25:50,419
at the Milky Way it's when our eye see

558
00:25:54,880 --> 00:25:52,070
because our eyes process optical light

559
00:25:57,730 --> 00:25:54,890
but our telescopes and our instruments

560
00:26:00,430 --> 00:25:57,740
give us a much greater picture of what

561
00:26:02,350 --> 00:26:00,440
the Milky Way is we know what the Milky

562
00:26:04,860 --> 00:26:02,360
Way looks like in gamma rays x-rays

563
00:26:08,110 --> 00:26:04,870

optical near-infrared mid infrared

564
00:26:11,860 --> 00:26:08,120
infrared molecular hydrogen radio

565
00:26:15,399 --> 00:26:11,870
continuum atomic hydrogen and even lower

566
00:26:17,169 --> 00:26:15,409
frequency radio continuum and the reason

567
00:26:19,390 --> 00:26:17,179
astronomers like to do this is because

568
00:26:20,950 --> 00:26:19,400
each one of these can tell us something

569
00:26:22,450 --> 00:26:20,960
a little bit different about the

570
00:26:27,070 --> 00:26:22,460
universe a little bit different about

571
00:26:29,169 --> 00:26:27,080
our world so the ones I think about or I

572
00:26:31,450 --> 00:26:29,179
like to think about this one I like to

573
00:26:35,230 --> 00:26:31,460
think about where the molecular hydrogen

574
00:26:37,299 --> 00:26:35,240
is where the cold dense gases because

575
00:26:38,649 --> 00:26:37,309
where the cold dense gases that's

576
00:26:40,090 --> 00:26:38,659
actually where you're gonna find your

577
00:26:42,130 --> 00:26:40,100
stellar nurseries that's where you're

578
00:26:44,169 --> 00:26:42,140
going to find the places that you are

579
00:26:47,169 --> 00:26:44,179
birthing new stars and keeping your

580
00:26:52,299 --> 00:26:47,179
galaxies blue and vibrant and star

581
00:26:54,490 --> 00:26:52,309
forming how we see these different

582
00:26:58,480 --> 00:26:54,500
wavelengths is with a lot of really cool

583
00:27:00,850 --> 00:26:58,490
telescopes I obviously have not seen all

584
00:27:04,590 --> 00:27:00,860
of these in person given that this is in

585
00:27:07,840 --> 00:27:04,600
space and I am NOT an astronaut but

586
00:27:10,390 --> 00:27:07,850
astronomers get to use an incredible set

587
00:27:12,490 --> 00:27:10,400
of tools with which we can actually look

588
00:27:13,780 --> 00:27:12,500

at these different wavelengths to

589
00:27:17,980 --> 00:27:13,790
understand different things about the

590
00:27:21,760 --> 00:27:17,990
universe how do we find star formation

591
00:27:25,649 --> 00:27:21,770
well one thing we can look at is the

592
00:27:29,590 --> 00:27:25,659
ultraviolet this is the Whirlpool Galaxy

593
00:27:31,149 --> 00:27:29,600
this is done by Galax there are images

594
00:27:33,549 --> 00:27:31,159
of this with Hubble that are

595
00:27:35,380 --> 00:27:33,559
significantly better than this but

596
00:27:37,539 --> 00:27:35,390
because ultraviolet light is coming

597
00:27:39,340 --> 00:27:37,549
again from very hot very young stars

598
00:27:43,260 --> 00:27:39,350
you're able to trace our formation with

599
00:27:45,340 --> 00:27:43,270
it you can also trace it in H alpha

600
00:27:47,289 --> 00:27:45,350
again I can think back to that little

601
00:27:50,409 --> 00:27:47,299
diagram I showed you one of the things

602
00:27:52,299 --> 00:27:50,419
that these hot stars do is they radiate

603
00:27:55,320 --> 00:27:52,309
the gas that is around them and that gas

604
00:27:57,549 --> 00:27:55,330
being radiated will re radiate that

605
00:28:02,139 --> 00:27:57,559
ultraviolet light that it that it's

606
00:28:06,850 --> 00:28:02,149
absorbed in line-in lines including the

607
00:28:09,130 --> 00:28:06,860
H alpha line and finally

608
00:28:11,799 --> 00:28:09,140
you can see star formation and dust this

609
00:28:13,900 --> 00:28:11,809
image being an image of the Whirlpool

610
00:28:15,940 --> 00:28:13,910
Galaxy from Herschel and what you can

611
00:28:17,710 --> 00:28:15,950
see here is again where you have those

612
00:28:20,110 --> 00:28:17,720
those gas envelopes that are around

613
00:28:22,539 --> 00:28:20,120

those stars you also have dust and the

614
00:28:27,400 --> 00:28:22,549
dust is taking those ultraviolet photons

615
00:28:32,289 --> 00:28:27,410
and reradiating it as well okay that's

616
00:28:34,870 --> 00:28:32,299
great but what about the fuel how do you

617
00:28:36,640 --> 00:28:34,880
form those stars we now know that you

618
00:28:38,860 --> 00:28:36,650
can look at ultraviolet light you can

619
00:28:41,200 --> 00:28:38,870
look at optical light to some degree you

620
00:28:42,669 --> 00:28:41,210
can look at spectra you can look at dust

621
00:28:44,950 --> 00:28:42,679
and you can find where the stars are

622
00:28:47,260 --> 00:28:44,960
actually forming well what if you don't

623
00:28:48,340 --> 00:28:47,270
want to just think about the the product

624
00:28:52,299 --> 00:28:48,350
what if you want to think about the

625
00:28:54,430 --> 00:28:52,309
source well where you see young stars

626
00:28:57,430 --> 00:28:54,440
you have to have fuel that is forming

627
00:29:00,870 --> 00:28:57,440
the young stars so first thing you do is

628
00:29:03,520 --> 00:29:00,880
you look at where the young stars are

629
00:29:06,070 --> 00:29:03,530
you can also look where the dust is

630
00:29:08,520 --> 00:29:06,080
because again the dust is in those

631
00:29:15,130 --> 00:29:08,530
envelopes those whole pockets of gas

632
00:29:20,470 --> 00:29:15,140
with that gas reradiating and finally

633
00:29:23,860 --> 00:29:20,480
you can look at the molecular gas in

634
00:29:29,049 --> 00:29:23,870
order to form a star you need to be in

635
00:29:30,940 --> 00:29:29,059
gas that is both dense and cold because

636
00:29:34,740 --> 00:29:30,950
it has to be dense because you need it

637
00:29:37,390 --> 00:29:34,750
to be able to overcome gravity and

638
00:29:40,180 --> 00:29:37,400

collapse upon itself to form that star

639
00:29:42,700 --> 00:29:40,190
and the thing about hydrogen is you're

640
00:29:44,530 --> 00:29:42,710
not going to find hydrogen just atoms of

641
00:29:47,080 --> 00:29:44,540
hydrogen in places where you don't have

642
00:29:50,710 --> 00:29:47,090
cold gas you need to find molecular

643
00:29:52,780 --> 00:29:50,720
hydrogen so molecular hydrogen makes up

644
00:29:55,360 --> 00:29:52,790
about 70% of the mass in our universe

645
00:29:57,190 --> 00:29:55,370
and this also I guess it's not molecular

646
00:29:59,380 --> 00:29:57,200
hydrogen make 70% of the mass every

647
00:30:02,350 --> 00:29:59,390
universe molecular hydrogen is where you

648
00:30:06,120 --> 00:30:02,360
form stars there's this problem with

649
00:30:09,610 --> 00:30:06,130
hydrogen the problem with hydrogen is

650
00:30:12,370 --> 00:30:09,620
what it is trying to radiate when its

651
00:30:15,130 --> 00:30:12,380
spinning it doesn't have a dipole moment

652
00:30:20,130 --> 00:30:15,140
that means that it's really really hard

653
00:30:24,270 --> 00:30:20,140
to detect it directly but it has

654
00:30:26,910 --> 00:30:24,280
neighbor and I know in our world carbon

655
00:30:30,320 --> 00:30:26,920
monoxide is not so great but for radio

656
00:30:32,880 --> 00:30:30,330
astronomers this is a wonderful molecule

657
00:30:34,800 --> 00:30:32,890
it's wonderful because it forms in

658
00:30:37,590 --> 00:30:34,810
exactly the same environments that you

659
00:30:39,150 --> 00:30:37,600
find molecular hydrogen that is if the

660
00:30:41,070 --> 00:30:39,160
conditions are right to form molecular

661
00:30:44,070 --> 00:30:41,080
hydrogen the conditions are right to

662
00:30:46,740 --> 00:30:44,080
make stars the conditions are also right

663
00:30:48,150 --> 00:30:46,750

to form carbon monoxide carbon and

664
00:30:51,120 --> 00:30:48,160
oxygen are also two of the first

665
00:30:52,860 --> 00:30:51,130
molecules of formed in stars so really

666
00:30:54,440 --> 00:30:52,870
early on in the universe you had plenty

667
00:30:56,850 --> 00:30:54,450
of carbon and you had plenty of oxygen

668
00:30:59,940 --> 00:30:56,860
but the thing about this molecule that's

669
00:31:03,810 --> 00:30:59,950
even better is that carbon and oxygen

670
00:31:06,510 --> 00:31:03,820
have a big dipole moment so the second

671
00:31:08,790 --> 00:31:06,520
they start rotating they radiate and we

672
00:31:12,780 --> 00:31:08,800
can pick that up we can pick that up in

673
00:31:14,040 --> 00:31:12,790
radio telescopes so despite the fact

674
00:31:16,100 --> 00:31:14,050
that unfortunately the thing we would

675
00:31:19,410 --> 00:31:16,110
want to detect most molecular hydrogen

676
00:31:21,690 --> 00:31:19,420
sort of out of our reach carbon monoxide

677
00:31:24,830 --> 00:31:21,700
is not and it is best friends and

678
00:31:30,050 --> 00:31:24,840
neighbors with that molecular hydrogen

679
00:31:33,540 --> 00:31:30,060
so we use radio telescopes for it

680
00:31:35,610 --> 00:31:33,550
carbon monoxide is brightest at a

681
00:31:37,140 --> 00:31:35,620
frequency of about one hundred fifty one

682
00:31:40,020 --> 00:31:37,150
hundred fifteen point two seven one two

683
00:31:41,580 --> 00:31:40,030
oh two gigahertz yes I've had to type

684
00:31:43,620 --> 00:31:41,590
that number into a lot of programs to

685
00:31:45,780 --> 00:31:43,630
process data which is why I remember too

686
00:31:47,520 --> 00:31:45,790
that many significant figures but the

687
00:31:50,520 --> 00:31:47,530
idea is this is something that you can

688
00:31:52,070 --> 00:31:50,530

see in in radio and with radio

689
00:31:55,680 --> 00:31:52,080
telescopes you're actually able to

690
00:31:57,510 --> 00:31:55,690
monitor it this video was taken of

691
00:31:58,770 --> 00:31:57,520
unfortunately the now-defunct combined

692
00:32:01,800 --> 00:31:58,780
array for research and millimeter

693
00:32:03,990 --> 00:32:01,810
astronomy which was in the which was in

694
00:32:07,140 --> 00:32:04,000
the desert just outside of Mammoth Lakes

695
00:32:09,900 --> 00:32:07,150
in California and Carmel was a great

696
00:32:12,060 --> 00:32:09,910
instrument for finding carbon monoxide

697
00:32:13,890 --> 00:32:12,070
in galaxies and thus finding molecular

698
00:32:16,950 --> 00:32:13,900
hydrogen and just finding star forming

699
00:32:20,160 --> 00:32:16,960
fuel and now even better is in the

700
00:32:23,010 --> 00:32:20,170
Atacama Desert it all my husband has

701
00:32:25,230 --> 00:32:23,020
been out there doing incredibly

702
00:32:26,910 --> 00:32:25,240
incredible revolutionary things where

703
00:32:29,340 --> 00:32:26,920
it's being able to find carbon monoxide

704
00:32:33,140 --> 00:32:29,350
not only in nearby neighbor galaxies but

705
00:32:39,100 --> 00:32:36,080
so what does this all mean I've not told

706
00:32:43,100 --> 00:32:39,110
you about how I like to observe stars

707
00:32:46,220 --> 00:32:43,110
stars forming old stars young stars red

708
00:32:47,330 --> 00:32:46,230
stars green stars blue stars and I've

709
00:32:48,920 --> 00:32:47,340
told you how I wanted to look at the

710
00:32:51,470 --> 00:32:48,930
star forming gaps

711
00:32:54,890 --> 00:32:51,480
well what do you have to do to see a

712
00:33:03,160 --> 00:32:54,900
galaxy March from this vibrant spiral

713
00:33:08,960 --> 00:33:06,560

we've thought of a few ways and like

714
00:33:10,820 --> 00:33:08,970
I'll say maybe like galaxy evolution

715
00:33:13,400 --> 00:33:10,830
astronomers are some of the most macabre

716
00:33:16,250 --> 00:33:13,410
astronomers but I like thinking about

717
00:33:19,010 --> 00:33:16,260
this even if it's just to think about

718
00:33:21,169 --> 00:33:19,020
how to prevent it so if you're a spiral

719
00:33:23,930 --> 00:33:21,179
galaxy how do you become an elliptical

720
00:33:26,030 --> 00:33:23,940
how do you lose the ability to form

721
00:33:29,210 --> 00:33:26,040
those new young stars how do you lose

722
00:33:31,070 --> 00:33:29,220
that star forming fuel you can fall into

723
00:33:33,049 --> 00:33:31,080
a cluster you can go through a merger

724
00:33:36,320 --> 00:33:33,059
you can be in a Galaxy group you can

725
00:33:37,460 --> 00:33:36,330
have death by black hole and galaxies

726
00:33:40,490 --> 00:33:37,470
shapes which I don't think I will talk

727
00:33:44,390 --> 00:33:40,500
about today don't worry I will talk

728
00:33:46,540 --> 00:33:44,400
about most of these so death by

729
00:33:52,490 --> 00:33:46,550
strangulation ie

730
00:33:55,790 --> 00:33:52,500
falling into a cluster galaxy clusters

731
00:33:57,710 --> 00:33:55,800
are huge conglomerates of a lot of

732
00:34:00,650 --> 00:33:57,720
galaxies that are in basically a big

733
00:34:03,650 --> 00:34:00,660
pocket of hot gas this represents our

734
00:34:05,000 --> 00:34:03,660
hot cluster x-ray gas and because of the

735
00:34:07,160 --> 00:34:05,010
fact that they are gravitational

736
00:34:09,139 --> 00:34:07,170
sinkholes galaxies that are near

737
00:34:12,649 --> 00:34:09,149
clusters are pretty much doomed to

738
00:34:15,770 --> 00:34:12,659

become part of the clusters so

739
00:34:18,080 --> 00:34:15,780
unfortunately this little guy galaxy has

740
00:34:21,590 --> 00:34:18,090
been caught by the cluster is now

741
00:34:24,290 --> 00:34:21,600
falling into the cluster gas when it

742
00:34:26,149 --> 00:34:24,300
falls into this Ram pressure stripping

743
00:34:28,520 --> 00:34:26,159
actually starts to strip all of that

744
00:34:31,389 --> 00:34:28,530
nice star forming fuel out of the galaxy

745
00:34:33,889 --> 00:34:31,399
and it pulls the gas out of the system

746
00:34:35,869 --> 00:34:33,899
without the gas unfortunately for that

747
00:34:37,250 --> 00:34:35,879
galaxy it's not going to be forming

748
00:34:39,290 --> 00:34:37,260
stars so it's not going to be blue

749
00:34:42,790 --> 00:34:39,300
anymore because all of a sudden those

750
00:34:45,770 --> 00:34:42,800
yellow and red sort of easygoing stars

751
00:34:48,020 --> 00:34:45,780
start to dominate the light in the Gow

752
00:34:52,850 --> 00:34:48,030
lexy and to us the galaxy actually looks

753
00:34:56,480 --> 00:34:52,860
green and then finally upon losing all

754
00:34:59,540 --> 00:34:56,490
of its gas the galaxy stops being able

755
00:35:01,820 --> 00:34:59,550
to form stars at all and it becomes red

756
00:35:04,310 --> 00:35:01,830
and dead it fades into becoming red

757
00:35:08,080 --> 00:35:04,320
where again the only stars you're seeing

758
00:35:11,150 --> 00:35:08,090
in it now are those older easygoing

759
00:35:13,790 --> 00:35:11,160
smaller stars that are ten billion years

760
00:35:15,920 --> 00:35:13,800
old as opposed to those young supernova

761
00:35:18,830 --> 00:35:15,930
rock star stars which are going to die

762
00:35:22,610 --> 00:35:18,840
and about 50 million years ten million

763
00:35:24,380 --> 00:35:22,620

years they don't last long and just in

764
00:35:28,610 --> 00:35:24,390
case you wonder if we've ever observed

765
00:35:31,370 --> 00:35:28,620
this we have we've actually seen this

766
00:35:32,360 --> 00:35:31,380
process taking place I don't know

767
00:35:37,100 --> 00:35:32,370
whether you can see these little

768
00:35:39,170 --> 00:35:37,110
filaments here but those are actually

769
00:35:40,910 --> 00:35:39,180
the places that the gas is being

770
00:35:43,220 --> 00:35:40,920
stripped out of that galaxy is that

771
00:35:46,070 --> 00:35:43,230
galaxy falls into a cluster we call them

772
00:35:49,060 --> 00:35:46,080
jellyfish galaxies who said astronomers

773
00:35:51,920 --> 00:35:49,070
are not creative in their naming schemes

774
00:35:56,720 --> 00:35:51,930
so it's why when you look at a cluster

775
00:35:59,720 --> 00:35:56,730
like this most of what you see is are

776
00:36:01,490 --> 00:35:59,730
these red and dead galaxies now there's

777
00:36:03,080 --> 00:36:01,500
something fairly special about clusters

778
00:36:05,330 --> 00:36:03,090
is that you actually get to magnify

779
00:36:06,710 --> 00:36:05,340
background galaxies but for the most

780
00:36:10,070 --> 00:36:06,720
part the galaxies that are in this

781
00:36:13,640 --> 00:36:10,080
cluster have had all of their star

782
00:36:15,440 --> 00:36:13,650
forming fuel gone they have not been

783
00:36:16,850 --> 00:36:15,450
able to form new stars those new stars

784
00:36:18,920 --> 00:36:16,860
have not been able to turn return the

785
00:36:24,880 --> 00:36:18,930
galaxies to looking blue so those

786
00:36:31,370 --> 00:36:24,890
galaxies now look Brett death by battle

787
00:36:33,470 --> 00:36:31,380
mergers and interactions so let's say

788
00:36:36,340 --> 00:36:33,480

you take two equal mass progenitors

789
00:36:38,780 --> 00:36:36,350
progenitors just means original galaxies

790
00:36:41,150 --> 00:36:38,790
either spirals that are elliptical so

791
00:36:43,250 --> 00:36:41,160
you let them encounter each other their

792
00:36:47,300 --> 00:36:43,260
murder is gonna produce an elliptical

793
00:36:50,900 --> 00:36:47,310
galaxy and the colliding galaxies have

794
00:36:52,430 --> 00:36:50,910
explosions of star formation but in

795
00:36:54,320 --> 00:36:52,440
those explosions of star formation they

796
00:36:57,950 --> 00:36:54,330
basically use up their gas really

797
00:36:59,240 --> 00:36:57,960
quickly so this is a simulation done by

798
00:37:01,550 --> 00:36:59,250
Phil Hopkins

799
00:37:03,890 --> 00:37:01,560
which shows a video of what this process

800
00:37:06,680 --> 00:37:03,900
looks like now I should point out up

801
00:37:08,960 --> 00:37:06,690
here you can see the time scale one gig

802
00:37:10,760 --> 00:37:08,970
a year so unfortunately for us we don't

803
00:37:26,220 --> 00:37:10,770
get to watch this fireworks show in real

804
00:37:33,030 --> 00:37:29,640
as you saw we started with two disk

805
00:37:34,859 --> 00:37:33,040
galaxies this is not looking so disc II

806
00:37:36,330 --> 00:37:34,869
anymore is it does it have spiral

807
00:37:38,460 --> 00:37:36,340
structure that thing that tells us

808
00:37:42,720 --> 00:37:38,470
whether or not we consider it a spiral

809
00:37:45,390 --> 00:37:42,730
galaxy not so much there is still a dust

810
00:37:47,940 --> 00:37:45,400
line because again we just smashed to

811
00:37:49,740 --> 00:37:47,950
gas rich galaxies into each other but

812
00:37:54,720 --> 00:37:49,750
slowly but surely that dust is being

813
00:37:58,470 --> 00:37:54,730

consumed by star formation and the thing

814
00:38:00,300 --> 00:37:58,480
that's great about this is that we know

815
00:38:02,670 --> 00:38:00,310
what we know what we think we should see

816
00:38:05,220 --> 00:38:02,680
again you just saw the simulation and we

817
00:38:09,870 --> 00:38:05,230
see this in the real world when we look

818
00:38:11,940 --> 00:38:09,880
at galaxies we see absolutely beautiful

819
00:38:13,950 --> 00:38:11,950
images of galaxies as they're colliding

820
00:38:16,320 --> 00:38:13,960
with one another you see the explosions

821
00:38:17,730 --> 00:38:16,330
of their star formation and again you

822
00:38:24,120 --> 00:38:17,740
see them at all different stages

823
00:38:26,970 --> 00:38:24,130
thank you Hubble so why is it

824
00:38:29,010 --> 00:38:26,980
that's colliding these two galaxies you

825
00:38:31,560 --> 00:38:29,020
know that how pop gas they're exploding

826
00:38:33,660 --> 00:38:31,570
their star formation for a while why is

827
00:38:38,430 --> 00:38:33,670
it that they turn into this red and dead

828
00:38:40,740 --> 00:38:38,440
galaxies what has to do with gas so I'm

829
00:38:42,180 --> 00:38:40,750
playing the same movie again but this

830
00:38:44,160 --> 00:38:42,190
time I'm showing you two images I'm

831
00:38:46,080 --> 00:38:44,170
showing you the one that if we were you

832
00:38:47,849 --> 00:38:46,090
know omniscient energy creatures who

833
00:38:49,730 --> 00:38:47,859
lived for billions and billions of years

834
00:38:51,780 --> 00:38:49,740
we might be able to see in real time

835
00:38:53,880 --> 00:38:51,790
unfortunately for you and me that is not

836
00:38:55,770 --> 00:38:53,890
the case and over here I'm actually

837
00:38:57,330 --> 00:38:55,780
showing what would happen if you had

838
00:39:00,030 --> 00:38:57,340

eyes that could look at the gas in the

839
00:39:03,030 --> 00:39:00,040
galaxies the hot gas that is gas that is

840
00:39:05,160 --> 00:39:03,040
traced by x-rays the warm gas which is

841
00:39:09,570 --> 00:39:05,170
traced by things like ionized gas and

842
00:39:11,099 --> 00:39:09,580
again the cold gas that blue gas is the

843
00:39:12,900 --> 00:39:11,109
most important gas in this system

844
00:39:15,900 --> 00:39:12,910
because that's the gas it's forming

845
00:39:18,450 --> 00:39:15,910
stars and what you can see is as this

846
00:39:19,859 --> 00:39:18,460
merger keeps going on yes you're getting

847
00:39:23,490 --> 00:39:19,869
these little explosions of star

848
00:39:26,160 --> 00:39:23,500
formation but all of a sudden all of

849
00:39:28,620 --> 00:39:26,170
that warm and cold gas now you're seeing

850
00:39:30,690 --> 00:39:28,630
is really either concentrated in the

851
00:39:34,080 --> 00:39:30,700
very center as it's forming more stars

852
00:39:36,720 --> 00:39:34,090
and just finishing off but mostly it's

853
00:39:37,840 --> 00:39:36,730
becoming hot gas and unfortunately for

854
00:39:45,550 --> 00:39:37,850
star

855
00:39:46,170 --> 00:39:45,560
actually happens here why does it happen

856
00:39:50,400 --> 00:39:46,180
like that

857
00:39:53,470 --> 00:39:50,410
well I have a handy-dandy schematic here

858
00:39:55,360 --> 00:39:53,480
first you have your isolated disks you

859
00:39:57,070 --> 00:39:55,370
go through the first interaction there's

860
00:39:59,050 --> 00:39:57,080
a coalescence that is when the two

861
00:40:02,530 --> 00:39:59,060
galaxies finding smoosh into each other

862
00:40:04,810 --> 00:40:02,540
there's a gas blowout phase a quasar

863
00:40:07,090 --> 00:40:04,820

phase which might be previewing till the

864
00:40:09,550 --> 00:40:07,100
next part of my talk once the quasar

865
00:40:11,530 --> 00:40:09,560
phase has removed all the gas you get to

866
00:40:13,950 --> 00:40:11,540
the decay slash of dying phase that is

867
00:40:16,960 --> 00:40:13,960
the post starburst phase until

868
00:40:25,930 --> 00:40:16,970
inevitably you march into the run and

869
00:40:28,390 --> 00:40:25,940
dead face death by melee so we've now

870
00:40:30,550 --> 00:40:28,400
talked about clusters which is hundreds

871
00:40:32,530 --> 00:40:30,560
of galaxies and one galaxy falling into

872
00:40:34,630 --> 00:40:32,540
that and being doomed to lose all of its

873
00:40:36,400 --> 00:40:34,640
gas we've talked about a pair of

874
00:40:38,470 --> 00:40:36,410
galaxies having a battle to the death

875
00:40:41,020 --> 00:40:38,480
for their gas now we're going to talk

876
00:40:42,730 --> 00:40:41,030
about something right in between the fun

877
00:40:44,980 --> 00:40:42,740
thing about the right in-between for

878
00:40:47,560 --> 00:40:44,990
astronomers is it's actually one of the

879
00:40:49,240 --> 00:40:47,570
most complicated things to model because

880
00:40:51,760 --> 00:40:49,250
the two galaxies you can kind of model

881
00:40:53,560 --> 00:40:51,770
together a really big massive cluster

882
00:40:55,740 --> 00:40:53,570
can actually be modeled as just that one

883
00:40:58,510 --> 00:40:55,750
little dinky galaxy and the big cluster

884
00:41:00,280 --> 00:40:58,520
unfortunately this galaxy doesn't just

885
00:41:02,020 --> 00:41:00,290
care about that galaxy this galaxy cares

886
00:41:06,580 --> 00:41:02,030
about that galaxy and this galaxy and

887
00:41:08,740 --> 00:41:06,590
that galaxy in that galaxy so when we

888
00:41:11,020 --> 00:41:08,750

say compact group because we're

889
00:41:13,390 --> 00:41:11,030
astronomers the first way we actually

890
00:41:15,430 --> 00:41:13,400
define this like that when Hubble was a

891
00:41:17,740 --> 00:41:15,440
small relatively isolated system of

892
00:41:20,320 --> 00:41:17,750
typically four or five galaxies in close

893
00:41:23,080 --> 00:41:20,330
proximity to one another when Paul

894
00:41:25,120 --> 00:41:23,090
Hickson actually did this he was not

895
00:41:26,230 --> 00:41:25,130
looking at spectra he was not comparing

896
00:41:28,090 --> 00:41:26,240
redshifts you did not have

897
00:41:31,390 --> 00:41:28,100
three-dimensional information on these

898
00:41:32,920 --> 00:41:31,400
galaxies he had images and from those

899
00:41:34,720 --> 00:41:32,930
images he basically looked at places

900
00:41:36,340 --> 00:41:34,730
where he saw a few galaxies that were

901
00:41:38,710 --> 00:41:36,350
close to each other and then he

902
00:41:40,450 --> 00:41:38,720
carefully calculated the brightnesses of

903
00:41:42,520 --> 00:41:40,460
those galaxies to see if they were

904
00:41:45,580 --> 00:41:42,530
pretty much as bright as each other and

905
00:41:47,620 --> 00:41:45,590
he came up with a list of 100 compact

906
00:41:49,780 --> 00:41:47,630
groups which we now call Hicks and

907
00:41:50,860 --> 00:41:49,790
compact groups and of those 100 I think

908
00:41:53,020 --> 00:41:50,870
that 90

909
00:41:55,300 --> 00:41:53,030
three of them when we went back and took

910
00:41:57,810 --> 00:41:55,310
spectra so that we had their distances

911
00:42:00,010 --> 00:41:57,820
we found to actually be correctly

912
00:42:01,870 --> 00:42:00,020
identified as compact groups that were

913
00:42:05,190 --> 00:42:01,880

together so I think that's pretty good

914
00:42:07,330 --> 00:42:05,200
for somebody having just you know images

915
00:42:09,670 --> 00:42:07,340
they have a high fraction of dead

916
00:42:12,970 --> 00:42:09,680
galaxies they have evidence of tidal

917
00:42:15,760 --> 00:42:12,980
interactions and again the high density

918
00:42:17,680 --> 00:42:15,770
means they have lots and lots and lots

919
00:42:19,390 --> 00:42:17,690
of interactions with each other they get

920
00:42:21,610 --> 00:42:19,400
the worst of both worlds

921
00:42:23,050 --> 00:42:21,620
there's hot gas in those systems so

922
00:42:24,910 --> 00:42:23,060
they're getting that hot gas dripping

923
00:42:26,680 --> 00:42:24,920
away some of their gas and they're also

924
00:42:29,530 --> 00:42:26,690
having interaction after interaction

925
00:42:31,990 --> 00:42:29,540
after interaction which is again pulling

926
00:42:35,320 --> 00:42:32,000
it they're pulling their gas away from

927
00:42:37,210 --> 00:42:35,330
them so they start as a loose group at

928
00:42:39,250 --> 00:42:37,220
some point they become a compact group

929
00:42:41,080 --> 00:42:39,260
the star formation fuels starts to be

930
00:42:42,760 --> 00:42:41,090
dispersed again when you have an

931
00:42:44,920 --> 00:42:42,770
interaction a lot of your cold gas

932
00:42:47,710 --> 00:42:44,930
starts being being heated and becoming

933
00:42:49,180 --> 00:42:47,720
part of that hot gas halo the galaxies

934
00:42:52,870 --> 00:42:49,190
evolve into ellipticals and lenticular

935
00:42:57,810 --> 00:42:52,880
x' again a big extra gas bubbles is

936
00:43:00,130 --> 00:42:57,820
shown and maybe we're not sure but maybe

937
00:43:02,680 --> 00:43:00,140
compact groups can actually make giant

938
00:43:04,690 --> 00:43:02,690

ellipticals most of the time when we see

939
00:43:06,370 --> 00:43:04,700
the ultra massive elliptical galaxies

940
00:43:08,380 --> 00:43:06,380
those are the ultra big red and dead

941
00:43:11,860 --> 00:43:08,390
galaxies we see them in the center of

942
00:43:13,780 --> 00:43:11,870
clusters but once in a while you

943
00:43:15,760 --> 00:43:13,790
actually find these very rare things in

944
00:43:17,800 --> 00:43:15,770
the field that is not around these big

945
00:43:19,630 --> 00:43:17,810
hundred galaxy clusters but by

946
00:43:21,430 --> 00:43:19,640
themselves and so one of the big

947
00:43:23,680 --> 00:43:21,440
questions we've asked is how do they get

948
00:43:25,780 --> 00:43:23,690
there and it looks like it's very

949
00:43:30,240 --> 00:43:25,790
possible that these compact groups are

950
00:43:35,260 --> 00:43:30,250
one of the ways to do it again

951
00:43:42,040 --> 00:43:35,270
death by black hole which we call a GN

952
00:43:45,400 --> 00:43:42,050
feedback so I can't help this this is my

953
00:43:49,860 --> 00:43:45,410
favorite galaxy I was a graduate student

954
00:43:53,700 --> 00:43:49,870
when this galaxy appeared in my life and

955
00:43:56,350 --> 00:43:53,710
it was super weird which is both

956
00:43:59,500 --> 00:43:56,360
wonderful and terrible for a graduate

957
00:44:03,600 --> 00:43:59,510
student especially one as stubborn as I

958
00:44:05,700 --> 00:44:03,610
am because again from

959
00:44:09,000 --> 00:44:05,710
picture you're seeing it it doesn't look

960
00:44:11,460 --> 00:44:09,010
all that interesting but it was a

961
00:44:12,900 --> 00:44:11,470
mystery that all of these different

962
00:44:16,410 --> 00:44:12,910
things were happening in it that were

963
00:44:19,230 --> 00:44:16,420

very very hard to explain again it's a

964
00:44:23,310 --> 00:44:19,240
treasure but it's also a Pandora's box

965
00:44:25,890 --> 00:44:23,320
and I bought it hook line and sinker and

966
00:44:27,780 --> 00:44:25,900
said okay I am going to learn why this

967
00:44:31,440 --> 00:44:27,790
galaxy is doing the things this galaxy

968
00:44:34,380 --> 00:44:31,450
is doing so one of the first things I

969
00:44:38,550 --> 00:44:34,390
did is I took a picture I managed to

970
00:44:40,620 --> 00:44:38,560
convince the scientists who determine

971
00:44:41,490 --> 00:44:40,630
what Hubble is going to look at to look

972
00:44:45,690 --> 00:44:41,500
at it for me

973
00:44:48,480 --> 00:44:45,700
and luckily for me the little graduate

974
00:44:51,240 --> 00:44:48,490
student they said yes so again let's go

975
00:44:53,550 --> 00:44:51,250
back to this picture this is NGC 1266

976
00:44:56,040 --> 00:44:53,560
taken from the ground with a really good

977
00:44:59,850 --> 00:44:56,050
ground-based telescope in the optical

978
00:45:03,000 --> 00:44:59,860
with really deep observations and this

979
00:45:04,770 --> 00:45:03,010
is what Hubble showed us so yes this is

980
00:45:07,590 --> 00:45:04,780
a non photoshopped version

981
00:45:09,450 --> 00:45:07,600
I'm very sad Zoltan Levay has retired

982
00:45:12,030 --> 00:45:09,460
because I can just imagine how beautiful

983
00:45:14,940 --> 00:45:12,040
this would be with results incredible

984
00:45:17,340 --> 00:45:14,950
image processing mastery but instead of

985
00:45:19,200 --> 00:45:17,350
just seeing this kind of amorphous blob

986
00:45:22,080 --> 00:45:19,210
maybe a little bit bright in the middle

987
00:45:23,790 --> 00:45:22,090
maybe a little bit weird you see that

988
00:45:25,860 --> 00:45:23,800

this thing is really bright in the

989
00:45:27,060 --> 00:45:25,870
center and you can actually see a dust

990
00:45:30,570 --> 00:45:27,070
cone now coming out of it

991
00:45:33,770 --> 00:45:30,580
that's because NGC 1266 was one of the

992
00:45:36,300 --> 00:45:33,780
first galaxies we discovered that had a

993
00:45:38,640 --> 00:45:36,310
supermassive black hole that was

994
00:45:41,880 --> 00:45:38,650
actively removing the gas from the

995
00:45:44,220 --> 00:45:41,890
system a lot of it we're not talking

996
00:45:45,900 --> 00:45:44,230
about one solar mass per year here which

997
00:45:47,880 --> 00:45:45,910
is about the star formation rate of the

998
00:45:49,500 --> 00:45:47,890
Milky Way we're talking about the fact

999
00:45:51,900 --> 00:45:49,510
that this little black hole is doing

1000
00:45:54,180 --> 00:45:51,910
some work this is a hundred solar masses

1001
00:45:59,010 --> 00:45:54,190
per year that is managing to move around

1002
00:46:00,990 --> 00:45:59,020
in the center of this thing so the next

1003
00:46:03,420 --> 00:46:01,000
thing you do again another gorgeous

1004
00:46:05,700 --> 00:46:03,430
Hubble image this time I took it in the

1005
00:46:09,180 --> 00:46:05,710
near-infrared which is a very good way

1006
00:46:10,800 --> 00:46:09,190
to trace stars in particular to look and

1007
00:46:13,230 --> 00:46:10,810
see if I could find any signatures of

1008
00:46:14,910 --> 00:46:13,240
some massive interactions some big

1009
00:46:17,410 --> 00:46:14,920
battle that took place with another

1010
00:46:23,049 --> 00:46:17,420
galaxy like those those simulations I

1011
00:46:24,970 --> 00:46:23,059
you know not really but then when you

1012
00:46:27,970 --> 00:46:24,980
look at it and you combine not only the

1013
00:46:29,980 --> 00:46:27,980

Hubble imaging with the radio telescope

1014
00:46:32,650 --> 00:46:29,990
imaging which was able to show me the

1015
00:46:38,500 --> 00:46:32,660
carbon monoxide thus the star forming

1016
00:46:41,710 --> 00:46:38,510
gas I saw this so radio astronomers like

1017
00:46:43,930 --> 00:46:41,720
contours I'll just warn you this is very

1018
00:46:47,500 --> 00:46:43,940
red shifted yes so this is gas this red

1019
00:46:51,609 --> 00:46:47,510
blob here is gas going 400 kilometers

1020
00:46:53,980 --> 00:46:51,619
per second away from this point and the

1021
00:46:58,720 --> 00:46:53,990
gas here is going 400 kilometers per

1022
00:47:01,960 --> 00:46:58,730
second away towards us and that's in the

1023
00:47:03,099 --> 00:47:01,970
middle so when you see this this tells

1024
00:47:05,680 --> 00:47:03,109
you you're actually looking at an

1025
00:47:08,500 --> 00:47:05,690
outflow we were looking at an outflow in

1026
00:47:11,289 --> 00:47:08,510
the cold star forming gas there was cold

1027
00:47:13,059 --> 00:47:11,299
star forming gas that this a GN /

1028
00:47:18,450 --> 00:47:13,069
supermassive black hole was picking up

1029
00:47:21,700 --> 00:47:18,460
and throwing out of the galaxy so again

1030
00:47:24,190 --> 00:47:21,710
this picture I hope you can also see

1031
00:47:26,440 --> 00:47:24,200
where this Hubble image is showing you

1032
00:47:28,390 --> 00:47:26,450
dust that's telling you that there is

1033
00:47:29,950 --> 00:47:28,400
cold gas at the core of a dust cone

1034
00:47:35,640 --> 00:47:29,960
which again Hubble's image for us

1035
00:47:40,900 --> 00:47:35,650
beautifully so that's really interesting

1036
00:47:44,260 --> 00:47:40,910
we've now found a way to take gas that

1037
00:47:46,030 --> 00:47:44,270
is right in the center of a galaxy throw

1038
00:47:49,750 --> 00:47:46,040

it out of that galaxy so that galaxy is

1039
00:47:52,299 --> 00:47:49,760
done it might not be a case that gas way

1040
00:47:54,609 --> 00:47:52,309
out here this black hole can do much to

1041
00:47:57,250 --> 00:47:54,619
it has to be a really really bright

1042
00:47:59,200 --> 00:47:57,260
terrible thing to affect gas out here

1043
00:48:01,780 --> 00:47:59,210
this should also make you feel pretty

1044
00:48:03,609 --> 00:48:01,790
safe we are eight kiloparsecs that is

1045
00:48:06,400 --> 00:48:03,619
like way out here compared to the center

1046
00:48:08,049 --> 00:48:06,410
of the Milky Way so it would take a lot

1047
00:48:09,880 --> 00:48:08,059
of really crazy stuff to happen at

1048
00:48:11,950 --> 00:48:09,890
Sagittarius a star the center of our own

1049
00:48:14,200 --> 00:48:11,960
galaxy in the supermassive black hole

1050
00:48:17,410 --> 00:48:14,210
there to do anything really significant

1051
00:48:20,380 --> 00:48:17,420
and terrible to us so that's again great

1052
00:48:22,180 --> 00:48:20,390
for us annoying for astronomers because

1053
00:48:23,980 --> 00:48:22,190
their astronomers you want to get rid of

1054
00:48:26,380 --> 00:48:23,990
gas here because again we know these

1055
00:48:28,510 --> 00:48:26,390
galaxies are red and dead you can't do

1056
00:48:30,750 --> 00:48:28,520
it with something there if you move the

1057
00:48:33,720 --> 00:48:30,760
gas in to there

1058
00:48:36,690 --> 00:48:33,730
we now know even a little wimpy not

1059
00:48:43,200 --> 00:48:36,700
super powerful blackhole can do a huge

1060
00:48:44,430 --> 00:48:43,210
amount so that's great it's wonderful

1061
00:48:45,950 --> 00:48:44,440
when you find a thing that starts to

1062
00:48:49,040 --> 00:48:45,960
answer some of the questions you have

1063
00:48:54,240 --> 00:48:49,050

but there's a problem

1064
00:48:56,870 --> 00:48:54,250
like any case study it's one thing has

1065
00:49:00,590 --> 00:48:56,880
anyone ever fit a line to a single point

1066
00:49:03,300 --> 00:49:00,600
you should not do that that's bad

1067
00:49:06,150 --> 00:49:03,310
because you can fit an infinite number

1068
00:49:08,430 --> 00:49:06,160
of lines to that point that means to us

1069
00:49:10,290 --> 00:49:08,440
yes we found one way one thing to do a

1070
00:49:11,910 --> 00:49:10,300
thing and that's great that means

1071
00:49:13,770 --> 00:49:11,920
probably in the universe there are more

1072
00:49:15,450 --> 00:49:13,780
galaxies like this more places that

1073
00:49:17,880 --> 00:49:15,460
dinky little black holes are able to

1074
00:49:21,270 --> 00:49:17,890
remove their gas and effectively kill

1075
00:49:23,370 --> 00:49:21,280
off their galaxies but I kind of want to

1076
00:49:25,440 --> 00:49:23,380
know if that's really common is it

1077
00:49:28,290 --> 00:49:25,450
something you see all the time if you

1078
00:49:30,000 --> 00:49:28,300
look at the early universe when all of

1079
00:49:32,520 --> 00:49:30,010
the star formation seems to be falling

1080
00:49:35,670 --> 00:49:32,530
off at the same time is that kind of

1081
00:49:37,800 --> 00:49:35,680
thing happening there too is it rare and

1082
00:49:40,290 --> 00:49:37,810
I just got really lucky as a graduate

1083
00:49:42,030 --> 00:49:40,300
student or is it common and I just

1084
00:49:44,370 --> 00:49:42,040
happen to be one of the first people who

1085
00:49:45,060 --> 00:49:44,380
had instruments available to me to put

1086
00:49:49,020 --> 00:49:45,070
it all together

1087
00:49:51,000 --> 00:49:49,030
is there a circle of life in the

1088
00:49:52,670 --> 00:49:51,010

galaxies is it a case that these

1089
00:49:54,750 --> 00:49:52,680
galaxies are gonna come back someday

1090
00:49:55,380 --> 00:49:54,760
well it turns out to do any of that

1091
00:49:58,109 --> 00:49:55,390
stuff

1092
00:50:00,300 --> 00:49:58,119
ya actually need to find more you can't

1093
00:50:03,300 --> 00:50:00,310
just make all of the answers up with one

1094
00:50:08,190 --> 00:50:03,310
thing unfortunately as much as poor

1095
00:50:10,920 --> 00:50:08,200
graduate student may wish you could so I

1096
00:50:12,359 --> 00:50:10,930
wanted to find new ones of these and

1097
00:50:16,170 --> 00:50:12,369
that's actually a part of the reason I'm

1098
00:50:18,720 --> 00:50:16,180
now here is how do you find and the way

1099
00:50:21,930 --> 00:50:18,730
we did it was we looked at special

1100
00:50:24,840 --> 00:50:21,940
things about NGC 1266 I told you really

1101
00:50:27,240 --> 00:50:24,850
early on about ionized gas in star

1102
00:50:29,460 --> 00:50:27,250
forming regions the hot ultraviolet

1103
00:50:32,400 --> 00:50:29,470
light and stars are able to irradiate

1104
00:50:35,430 --> 00:50:32,410
the gas and that gas is going to rear 88

1105
00:50:37,680 --> 00:50:35,440
out in lines it turns out there are

1106
00:50:40,290 --> 00:50:37,690
other things that can do that if for

1107
00:50:42,970 --> 00:50:40,300
instance you shock the gas that is you

1108
00:50:44,560 --> 00:50:42,980
collide the gas into itself your

1109
00:50:47,580 --> 00:50:44,570
also going to heat up that gas and that

1110
00:50:51,010 --> 00:50:47,590
gas is also going to radiate and finally

1111
00:50:53,590 --> 00:50:51,020
when a galaxy has stopped has stopped

1112
00:50:55,660 --> 00:50:53,600
forming stars there is a period of time

1113
00:50:57,790 --> 00:50:55,670

that's a little bit special because that

1114
00:51:00,310 --> 00:50:57,800
galaxy is still going to have some young

1115
00:51:04,690 --> 00:51:00,320
stars but it's no longer gonna have

1116
00:51:07,330 --> 00:51:04,700
infinite stars and because maybe you can

1117
00:51:09,670 --> 00:51:07,340
find that snapshot on time you can find

1118
00:51:11,230 --> 00:51:09,680
more of these things when we looked we

1119
00:51:14,859 --> 00:51:11,240
found these were two things that NGC

1120
00:51:17,440 --> 00:51:14,869
1266 had it had shocked gas and we were

1121
00:51:19,720 --> 00:51:17,450
able to tell because the energy coming

1122
00:51:21,849 --> 00:51:19,730
out of a shock makes the gas emission

1123
00:51:23,080 --> 00:51:21,859
lines look a little bit different than

1124
00:51:25,480 --> 00:51:23,090
it does when it's coming from star

1125
00:51:29,560 --> 00:51:25,490
formation and we could find through

1126
00:51:32,140 --> 00:51:29,570
absorption of the through a spectral

1127
00:51:35,080 --> 00:51:32,150
absorption that is certain kinds of

1128
00:51:38,109 --> 00:51:35,090
stars have certain gas that's absorbing

1129
00:51:41,050 --> 00:51:38,119
different different lines different

1130
00:51:44,830 --> 00:51:41,060
radiation you find young but not infant

1131
00:51:47,760 --> 00:51:44,840
stars and so we formed a team and an

1132
00:51:50,200 --> 00:51:47,770
acronym which in astronomy is a big deal

1133
00:51:54,940 --> 00:51:50,210
we were looking for shock to post

1134
00:51:56,859 --> 00:51:54,950
starburst galaxies or Sparks and I will

1135
00:51:59,290 --> 00:51:56,869
warn you you might not take much from my

1136
00:52:02,530 --> 00:51:59,300
talk today you will probably remember

1137
00:52:04,510 --> 00:52:02,540
this acronym that's what makes it good

1138
00:52:09,820 --> 00:52:04,520

not that it's creative not that it makes

1139
00:52:12,810 --> 00:52:09,830
you smile it's sticks in your brain and

1140
00:52:16,000 --> 00:52:12,820
so that's what I did is I looked at a

1141
00:52:18,190 --> 00:52:16,010
survey of millions of galaxies spectra

1142
00:52:21,030 --> 00:52:18,200
and I looked for that special

1143
00:52:24,460 --> 00:52:21,040
combination that we found in NGC 1266 I

1144
00:52:26,320 --> 00:52:24,470
looked for the special spectral

1145
00:52:28,240 --> 00:52:26,330
signatures that told me there was gas in

1146
00:52:31,420 --> 00:52:28,250
those galaxies but that gas was not

1147
00:52:34,180 --> 00:52:31,430
forming stars that gas was shocked and I

1148
00:52:37,540 --> 00:52:34,190
looked for signs in the spectra of young

1149
00:52:39,400 --> 00:52:37,550
stars but not infant stars so not the

1150
00:52:41,200 --> 00:52:39,410
ones that are gonna supernova right now

1151
00:52:44,050 --> 00:52:41,210
because they're still actively forming

1152
00:52:46,060 --> 00:52:44,060
and we found out of millions of galaxies

1153
00:52:47,650 --> 00:52:46,070
we had to cut it down to about a hundred

1154
00:52:49,210 --> 00:52:47,660
thousand that had high enough

1155
00:52:50,680 --> 00:52:49,220
signal-to-noise that is they were bright

1156
00:52:53,650 --> 00:52:50,690
enough for us to actually do the search

1157
00:52:55,719 --> 00:52:53,660
we found over about a thousand galaxies

1158
00:53:01,329 --> 00:52:55,729
that were

1159
00:53:06,079 --> 00:53:01,339
1266 they were kind of galactic zombies

1160
00:53:08,989 --> 00:53:06,089
and because astronomers actually tried

1161
00:53:10,609 --> 00:53:08,999
like to share their knowledge you can

1162
00:53:14,779 --> 00:53:10,619
actually go and look at the catalog of

1163
00:53:16,309 --> 00:53:14,789

all 1067 of these galaxies on a little

1164
00:53:18,349 --> 00:53:16,319
website and again

1165
00:53:20,719 --> 00:53:18,359
luckily the acronym fog will stick in

1166
00:53:22,699 --> 00:53:20,729
your head so that website might - and

1167
00:53:24,769 --> 00:53:22,709
again this is just fun this is all

1168
00:53:26,569 --> 00:53:24,779
science there's nothing on there to buy

1169
00:53:28,609 --> 00:53:26,579
nothing like that you just basically go

1170
00:53:30,799 --> 00:53:28,619
get get to go look at like thumbnails of

1171
00:53:35,959 --> 00:53:30,809
cool galaxies for a while because some

1172
00:53:39,769 --> 00:53:35,969
of them look pretty wild then comes the

1173
00:53:41,029 --> 00:53:39,779
final phase so I've told you some of the

1174
00:53:43,759 --> 00:53:41,039
ways that we have figured out how

1175
00:53:46,789 --> 00:53:43,769
galaxies trigger their transition and

1176
00:53:49,099 --> 00:53:46,799
become dead I talked to you about the

1177
00:53:51,169 --> 00:53:49,109
ways that something inside of the galaxy

1178
00:53:53,719 --> 00:53:51,179
itself can actually cause this these

1179
00:53:56,329 --> 00:53:53,729
galaxies to die and I've talked to you

1180
00:53:58,429 --> 00:53:56,339
about how maybe we can find more that

1181
00:54:01,729 --> 00:53:58,439
are just on this cusp of death where we

1182
00:54:03,380 --> 00:54:01,739
can learn a lot but there's something

1183
00:54:05,449 --> 00:54:03,390
cool about the ones that are the walking

1184
00:54:07,699 --> 00:54:05,459
dead the ellipticals and the lenticular

1185
00:54:09,439 --> 00:54:07,709
x' those that have already gone through

1186
00:54:12,199 --> 00:54:09,449
all of these processes are done with

1187
00:54:17,799 --> 00:54:12,209
their star forming gaps and really just

1188
00:54:20,179 --> 00:54:17,809

are red don't have young stars so again

1189
00:54:22,159 --> 00:54:20,189
the murder takes the gas out of the

1190
00:54:24,140 --> 00:54:22,169
ghoul the murderer puts the gas into the

1191
00:54:26,029 --> 00:54:24,150
middle of the galaxy the black hole does

1192
00:54:30,199 --> 00:54:26,039
the rest and gets the gas out of the

1193
00:54:32,359 --> 00:54:30,209
galaxy then because at some point you

1194
00:54:34,130 --> 00:54:32,369
can't recover that gas be fell into a

1195
00:54:38,120 --> 00:54:34,140
cluster that gas is gone it's all part

1196
00:54:42,649 --> 00:54:38,130
of the hot cluster halo you end with

1197
00:54:45,529 --> 00:54:42,659
just this big bright thing these are

1198
00:54:47,630 --> 00:54:45,539
interesting too because just because

1199
00:54:49,130 --> 00:54:47,640
it's red doesn't mean there is not

1200
00:54:53,979 --> 00:54:49,140
something interesting going on in it

1201
00:54:56,209 --> 00:54:53,989
because those stars are old stars and

1202
00:54:59,449 --> 00:54:56,219
their stars that have been around a

1203
00:55:01,429 --> 00:54:59,459
really long time so it turns out if we

1204
00:55:02,989 --> 00:55:01,439
look at those kinds of stars the stars

1205
00:55:04,549 --> 00:55:02,999
we see that make up these red and dead

1206
00:55:06,919 --> 00:55:04,559
galaxies for instance in the Bulge of

1207
00:55:07,520 --> 00:55:06,929
our own galaxy we're starting to learn

1208
00:55:10,250 --> 00:55:07,530
things

1209
00:55:12,500 --> 00:55:10,260
stars that formed towards the beginning

1210
00:55:15,770 --> 00:55:12,510
of the universe as opposed to these

1211
00:55:17,690 --> 00:55:15,780
young rock star supernova stars that are

1212
00:55:19,010 --> 00:55:17,700
there and gone but they're not telling

1213
00:55:25,370 --> 00:55:19,020

us about the beginning of the universe

1214
00:55:27,230 --> 00:55:25,380
where some of these can so here are some

1215
00:55:28,840 --> 00:55:27,240
of the galaxies these are again NGC

1216
00:55:31,520 --> 00:55:28,850
numbers which is new galactic catalog

1217
00:55:33,500 --> 00:55:31,530
some of these red and galaxies got into

1218
00:55:36,380 --> 00:55:33,510
mezes catalog and maybe seven is a

1219
00:55:37,880 --> 00:55:36,390
really good example of one Messier 807

1220
00:55:42,710 --> 00:55:37,890
is at the center of the Coma Cluster

1221
00:55:44,510 --> 00:55:42,720
which is a very nearby cluster to us and

1222
00:55:47,510 --> 00:55:44,520
I guess I leave with the more

1223
00:55:51,650 --> 00:55:47,520
philosophical question here which is

1224
00:55:53,660 --> 00:55:51,660
what will become of us so you might have

1225
00:55:55,730 --> 00:55:53,670
seen that murder those two beautiful gas

1226
00:55:58,670 --> 00:55:55,740
rich discs that I showed and talk to

1227
00:56:00,110 --> 00:55:58,680
yourself huh we have a gas rich disk

1228
00:56:04,430 --> 00:56:00,120
that's kind of next door

1229
00:56:08,240 --> 00:56:04,440
I wonder what's gonna happen well I will

1230
00:56:12,260 --> 00:56:08,250
say this is a visualization an artist's

1231
00:56:15,440 --> 00:56:12,270
rendition not a simulation but let's say

1232
00:56:18,110 --> 00:56:15,450
in the billion year future future

1233
00:56:20,060 --> 00:56:18,120
Earthlings who have evolved beyond

1234
00:56:23,480 --> 00:56:20,070
bodies and now can live sort of

1235
00:56:26,030 --> 00:56:23,490
immortally we're sitting on earth what

1236
00:56:29,350 --> 00:56:26,040
would it look like to them as time

1237
00:56:36,230 --> 00:56:29,360
marched on and we met our friend

1238
00:56:39,680 --> 00:56:36,240

Andromeda usually this comes with music

1239
00:56:44,300 --> 00:56:39,690
we could not make it work so I shall

1240
00:56:47,810 --> 00:56:44,310
narrate so again when you look up in the

1241
00:56:49,970 --> 00:56:47,820
sky this is kind of what you see you see

1242
00:56:58,250 --> 00:56:49,980
that right there I bet you can guess

1243
00:57:00,680 --> 00:56:58,260
what that is that's Andromeda so we're

1244
00:57:02,780 --> 00:57:00,690
going around again this is supposed to

1245
00:57:05,570 --> 00:57:02,790
be from the perspective of an earthling

1246
00:57:09,230 --> 00:57:05,580
sitting on earth moving around the

1247
00:57:11,710 --> 00:57:09,240
galaxy because we orbit the Sun the Sun

1248
00:57:14,600 --> 00:57:11,720
also is orbiting the whole galaxy and

1249
00:57:16,880 --> 00:57:14,610
watching as we get closer and closer

1250
00:57:18,890 --> 00:57:16,890
because of the inevitable pull of

1251
00:57:26,770 --> 00:57:18,900
gravity between the Milky Way and

1252
00:57:31,370 --> 00:57:28,130
yeah

1253
00:57:33,590 --> 00:57:31,380
now again they don't just come together

1254
00:57:38,030 --> 00:57:33,600
and smash into each other we're on

1255
00:57:39,880 --> 00:57:38,040
orbits but this probably looks like that

1256
00:57:46,340 --> 00:57:39,890
nice photos on the sheet that you have

1257
00:57:48,350 --> 00:57:46,350
that's again our future maybe but you

1258
00:57:51,080 --> 00:57:48,360
can also see that now there's a lot more

1259
00:57:53,720 --> 00:57:51,090
blue because as these two things collide

1260
00:57:55,760 --> 00:57:53,730
into each other the gas is starting to

1261
00:57:57,980 --> 00:57:55,770
compress it starting to shock it's

1262
00:58:01,010 --> 00:57:57,990
starting to make super star starbursts

1263
00:58:03,590 --> 00:58:01,020

but also unfortunately that gravity

1264
00:58:06,590 --> 00:58:03,600
coming from that pesky Andromeda has now

1265
00:58:09,080 --> 00:58:06,600
thrown us into a really really bad orbit

1266
00:58:11,810 --> 00:58:09,090
we are no longer safely in the disk of

1267
00:58:17,840 --> 00:58:11,820
the galaxy we are now getting shot off

1268
00:58:25,850 --> 00:58:17,850
all over the place in our orbit it's

1269
00:58:35,000 --> 00:58:25,860
great for the view but maybe not so much

1270
00:58:39,140 --> 00:58:35,010
for us so again I turn to my little

1271
00:58:40,790 --> 00:58:39,150
summary of the different ways you can

1272
00:58:44,660 --> 00:58:40,800
die in the universe I know I promised

1273
00:58:47,870 --> 00:58:44,670
you a hundred ways I apologize I was

1274
00:58:56,500 --> 00:58:47,880
going for the gimmick but I've given you

1275
00:59:02,900 --> 00:59:01,160
obviously even though we have thousands

1276
00:59:04,790 --> 00:59:02,910
of galaxies even though Hubble has

1277
00:59:07,100 --> 00:59:04,800
revolutionized our world even though the

1278
00:59:09,410 --> 00:59:07,110
launch of James Webb is going to do

1279
00:59:12,910 --> 00:59:09,420
these in gorgeous Hubble images but even

1280
00:59:15,520 --> 00:59:12,920
further back in the universe and in time

1281
00:59:18,740 --> 00:59:15,530
we still don't have all the answers

1282
00:59:21,890 --> 00:59:18,750
we found one galaxy like NGC we found

1283
00:59:24,680 --> 00:59:21,900
one NGC 1266 that is teaching us a huge

1284
00:59:26,690 --> 00:59:24,690
amount about what happens after the

1285
00:59:29,420 --> 00:59:26,700
galaxy is dying and after that galaxy

1286
00:59:32,760 --> 00:59:29,430
has stopped has been doomed to stop

1287
00:59:35,609 --> 00:59:32,770
forming stars and yet

1288
00:59:36,720 --> 00:59:35,619

we don't know how common that is we

1289
00:59:39,090 --> 00:59:36,730
don't know if that's the way all

1290
00:59:41,760 --> 00:59:39,100
galaxies across all of the universe have

1291
00:59:43,770 --> 00:59:41,770
died we do not know if falling into the

1292
00:59:46,770 --> 00:59:43,780
cluster is the most important part

1293
00:59:49,070 --> 00:59:46,780
or if galaxies merge and die in groups

1294
00:59:55,140 --> 00:59:49,080
before they fall into those clusters and

1295
01:00:15,810 --> 00:59:55,150
so again I have to say as an observer we

1296
01:00:18,240 --> 01:00:15,820
always need more data Thank You microns

1297
01:00:20,730 --> 01:00:18,250
on good alright so we are now at

1298
01:00:23,930 --> 01:00:20,740
questions so who has a question and

1299
01:00:25,890 --> 01:00:23,940
we'll bring the microphone to you I

1300
01:00:35,430 --> 01:00:25,900
guess somebody's phoning in with a

1301
01:00:38,580 --> 01:00:35,440
question you should an example of the

1302
01:00:40,320 --> 01:00:38,590
jellyfish galaxies so my question was

1303
01:00:42,090 --> 01:00:40,330
what would cause the gas to be siphoned

1304
01:00:43,770 --> 01:00:42,100
off and multiple distinct tendrils

1305
01:00:49,170 --> 01:00:43,780
rather than being siphoned off uniformly

1306
01:00:50,790 --> 01:00:49,180
all around oh that's actually so I'm

1307
01:00:52,650 --> 01:00:50,800
gonna assume everyone heard the question

1308
01:00:55,290 --> 01:00:52,660
because of that awesome cute microphone

1309
01:00:56,460 --> 01:00:55,300
so that's because gas and galaxies does

1310
01:00:58,590 --> 01:00:56,470
not look uniform

1311
01:01:00,630 --> 01:00:58,600
if the galaxies if the gas at the

1312
01:01:02,730 --> 01:01:00,640
galaxy's falling into is completely

1313
01:01:04,470 --> 01:01:02,740

uniform and smooth and the gas in the

1314
01:01:06,900 --> 01:01:04,480
galaxy was completely uniform and smooth

1315
01:01:09,570 --> 01:01:06,910
you might expect that but in both cases

1316
01:01:12,030 --> 01:01:09,580
we know that the gas is extremely clumpy

1317
01:01:14,640 --> 01:01:12,040
so the fact that you're falling you're a

1318
01:01:16,590 --> 01:01:14,650
clumpy thing that's falling into kind of

1319
01:01:18,359 --> 01:01:16,600
a clumpy thing though the gas in the

1320
01:01:19,980 --> 01:01:18,369
galaxy is probably clunkier than the gas

1321
01:01:26,400 --> 01:01:19,990
in the cluster that's why there are

1322
01:01:28,800 --> 01:01:26,410
tendrils yeah in front of what structure

1323
01:01:32,220 --> 01:01:28,810
are you standing and where is it oh um

1324
01:01:34,560 --> 01:01:32,230
again this is unfortunately the Karma

1325
01:01:36,780 --> 01:01:34,570
array up in Owens Valley California

1326
01:01:41,790 --> 01:01:36,790
which is now in the valley and has been

1327
01:01:44,670 --> 01:01:41,800
decommissioned yeah there is Alma which

1328
01:01:46,200 --> 01:01:44,680
is at 16,000 feet in the Atacama Desert

1329
01:01:49,260 --> 01:01:46,210
of Chile but I have never

1330
01:01:53,550 --> 01:01:49,270
myself up enough to go so really that's

1331
01:01:57,210 --> 01:01:53,560
that's high-altitude but there's a there

1332
01:01:58,920 --> 01:01:57,220
telescopes like this in on Mauna Kea

1333
01:02:00,660 --> 01:01:58,930
called the submillimetre array for

1334
01:02:02,820 --> 01:02:00,670
anyone who's ever thought to go to Mauna

1335
01:02:07,050 --> 01:02:02,830
Kea you can actually see structures like

1336
01:02:11,280 --> 01:02:07,060
this in the case there of the the

1337
01:02:13,620 --> 01:02:11,290
collision scenarios do we ever get

1338
01:02:16,800 --> 01:02:13,630

relativistic effects general relativity

1339
01:02:19,440 --> 01:02:16,810
effects you talked about the gradients

1340
01:02:21,839 --> 01:02:19,450
the contour lines are their

1341
01:02:24,720 --> 01:02:21,849
gravitational contour lines as we get

1342
01:02:27,390 --> 01:02:24,730
closer to the center as they begin to

1343
01:02:29,070 --> 01:02:27,400
intersect I realized that these are

1344
01:02:31,230 --> 01:02:29,080
clusters and I realized that the

1345
01:02:35,430 --> 01:02:31,240
majority of the mass is actually dust

1346
01:02:37,620 --> 01:02:35,440
not solid objects would spill right so I

1347
01:02:39,420 --> 01:02:37,630
will say that ideal on the meso scale so

1348
01:02:40,980 --> 01:02:39,430
most of the scales I'm working on are

1349
01:02:45,359 --> 01:02:40,990
Killip hundreds of parsecs to

1350
01:02:47,190 --> 01:02:45,369
kiloparsecs so 300 light years to 3,000

1351
01:02:48,690 --> 01:02:47,200
light years I'm on those scales you

1352
01:02:51,359 --> 01:02:48,700
don't really see those relativistic

1353
01:02:53,310 --> 01:02:51,369
effects that being said there are a

1354
01:02:55,859 --> 01:02:53,320
couple of very cool scenarios and things

1355
01:02:58,140 --> 01:02:55,869
that do have relativistic effects first

1356
01:02:59,880 --> 01:02:58,150
is in some of these kinds of galaxies

1357
01:03:02,550 --> 01:02:59,890
there seemed to be relativistic radio

1358
01:03:05,490 --> 01:03:02,560
jets that can form that they're called

1359
01:03:08,490 --> 01:03:05,500
radio galaxies and in those cases you

1360
01:03:10,760 --> 01:03:08,500
actually have such a big black hole that

1361
01:03:13,650 --> 01:03:10,770
you have basically high-powered radio

1362
01:03:15,540 --> 01:03:13,660
plasmas coming out and you can see it

1363
01:03:17,700 --> 01:03:15,550

really really far away from the galaxies

1364
01:03:19,560 --> 01:03:17,710
the other place that relativistic

1365
01:03:21,630 --> 01:03:19,570
effects are sort of interesting is that

1366
01:03:24,329 --> 01:03:21,640
in some of these mergers and these

1367
01:03:26,280 --> 01:03:24,339
galaxies that are very post-merger those

1368
01:03:28,800 --> 01:03:26,290
are actually the galaxies that have such

1369
01:03:30,870 --> 01:03:28,810
a wacky gravitational torques in the

1370
01:03:32,910 --> 01:03:30,880
centres you can actually get tidal

1371
01:03:38,010 --> 01:03:32,920
disruption events which is where stars

1372
01:03:40,650 --> 01:03:38,020
fall directly into the black holes yeah

1373
01:03:42,870 --> 01:03:40,660
so I mean the the relativistic effects

1374
01:03:44,730 --> 01:03:42,880
are really strong around the

1375
01:03:46,200 --> 01:03:44,740
supermassive black holes and you get

1376
01:03:51,239 --> 01:03:46,210
that but that's much smaller scale than

1377
01:03:56,709 --> 01:03:54,789
it is and we learned we actually have

1378
01:03:58,779 --> 01:03:56,719
learned a lot from a couple of these

1379
01:04:00,939 --> 01:03:58,789
tidal disruption events we've seen I'm

1380
01:04:02,380 --> 01:04:00,949
again the thing the super cool is we

1381
01:04:04,900 --> 01:04:02,390
keep seeing these tidal disruption

1382
01:04:07,150 --> 01:04:04,910
events in these weird types of galaxies

1383
01:04:10,539 --> 01:04:07,160
these galaxies are rare the kind of

1384
01:04:13,569 --> 01:04:10,549
zombie galaxies I study are 1% of modern

1385
01:04:15,160 --> 01:04:13,579
galaxies and yet in in these events

1386
01:04:16,539 --> 01:04:15,170
where you're finding these stars that

1387
01:04:18,309 --> 01:04:16,549
are actually starting to give you an

1388
01:04:20,739 --> 01:04:18,319

idea of what the black hole spin is

1389
01:04:21,819 --> 01:04:20,749
because you can actually model it you're

1390
01:04:23,949 --> 01:04:21,829
finding them in these weird

1391
01:04:27,400 --> 01:04:23,959
one-percenters and not really finding

1392
01:04:30,609 --> 01:04:27,410
them as much in other things when when

1393
01:04:32,709 --> 01:04:30,619
the galaxies collide do you and the

1394
01:04:35,349 --> 01:04:32,719
actually do the actually form new

1395
01:04:37,630 --> 01:04:35,359
molecular structure when when they

1396
01:04:40,269 --> 01:04:37,640
actually come together to the what

1397
01:04:44,289 --> 01:04:40,279
actually does collide um for the most

1398
01:04:45,670 --> 01:04:44,299
part gas so the the actual stars for the

1399
01:04:47,679 --> 01:04:45,680
most part don't collide with one another

1400
01:04:49,959 --> 01:04:47,689
there's probably I don't know what the

1401
01:04:51,279 --> 01:04:49,969
chances are there's like a 1% chance in

1402
01:04:54,819 --> 01:04:51,289
one of these collisions you have one

1403
01:04:57,069 --> 01:04:54,829
star hit one star yeah lower it's very

1404
01:04:58,509 --> 01:04:57,079
very small the gas on the other hand

1405
01:05:01,359 --> 01:04:58,519
actually does collide with each other

1406
01:05:03,880 --> 01:05:01,369
and it shocks and when it shocks it

1407
01:05:05,799 --> 01:05:03,890
turns out you do actually sometimes form

1408
01:05:07,509 --> 01:05:05,809
different molecular structures but

1409
01:05:10,479 --> 01:05:07,519
that's because the gas is being heated

1410
01:05:12,219 --> 01:05:10,489
so much that things like the dust which

1411
01:05:15,219 --> 01:05:12,229
has you know the dust which was normally

1412
01:05:17,019 --> 01:05:15,229
pretty happy is sublimated and so all of

1413
01:05:20,289 --> 01:05:17,029

a sudden the sublimated dust is now

1414
01:05:22,959 --> 01:05:20,299
gaseous and so for instance in some of

1415
01:05:24,969 --> 01:05:22,969
these galaxies uh but even closer to

1416
01:05:27,549 --> 01:05:24,979
home things like star protostars

1417
01:05:29,949 --> 01:05:27,559
you see things like silicon oxide in the

1418
01:05:32,859 --> 01:05:29,959
radio spectra because the dust has been

1419
01:05:35,799 --> 01:05:32,869
destroyed in them from these shocks okay

1420
01:05:39,039 --> 01:05:35,809
we have a comment from online while dare

1421
01:05:44,730 --> 01:05:39,049
grant given that your title is actually

1422
01:05:54,339 --> 01:05:48,999
whoever that is like cannot attend man

1423
01:05:57,759 --> 01:05:54,349
well I got to it's gotta to you

1424
01:06:01,269 --> 01:05:57,769
characterize the little galaxies is

1425
01:06:04,569 --> 01:06:01,279
sighing and but they seem to live live

1426
01:06:06,789 --> 01:06:04,579
long lives out of house their lifespan

1427
01:06:09,849 --> 01:06:06,799
on average compared with those of the

1428
01:06:13,240 --> 01:06:09,859
spiral galaxies um

1429
01:06:14,740 --> 01:06:13,250
I think the thing that oh wait was the

1430
01:06:20,740 --> 01:06:14,750
way that I always like to think about it

1431
01:06:23,620 --> 01:06:20,750
is galaxies are like cities so in let's

1432
01:06:25,180 --> 01:06:23,630
say New York City you have a set of

1433
01:06:26,650 --> 01:06:25,190
people who have been living you know a

1434
01:06:28,390 --> 01:06:26,660
nice life that are getting towards

1435
01:06:30,519 --> 01:06:28,400
retirement age and are pretty happy and

1436
01:06:32,859 --> 01:06:30,529
pretty calm but then you also have like

1437
01:06:35,680 --> 01:06:32,869
the young rock stars and like things

1438
01:06:38,289 --> 01:06:35,690

going on in those cities and so in in

1439
01:06:40,089 --> 01:06:38,299
disk galaxies um you still have those

1440
01:06:42,160 --> 01:06:40,099
star formation events but that city

1441
01:06:43,870 --> 01:06:42,170
could be very old and you just have like

1442
01:06:45,190 --> 01:06:43,880
the people who have been watching you

1443
01:06:46,720 --> 01:06:45,200
know on their balconies and like

1444
01:06:48,460 --> 01:06:46,730
smelling the fresh air and thinking

1445
01:06:50,620 --> 01:06:48,470
about how things were which is these red

1446
01:06:52,779 --> 01:06:50,630
stars are like looking down and seeing

1447
01:06:55,870 --> 01:06:52,789
the frenetic frantic activities of the

1448
01:06:57,370 --> 01:06:55,880
younger supernovae in stars whereas in

1449
01:06:58,990 --> 01:06:57,380
the elliptical galaxies you're basically

1450
01:07:00,700 --> 01:06:59,000
living in a place where all of the stars

1451
01:07:03,789 --> 01:07:00,710
are are old

1452
01:07:05,380 --> 01:07:03,799
so again Edwin Hubble had it wrong when

1453
01:07:07,390 --> 01:07:05,390
Edwin put together the sequence

1454
01:07:09,460 --> 01:07:07,400
he thought early types became late types

1455
01:07:11,079 --> 01:07:09,470
which is what we call them spiral

1456
01:07:12,730 --> 01:07:11,089
galaxies are late types I tried very

1457
01:07:18,430 --> 01:07:12,740
hard not to say it because I think it is

1458
01:07:21,339 --> 01:07:18,440
confusing but even in our Milky Way the

1459
01:07:22,660 --> 01:07:21,349
Bulge of our Milky Way is quite old even

1460
01:07:26,140 --> 01:07:22,670
though the disk of our Milky Way on

1461
01:07:28,240 --> 01:07:26,150
average is young so it just comes down

1462
01:07:31,450 --> 01:07:28,250
to the proportion of old to young they

1463
01:07:33,099 --> 01:07:31,460

can both have around the same age but

1464
01:07:35,049 --> 01:07:33,109
they just have been living and acting

1465
01:07:36,549 --> 01:07:35,059
differently in those ages because again

1466
01:07:40,599 --> 01:07:36,559
they're not people they're cities in

1467
01:07:42,819 --> 01:07:40,609
this case so it's the populations okay

1468
01:07:45,430 --> 01:07:42,829
we have a question from online why do

1469
01:07:49,980 --> 01:07:45,440
most young stars appear in the galaxy

1470
01:07:57,670 --> 01:07:54,279
well I want to think about that because

1471
01:07:59,770 --> 01:07:57,680
in my systems they're all of the nucleus

1472
01:08:02,289 --> 01:07:59,780
because that's where the gas is and I

1473
01:08:05,559 --> 01:08:02,299
think for the most part the start the

1474
01:08:07,750 --> 01:08:05,569
young stars follow where the gases so it

1475
01:08:09,880 --> 01:08:07,760
turns out in the center of the Milky Way

1476
01:08:11,319 --> 01:08:09,890
there is a lot of star information going

1477
01:08:13,779 --> 01:08:11,329
on it's called the central molecular

1478
01:08:15,400 --> 01:08:13,789
zone there's dense gas there's but the

1479
01:08:21,630 --> 01:08:15,410
arms is where you're seeing the majority

1480
01:08:37,990 --> 01:08:21,640
of it um so the answer is follow the gas

1481
01:08:41,740 --> 01:08:38,000
okay do all galaxies die eventually yeah

1482
01:08:45,550 --> 01:08:41,750
so our universe seems to show a

1483
01:08:47,470 --> 01:08:45,560
hierarchy the bigger a galaxy is the

1484
01:08:50,349 --> 01:08:47,480
more likely the galaxy is to be dead

1485
01:08:53,559 --> 01:08:50,359
which is what caused the pause so if

1486
01:08:56,530 --> 01:08:53,569
you're a small small galaxy you probably

1487
01:08:58,539 --> 01:08:56,540
have had the supply of gas available to

1488
01:09:00,070 --> 01:08:58,549

you for longer and it's going to be

1489
01:09:02,640 --> 01:09:00,080
available to you for longer than a

1490
01:09:06,039 --> 01:09:02,650
really big galaxy eventually yes

1491
01:09:07,840 --> 01:09:06,049
eventually it's likely all gas is going

1492
01:09:09,130 --> 01:09:07,850
to be consumed in galaxies all stars are

1493
01:09:10,419 --> 01:09:09,140
going to become white works and then

1494
01:09:15,970 --> 01:09:10,429
they're all going to fall into black

1495
01:09:18,370 --> 01:09:15,980
holes but right so that to me doesn't

1496
01:09:22,300 --> 01:09:18,380
seem like quite the answer you want the

1497
01:09:25,030 --> 01:09:22,310
answer is yes all galaxies probably will

1498
01:09:27,640 --> 01:09:25,040
die and the bigger more massive galaxies

1499
01:09:29,820 --> 01:09:27,650
seem to have died first and like

1500
01:09:34,269 --> 01:09:29,830
unfortunately for us in the Milky Way

1501
01:09:36,280 --> 01:09:34,279
we're coming soon another way to look at

1502
01:09:37,990 --> 01:09:36,290
it is if you look at the star formation

1503
01:09:39,519 --> 01:09:38,000
history of the universe it's sort of

1504
01:09:41,650 --> 01:09:39,529
Peaks about two to three billion years

1505
01:09:44,349 --> 01:09:41,660
into the universe and has been declining

1506
01:09:46,930 --> 01:09:44,359
ever since so the maximum amount of star

1507
01:09:49,479 --> 01:09:46,940
formation occurred about ten billion

1508
01:09:53,670 --> 01:09:49,489
years ago in the universe if I remember

1509
01:10:00,640 --> 01:09:58,060
right so so peaked and then it's falling

1510
01:10:02,890 --> 01:10:00,650
ever since so yeah we're on the decline

1511
01:10:06,520 --> 01:10:02,900
yeah at least from a universal

1512
01:10:08,880 --> 01:10:06,530
perspective all right other questions

1513
01:10:15,280 --> 01:10:08,890

[Music]

1514
01:10:19,060 --> 01:10:15,290
all right let's check online there's

1515
01:10:20,860 --> 01:10:19,070
something about will the you talked

1516
01:10:23,560 --> 01:10:20,870
about birth and they're saying you made

1517
01:10:26,110 --> 01:10:23,570
a doomsday prediction for Earth during

1518
01:10:28,180 --> 01:10:26,120
the Milky Way Andromeda collision but

1519
01:10:30,010 --> 01:10:28,190
then the question is of course will

1520
01:10:39,790 --> 01:10:30,020
earth still be here during that

1521
01:10:41,920 --> 01:10:39,800
collision poofed up big enough that it

1522
01:10:45,430 --> 01:10:41,930
basically fries us and maybe even in

1523
01:10:46,660 --> 01:10:45,440
develops us the stellar winds that are

1524
01:10:49,360 --> 01:10:46,670
going to be coming off of it at that

1525
01:10:53,860 --> 01:10:49,370
time will have absolutely crushed us so

1526
01:10:55,660 --> 01:10:53,870
no it will have to be new earth or you

1527
01:10:58,210 --> 01:10:55,670
know will have to be a Star Trek society

1528
01:11:00,070 --> 01:10:58,220
by then and wrists around the galaxy to

1529
01:11:02,110 --> 01:11:00,080
look for places hopefully by then we'll

1530
01:11:04,150 --> 01:11:02,120
have like super wormhole networks that

1531
01:11:07,780 --> 01:11:04,160
can connect us to a galaxy that's not

1532
01:11:09,370 --> 01:11:07,790
about to collide with Andromeda a really

1533
01:11:12,400 --> 01:11:09,380
long time from now we have a lot of

1534
01:11:13,750 --> 01:11:12,410
times the first pass of the collision is

1535
01:11:16,660 --> 01:11:13,760
gonna be about four billion years from

1536
01:11:18,160 --> 01:11:16,670
now and the final merger is about six

1537
01:11:21,340 --> 01:11:18,170
and a half seven billion years from now

1538
01:11:23,680 --> 01:11:21,350

yeah once the Milky Way and Andromeda

1539
01:11:26,740 --> 01:11:23,690
become an elliptical it'll you about six

1540
01:11:29,560 --> 01:11:26,750
seven billion years from now and our Sun

1541
01:11:33,430 --> 01:11:29,570
will have yeah it'll it'll have done its

1542
01:11:35,280 --> 01:11:33,440
own dying thing alright any last

1543
01:11:40,390 --> 01:11:35,290
questions from the audience

1544
01:11:43,480 --> 01:11:40,400
all right next month star is chasing

1545
01:11:47,080 --> 01:11:43,490
supernova with Kepler okay

1546
01:11:49,660 --> 01:11:47,090
in October arena stand up and wave

1547
01:11:51,390 --> 01:11:49,670
everyone say hi we haven't seen before

1548
01:11:53,560 --> 01:11:51,400
once

1549
01:11:54,970 --> 01:11:53,570
if you would like to go across the

1550
01:11:57,760 --> 01:11:54,980
street and look out through the

1551
01:12:04,050 --> 01:11:57,770
telescope in the observatory follow her

1552
01:12:08,890 --> 01:12:07,360
okay there are no there are safety

1553
01:12:11,710 --> 01:12:08,900
regulations there's only so many people

1554
01:12:15,100 --> 01:12:11,720
and they once we got a little bit too

1555
01:12:17,020 --> 01:12:15,110
much yet so uh thank you all for coming

1556
01:12:27,979 --> 01:12:17,030
let's give Katie one more big round and