

1  
00:00:00,000 --> 00:00:04,469  
and and welcome to the Space Telescope

2  
00:00:02,100 --> 00:00:06,778  
Science Institute public lecture series

3  
00:00:04,469 --> 00:00:09,120  
it is my pleasure to be your host

4  
00:00:06,778 --> 00:00:12,150  
I am dr. Frank summers of the office of

5  
00:00:09,119 --> 00:00:14,189  
public outreach as you come in as these

6  
00:00:12,150 --> 00:00:17,010  
gentlemen just are right now there are

7  
00:00:14,189 --> 00:00:19,379  
lithographs on the table that you can

8  
00:00:17,010 --> 00:00:24,029  
grab and take home tonight's lithograph

9  
00:00:19,379 --> 00:00:25,739  
is of interacting galaxies ARP 273 our

10  
00:00:24,028 --> 00:00:26,910  
speaker will be talking on the

11  
00:00:25,739 --> 00:00:29,669  
development of galaxies in the universe

12  
00:00:26,910 --> 00:00:31,259  
and this is a very interesting pair if

13  
00:00:29,670 --> 00:00:33,359  
you would like to know more about it

14  
00:00:31,260 --> 00:00:35,640  
turn over on the back and we have a few

15  
00:00:33,359 --> 00:00:38,820  
paragraphs telling you about the state

16  
00:00:35,640 --> 00:00:43,710  
of ARP 273 and where you can go to get

17  
00:00:38,820 --> 00:00:47,789  
more information our speaker tonight kvl

18  
00:00:43,710 --> 00:00:51,210  
Italo is talking about 100 ways to die

19  
00:00:47,789 --> 00:00:54,439  
in the universe okay she promises death

20  
00:00:51,210 --> 00:00:56,370  
and destruction here tonight okay

21  
00:00:54,439 --> 00:00:58,640  
astronomy usually doesn't have that much

22  
00:00:56,369 --> 00:01:00,149  
action but we're gonna have it tonight

23  
00:00:58,640 --> 00:01:02,820  
next month

24  
00:01:00,149 --> 00:01:05,728  
chasing supernovae with Kepler the

25  
00:01:02,820 --> 00:01:08,938  
Kepler satellite was out there to find

26  
00:01:05,728 --> 00:01:11,030  
planets but you can also use it because

27  
00:01:08,938 --> 00:01:13,889  
it can monitor the brightnesses of stars

28  
00:01:11,030 --> 00:01:16,829  
extremely carefully you can also use it

29

00:01:13,890 --> 00:01:18,719  
to find supernovae and Gotham Narayan

30  
00:01:16,829 --> 00:01:23,280  
will be telling us about that on October

31  
00:01:18,719 --> 00:01:25,679  
2nd November and because Election Day is

32  
00:01:23,280 --> 00:01:28,950  
the first Tuesday we will be skipping to

33  
00:01:25,680 --> 00:01:31,439  
the second Tuesday November 13th and

34  
00:01:28,950 --> 00:01:35,159  
we'll talk about exoplanet atmospheres G

35  
00:01:31,438 --> 00:01:37,289  
Giovanni Bruno now I got an email last

36  
00:01:35,159 --> 00:01:41,100  
week saying he might not be able to make

37  
00:01:37,290 --> 00:01:43,680  
that so this is gonna become a TBD

38  
00:01:41,099 --> 00:01:46,589  
probably next week as soon as I get in

39  
00:01:43,680 --> 00:01:48,689  
contact with him again so I guess some

40  
00:01:46,590 --> 00:01:51,000  
work to do as you can tell because

41  
00:01:48,688 --> 00:01:54,839  
December is listed as some intriguing

42  
00:01:51,000 --> 00:01:57,030  
topic by some amazing speaker so it's

43  
00:01:54,840 --> 00:01:58,170

difficult to get astronomers to commit

44

00:01:57,030 --> 00:02:00,390  
over the summer so I wait until

45

00:01:58,170 --> 00:02:02,189  
September to get them to commit and so

46

00:02:00,390 --> 00:02:05,009  
yes I'll be sending that email out this

47

00:02:02,188 --> 00:02:07,648  
this week are next okay don't worry I

48

00:02:05,009 --> 00:02:09,389  
always fill up the schedule alright and

49

00:02:07,649 --> 00:02:11,189  
you want to find out what these speakers

50

00:02:09,389 --> 00:02:13,049  
are when I do fill up that schedule you

51

00:02:11,189 --> 00:02:13,889  
go to our website go to your favorite

52

00:02:13,050 --> 00:02:16,050  
search engine

53

00:02:13,889 --> 00:02:20,069  
typing Hubble public talks you'll find

54

00:02:16,050 --> 00:02:22,680  
us or we have this go cuddle site or go

55

00:02:20,069 --> 00:02:25,590  
Toxteth to find us we have our list of

56

00:02:22,680 --> 00:02:27,930  
the upcoming lectures we have the links

57

00:02:25,590 --> 00:02:31,640  
to the live webcasting and YouTube

58  
00:02:27,930 --> 00:02:34,790  
events we also have our archives back to

59  
00:02:31,639 --> 00:02:39,059  
2014 on YouTube and all the way back to

60  
00:02:34,789 --> 00:02:41,429  
2005 in the webcast archive so our guys

61  
00:02:39,060 --> 00:02:44,490  
in the pack have been doing this for

62  
00:02:41,430 --> 00:02:46,709  
what is this now 13 years all right this

63  
00:02:44,490 --> 00:02:53,909  
is amazing stuff yeah yeah my hat my hat

64  
00:02:46,709 --> 00:02:56,879  
they deserve it so on our website you

65  
00:02:53,909 --> 00:02:58,650  
can sign up for our email list which is

66  
00:02:56,879 --> 00:03:00,629  
basically just reminders of the talks

67  
00:02:58,650 --> 00:03:04,319  
and telling you when the webcasts are

68  
00:03:00,629 --> 00:03:05,879  
posted on YouTube okay so yeah that's

69  
00:03:04,319 --> 00:03:08,340  
the announcements sign up the website if

70  
00:03:05,879 --> 00:03:10,229  
you don't like signing up on the website

71  
00:03:08,340 --> 00:03:11,759  
you can always just write your email

72  
00:03:10,229 --> 00:03:14,009  
address on a piece of paper and hand it

73  
00:03:11,759 --> 00:03:16,109  
to me at the end of the lecture if you

74  
00:03:14,009 --> 00:03:19,560  
have comments or questions we have an

75  
00:03:16,110 --> 00:03:22,980  
email set up public lecture at stsci edu

76  
00:03:19,560 --> 00:03:24,750  
and you can sent use that our social

77  
00:03:22,979 --> 00:03:26,689  
media for those who do it we've got

78  
00:03:24,750 --> 00:03:29,310  
Facebook Twitter YouTube and Instagram

79  
00:03:26,689 --> 00:03:32,099  
not just for the Hubble telescope not

80  
00:03:29,310 --> 00:03:34,680  
just for the Webb telescope also for the

81  
00:03:32,099 --> 00:03:36,900  
Space Telescope Science Institute so

82  
00:03:34,680 --> 00:03:39,510  
we've got three different brands that we

83  
00:03:36,900 --> 00:03:41,310  
are marketing here and we get it we

84  
00:03:39,509 --> 00:03:42,750  
actually you know these the folks who do

85  
00:03:41,310 --> 00:03:45,330  
this do a really good job of getting it

86

00:03:42,750 --> 00:03:48,299  
an interesting mix of things across the

87  
00:03:45,330 --> 00:03:50,250  
various channels I do not however do an

88  
00:03:48,299 --> 00:03:53,599  
interesting mix of things I rarely post

89  
00:03:50,250 --> 00:03:55,680  
online something I should do more of but

90  
00:03:53,599 --> 00:03:57,659  
frankly there's just too much cool

91  
00:03:55,680 --> 00:04:00,540  
things to do to spend all my time on

92  
00:03:57,659 --> 00:04:03,870  
social media so you can follow me but I

93  
00:04:00,539 --> 00:04:07,259  
will not be I will not not be on there

94  
00:04:03,870 --> 00:04:09,840  
all the time the weather is finally

95  
00:04:07,259 --> 00:04:12,298  
permitting I got the email from araignee

96  
00:04:09,840 --> 00:04:15,030  
today and yes the observatory will be

97  
00:04:12,299 --> 00:04:17,728  
open after the lecture okay so the

98  
00:04:15,030 --> 00:04:20,040  
Maryland Space Grant Observatory arena

99  
00:04:17,728 --> 00:04:21,358  
will come here toward the end of the

100  
00:04:20,040 --> 00:04:24,330

lecture she's probably watching this on

101

00:04:21,358 --> 00:04:26,939

YouTube right now when the questions

102

00:04:24,329 --> 00:04:27,310

start at Starcom and if you would like

103

00:04:26,939 --> 00:04:29,259

to go

104

00:04:27,310 --> 00:04:31,839

to the telescope to look through the

105

00:04:29,259 --> 00:04:34,360

telescope tonight it may be warm but

106

00:04:31,839 --> 00:04:38,138

we'll meet down here in the front at the

107

00:04:34,360 --> 00:04:41,069

end of the lecture okay alright and now

108

00:04:38,139 --> 00:04:42,870

the news from the universe for September

109

00:04:41,069 --> 00:04:47,069

2018

110

00:04:42,870 --> 00:04:50,709

our first story tonight ultra large

111

00:04:47,069 --> 00:04:54,459

ultra deep ultraviolet

112

00:04:50,709 --> 00:04:56,229

yes Hubble is going ultra here now what

113

00:04:54,459 --> 00:04:58,779

am I talking about I'm actually talking

114

00:04:56,230 --> 00:05:02,220

about the legacy of Hubble's deep fields



115  
00:04:58,779 --> 00:05:05,500  
and the first deep field was released in

116  
00:05:02,220 --> 00:05:07,690  
1996 this was done with wide field

117  
00:05:05,500 --> 00:05:12,000  
planetary camera 2 hence it has the

118  
00:05:07,689 --> 00:05:15,969  
chevron shape to it and it was a

119  
00:05:12,000 --> 00:05:18,189  
magnificent step in cosmology because we

120  
00:05:15,970 --> 00:05:19,540  
really didn't know what we would see

121  
00:05:18,189 --> 00:05:22,959  
when we looked at the universe this

122  
00:05:19,540 --> 00:05:25,660  
deeply when we use Hubble to expose for

123  
00:05:22,959 --> 00:05:27,519  
a week's worth of exposure time there

124  
00:05:25,660 --> 00:05:29,410  
were arguments amongst the cosmologists

125  
00:05:27,519 --> 00:05:31,629  
as whether this is a total waste of

126  
00:05:29,410 --> 00:05:34,060  
Hubble or hey we're gonna find out

127  
00:05:31,629 --> 00:05:35,978  
something really cool fortunately is the

128  
00:05:34,060 --> 00:05:38,709  
second one we did find out something

129  
00:05:35,978 --> 00:05:43,180  
really cool we found 3,000 galaxies in a

130  
00:05:38,709 --> 00:05:45,009  
tiny tiny tiny patch of sky and so what

131  
00:05:43,180 --> 00:05:46,930  
these art we're seeing galaxies all the

132  
00:05:45,009 --> 00:05:48,788  
way across the universe compressed into

133  
00:05:46,930 --> 00:05:50,709  
a single image we're seeing galaxies

134  
00:05:48,788 --> 00:05:53,050  
deeper and further into the universe

135  
00:05:50,709 --> 00:05:54,728  
than we had ever seen before so of

136  
00:05:53,050 --> 00:05:58,300  
course when we got a new instrument in

137  
00:05:54,728 --> 00:06:01,060  
2004 the advanced camera for surveys we

138  
00:05:58,300 --> 00:06:02,949  
started doing some surveys and one of

139  
00:06:01,060 --> 00:06:06,550  
the surveys we did in 2000 and I'm sorry

140  
00:06:02,949 --> 00:06:09,779  
the cameras in 2002 in 2003 the Great

141  
00:06:06,550 --> 00:06:14,829  
observatories origins deep survey in

142  
00:06:09,779 --> 00:06:18,038  
2003 this was fifteen pointings of

143

00:06:14,829 --> 00:06:20,439  
Hubble Accra and with a detector that's

144  
00:06:18,038 --> 00:06:22,329  
twice the size of whispering - so 30

145  
00:06:20,439 --> 00:06:25,120  
times the area on the sky of the

146  
00:06:22,329 --> 00:06:27,819  
original Hubble Deep Field well when you

147  
00:06:25,120 --> 00:06:30,550  
do that large of a region you can't go

148  
00:06:27,819 --> 00:06:33,668  
extremely deep so they chose a special

149  
00:06:30,550 --> 00:06:37,300  
region in here in which they really

150  
00:06:33,668 --> 00:06:39,359  
really been in and they million seconds

151  
00:06:37,300 --> 00:06:43,110  
of exposure time on it

152  
00:06:39,360 --> 00:06:45,479  
was the Hubble ultra-deep field in 2004

153  
00:06:43,110 --> 00:06:48,240  
the deepest visible light exposure of

154  
00:06:45,478 --> 00:06:50,038  
the universe taken to that time and

155  
00:06:48,240 --> 00:06:52,468  
remains to this day really because the

156  
00:06:50,038 --> 00:06:55,438  
only thing deeper are updates to the

157  
00:06:52,468 --> 00:06:57,598

Ultra Deep Field and so this had 10,000

158

00:06:55,439 --> 00:07:00,569

galaxies and really started letting us

159

00:06:57,598 --> 00:07:03,930

look out towards the the edge of the

160

00:07:00,569 --> 00:07:06,090

cosmos well in 2009 we had another

161

00:07:03,930 --> 00:07:09,629

servicing mission and that greatly

162

00:07:06,089 --> 00:07:11,728

improved our infrared capability so in

163

00:07:09,629 --> 00:07:14,310

this region here which is where the

164

00:07:11,728 --> 00:07:17,610

infrared detector covered we did the

165

00:07:14,310 --> 00:07:20,098

alternate field with infrared in 2009

166

00:07:17,610 --> 00:07:21,870

and infrared is extremely important for

167

00:07:20,098 --> 00:07:24,449

cosmology because the light from very

168

00:07:21,870 --> 00:07:26,310

distant galaxies is redshifted it's

169

00:07:24,449 --> 00:07:27,930

light is stretched and it goes from

170

00:07:26,310 --> 00:07:30,658

visible light even from ultraviolet

171

00:07:27,930 --> 00:07:32,610

light into the infrared so if you want

172  
00:07:30,658 --> 00:07:35,968  
to see the most distant galaxies you've

173  
00:07:32,610 --> 00:07:38,250  
got to look in the infrared well we also

174  
00:07:35,968 --> 00:07:39,959  
improve the ultraviolet capabilities at

175  
00:07:38,250 --> 00:07:41,430  
that time but we didn't get around to

176  
00:07:39,959 --> 00:07:47,579  
releasing and doing those observations

177  
00:07:41,430 --> 00:07:48,870  
on June 2014 with ultraviolet and this I

178  
00:07:47,579 --> 00:07:51,149  
like to call this the multi-wavelength

179  
00:07:48,870 --> 00:07:53,968  
deep field because it's got ultraviolet

180  
00:07:51,149 --> 00:07:56,908  
visible and infrared it covers the

181  
00:07:53,968 --> 00:08:00,028  
entire panoply of wavelengths that

182  
00:07:56,908 --> 00:08:03,478  
Hubble can look at and it was really an

183  
00:08:00,028 --> 00:08:07,168  
amazing piece but it showed us that we

184  
00:08:03,478 --> 00:08:10,139  
still wanted more so a bunch of

185  
00:08:07,168 --> 00:08:13,228  
astronomers proposed to do this but on

186  
00:08:10,139 --> 00:08:16,680  
the Hubble Deep alra violet legacy

187  
00:08:13,228 --> 00:08:21,300  
survey and we just released those a few

188  
00:08:16,680 --> 00:08:24,418  
weeks ago the HUD v2 fields this is the

189  
00:08:21,300 --> 00:08:26,819  
North field and this is the South field

190  
00:08:24,418 --> 00:08:30,538  
and I gotta say when you look at them

191  
00:08:26,819 --> 00:08:34,620  
you go okay yeah Mordy fields right yes

192  
00:08:30,538 --> 00:08:37,019  
and no okay because first of all the

193  
00:08:34,620 --> 00:08:38,490  
ultraviolet is extremely important

194  
00:08:37,019 --> 00:08:41,459  
because it shows us where stars are

195  
00:08:38,490 --> 00:08:43,909  
forming okay newborn stars the most

196  
00:08:41,458 --> 00:08:47,039  
massive stars shine brightly in the

197  
00:08:43,909 --> 00:08:49,769  
ultraviolet but they only do so for tens

198  
00:08:47,039 --> 00:08:52,318  
of millions of years so it's just the

199  
00:08:49,769 --> 00:08:53,069  
brand-new newborn stars that can be

200

00:08:52,318 --> 00:08:56,429  
found

201  
00:08:53,070 --> 00:08:59,370  
with ultraviolet and ultraviolet can't

202  
00:08:56,429 --> 00:09:00,750  
be seen from the ground we can't do good

203  
00:08:59,370 --> 00:09:02,429  
ultraviolet astronomers no ground we

204  
00:09:00,750 --> 00:09:04,409  
have to do it from space so having

205  
00:09:02,429 --> 00:09:08,459  
Hubble do these ultraviolet fields is

206  
00:09:04,409 --> 00:09:09,929  
extremely important furthermore the size

207  
00:09:08,460 --> 00:09:14,129  
of that Hubble ultra-deep field

208  
00:09:09,929 --> 00:09:18,629  
ultraviolet is only that and with these

209  
00:09:14,129 --> 00:09:21,929  
two fields we have 14 times more surface

210  
00:09:18,629 --> 00:09:24,870  
area on the sky 14 times more statistics

211  
00:09:21,929 --> 00:09:27,149  
of the ultraviolet galaxies so what

212  
00:09:24,870 --> 00:09:28,649  
we're doing is we're looking at the

213  
00:09:27,149 --> 00:09:31,139  
ultraviolet which we can see most

214  
00:09:28,649 --> 00:09:33,449

clearly in the nearby galaxies but in

215

00:09:31,139 --> 00:09:35,279

the far galaxies where the ultraviolet

216

00:09:33,450 --> 00:09:38,070

has been stretched to the visible or the

217

00:09:35,279 --> 00:09:41,129

infrared we now have a calibration data

218

00:09:38,070 --> 00:09:43,050

set of the nearby stuff took compared to

219

00:09:41,129 --> 00:09:44,610

what these objects look like in the

220

00:09:43,049 --> 00:09:47,069

visible or the infrared which is really

221

00:09:44,610 --> 00:09:49,500

the ultraviolet for them because their

222

00:09:47,070 --> 00:09:52,830

light has been stretched so we now get a

223

00:09:49,500 --> 00:09:54,690

much better comparison of what these

224

00:09:52,830 --> 00:09:56,879

distant galaxies might be looking like

225

00:09:54,690 --> 00:09:59,570

in the ultraviolet compared to this now

226

00:09:56,879 --> 00:10:02,669

this was just the announcement that the

227

00:09:59,570 --> 00:10:05,220

ultraviolet legacy Survey has completed

228

00:10:02,669 --> 00:10:08,419

their observations it's not the science



229  
00:10:05,220 --> 00:10:10,440  
results yet but it shows that Hubble is

230  
00:10:08,419 --> 00:10:13,559  
putting together what we call these

231  
00:10:10,440 --> 00:10:16,530  
legacy projects these important datasets

232  
00:10:13,559 --> 00:10:18,119  
that only Hubble can do during its last

233  
00:10:16,529 --> 00:10:20,789  
year's because we know Hubble you know

234  
00:10:18,120 --> 00:10:23,879  
hopefully it'll last a long long time

235  
00:10:20,789 --> 00:10:25,589  
but while we've got a problem is working

236  
00:10:23,879 --> 00:10:28,200  
really really well we want to make sure

237  
00:10:25,590 --> 00:10:31,050  
we get these legacy projects done that

238  
00:10:28,200 --> 00:10:34,740  
really cement I haven't read it said for

239  
00:10:31,049 --> 00:10:40,229  
astronomers to study in the future our

240  
00:10:34,740 --> 00:10:43,940  
second story the master retires there's

241  
00:10:40,230 --> 00:10:48,680  
been a gentleman his name is solavei and

242  
00:10:43,940 --> 00:10:51,420  
he has worked here for 35 years now

243  
00:10:48,679 --> 00:10:52,919  
those of you who do the math Hubble has

244  
00:10:51,419 --> 00:10:55,649  
only been around for 28 years

245  
00:10:52,919 --> 00:10:59,519  
okay Zolt has been working here for 35

246  
00:10:55,649 --> 00:11:02,730  
years for the last 25 of them he has had

247  
00:10:59,519 --> 00:11:05,970  
his hand in almost every single Hubble

248  
00:11:02,730 --> 00:11:06,779  
image you've ever seen he is I called

249  
00:11:05,970 --> 00:11:08,250  
him the

250  
00:11:06,779 --> 00:11:10,829  
sir in terms of master attire he's

251  
00:11:08,250 --> 00:11:14,490  
what's known his job title was master

252  
00:11:10,830 --> 00:11:17,100  
image processor so the look and feel of

253  
00:11:14,490 --> 00:11:21,419  
all the Hubble images has gone through

254  
00:11:17,100 --> 00:11:26,990  
his computer for the last 25 years and

255  
00:11:21,419 --> 00:11:29,969  
he has really put his stamp on it and he

256  
00:11:26,990 --> 00:11:33,060  
he's really well-loved around here but

257

00:11:29,970 --> 00:11:36,330  
he retired last Friday and we had a we

258  
00:11:33,059 --> 00:11:40,589  
had a big party for him for me it's

259  
00:11:36,330 --> 00:11:43,290  
especially important because well he was

260  
00:11:40,590 --> 00:11:45,660  
part of our visualization team this is

261  
00:11:43,289 --> 00:11:47,969  
the four of us holding a piece of IMAX

262  
00:11:45,659 --> 00:11:50,939  
film this is the former basically

263  
00:11:47,970 --> 00:11:53,490  
working the IMAX film Hubble 3d and some

264  
00:11:50,940 --> 00:11:57,390  
of the test negatives from IMAX Hubble

265  
00:11:53,490 --> 00:11:59,370  
3d and Zolt was a big part of it and so

266  
00:11:57,389 --> 00:12:01,860  
although I've worked with him for 17

267  
00:11:59,370 --> 00:12:03,779  
years I worked extremely closely with

268  
00:12:01,860 --> 00:12:08,220  
him for about the last 10 years on our

269  
00:12:03,779 --> 00:12:11,879  
visualization team and it he's a

270  
00:12:08,220 --> 00:12:13,460  
consummate professional and will truly

271  
00:12:11,879 --> 00:12:17,549

he'll truly be missed

272

00:12:13,460 --> 00:12:19,800

what's he gonna do well he also not only

273

00:12:17,549 --> 00:12:23,039

doing working with space images he also

274

00:12:19,799 --> 00:12:25,139

does nature photography this is an

275

00:12:23,039 --> 00:12:28,169

exhibit that he had in Jackson Hole

276

00:12:25,139 --> 00:12:30,360

Wyoming which then came to Baltimore

277

00:12:28,169 --> 00:12:33,389

this summer called celestial terrestrial

278

00:12:30,360 --> 00:12:34,830

convergence where he's comparing a bit

279

00:12:33,389 --> 00:12:37,949

of the Carina Nebula here

280

00:12:34,830 --> 00:12:40,889

to star trails over some rocks in Zion

281

00:12:37,950 --> 00:12:43,170

National Park and it's the combination

282

00:12:40,889 --> 00:12:46,740

of the terrestrial photography that he

283

00:12:43,169 --> 00:12:49,079

does as well as the celestial imagery

284

00:12:46,740 --> 00:12:51,000

that he has processed that's part of

285

00:12:49,080 --> 00:12:53,310

this art exhibit and he's going to spend

286  
00:12:51,000 --> 00:12:54,929  
a lot of his time now on the terrestrial

287  
00:12:53,309 --> 00:12:57,119  
part of it working was asked from

288  
00:12:54,929 --> 00:13:00,059  
astrophotography as I said he's been

289  
00:12:57,120 --> 00:13:04,169  
here for several decades and we just

290  
00:13:00,059 --> 00:13:06,089  
wanted to wish him well and congratulate

291  
00:13:04,169 --> 00:13:07,709  
him on his success in the years past and

292  
00:13:06,090 --> 00:13:14,649  
wish him well in the future

293  
00:13:07,710 --> 00:13:17,570  
[Applause]

294  
00:13:14,649 --> 00:13:22,039  
all right our featured speaker tonight

295  
00:13:17,570 --> 00:13:25,040  
is katie al italo who tells me she grew

296  
00:13:22,039 --> 00:13:26,899  
up in michigan and she stayed in

297  
00:13:25,039 --> 00:13:30,049  
michigan for her undergraduate work

298  
00:13:26,899 --> 00:13:32,059  
going to university of michigan oh yeah

299  
00:13:30,049 --> 00:13:33,259  
she has to say go blue so I'll make sure

300  
00:13:32,059 --> 00:13:36,469  
that the people in the webcast can hear

301  
00:13:33,259 --> 00:13:38,000  
that okay all right their arrival would

302  
00:13:36,470 --> 00:13:40,970  
be Ohio State right

303  
00:13:38,000 --> 00:13:43,519  
because I was at Michigan with Gus

304  
00:13:40,970 --> 00:13:46,670  
Everard and I was there during the week

305  
00:13:43,519 --> 00:13:48,919  
with the oh how I hate Ohio State you

306  
00:13:46,669 --> 00:13:51,229  
know going all over the place so that

307  
00:13:48,919 --> 00:13:53,179  
was one of the few things I remember

308  
00:13:51,230 --> 00:13:57,050  
from that from that week or two I spent

309  
00:13:53,179 --> 00:13:57,679  
there anyways Buckeye fans you know we

310  
00:13:57,049 --> 00:13:59,929  
love you too

311  
00:13:57,679 --> 00:14:04,489  
we just happen to have a Wolverine here

312  
00:13:59,929 --> 00:14:06,049  
tonight she did her graduate work at the

313  
00:14:04,490 --> 00:14:08,720  
University of California Berkeley where

314

00:14:06,049 --> 00:14:13,549  
I also did my PhD although separated by

315  
00:14:08,720 --> 00:14:19,759  
just a few years and she came here last

316  
00:14:13,549 --> 00:14:28,929  
April to work in the AI NS on what's the

317  
00:14:19,759 --> 00:14:31,700  
acronym here nears I and I are ISS

318  
00:14:28,929 --> 00:14:33,939  
spectroscope yes there we go I haven't

319  
00:14:31,700 --> 00:14:37,278  
gotten the AJ dais to the James Webb

320  
00:14:33,940 --> 00:14:39,740  
acronyms fully down yet but you know

321  
00:14:37,278 --> 00:14:48,230  
we'll get there oh and she's here to

322  
00:14:39,740 --> 00:14:50,269  
talk to us tonight all right 100 ways to

323  
00:14:48,230 --> 00:14:51,850  
die in the universe ladies and gentlemen

324  
00:14:50,269 --> 00:14:58,828  
Katey Allah Tala

325  
00:14:51,850 --> 00:15:01,300  
[Applause]

326  
00:14:58,828 --> 00:15:03,519  
Frank with an intro like that I'm not

327  
00:15:01,299 --> 00:15:05,379  
entirely sure I'm going to need some of

328  
00:15:03,519 --> 00:15:12,070

my slides thank you

329

00:15:05,379 --> 00:15:14,379

so yes I'm going to take a walk with you

330

00:15:12,070 --> 00:15:16,360

between through showdowns brawls and

331

00:15:14,379 --> 00:15:20,019

zombies and the life and death of

332

00:15:16,360 --> 00:15:23,589

galaxies so Frank has already actually

333

00:15:20,019 --> 00:15:26,940

covered this this is me born and raised

334

00:15:23,589 --> 00:15:29,399

in Michigan at Wolverine a proud one

335

00:15:26,940 --> 00:15:32,399

don't worry I do actually also

336

00:15:29,399 --> 00:15:36,278

appreciate people from Ohio State though

337

00:15:32,399 --> 00:15:39,669

there's one Saturday a year I might not

338

00:15:36,278 --> 00:15:41,769

so much but don't worry I then went to

339

00:15:39,669 --> 00:15:44,349

California and spent a long time in

340

00:15:41,769 --> 00:15:47,230

California and now here I am in the

341

00:15:44,350 --> 00:15:50,350

great state of Maryland I would call

342

00:15:47,230 --> 00:15:52,839

myself a galactic archaeologist if I



343  
00:15:50,350 --> 00:15:55,329  
were to put a name upon it I will say I

344  
00:15:52,839 --> 00:15:57,250  
have never had to go into any caves and

345  
00:15:55,328 --> 00:15:59,739  
like switch things and dodge boulders

346  
00:15:57,250 --> 00:16:01,629  
but some of the things I've had to do

347  
00:15:59,740 --> 00:16:04,870  
with radio telescopes we're a bit

348  
00:16:01,629 --> 00:16:07,860  
death-defying so you know maybe a little

349  
00:16:04,870 --> 00:16:10,570  
bit Indiana Jones but not completely

350  
00:16:07,860 --> 00:16:13,060  
so again when I say galactic

351  
00:16:10,570 --> 00:16:15,459  
archaeologists what I mean is I studied

352  
00:16:13,059 --> 00:16:18,219  
galaxies I searched for the imprints of

353  
00:16:15,458 --> 00:16:22,958  
their past interactions on their

354  
00:16:18,220 --> 00:16:25,509  
present-day cells I look for I look

355  
00:16:22,958 --> 00:16:28,149  
through huge datasets looking for a

356  
00:16:25,509 --> 00:16:33,278  
special subset of galaxies that are

357  
00:16:28,149 --> 00:16:35,379  
dying right now and I use the size of

358  
00:16:33,278 --> 00:16:37,179  
the universe as a time machine to look

359  
00:16:35,379 --> 00:16:39,549  
at galaxies from ten billion years ago

360  
00:16:37,179 --> 00:16:42,549  
and the great news about the the news

361  
00:16:39,549 --> 00:16:45,250  
today about the Hubble ultraviolet Ultra

362  
00:16:42,549 --> 00:16:47,318  
Deep Field is that that actually is one

363  
00:16:45,250 --> 00:16:49,899  
of the kinds of time machines I like to

364  
00:16:47,318 --> 00:16:51,969  
use because of the fact that when you

365  
00:16:49,899 --> 00:16:57,909  
are looking at distant galaxies you're

366  
00:16:51,970 --> 00:16:59,440  
also looking at old galaxies but I guess

367  
00:16:57,909 --> 00:17:02,649  
we will actually start with a history

368  
00:16:59,440 --> 00:17:05,350  
lesson here I start with Sheldon Messier

369  
00:17:02,649 --> 00:17:07,269  
in particular who was an astronomer and

370  
00:17:05,349 --> 00:17:10,119  
a lot of people know him as basically

371

00:17:07,269 --> 00:17:13,480  
putting together a catalog of alien

372  
00:17:10,119 --> 00:17:15,909  
that is not failures in what they were

373  
00:17:13,480 --> 00:17:18,338  
because again he categorized some of the

374  
00:17:15,910 --> 00:17:21,720  
open star clusters globular clusters

375  
00:17:18,338 --> 00:17:24,458  
planetary nebula star-forming galaxies

376  
00:17:21,720 --> 00:17:26,769  
star-forming nebula but it was mostly

377  
00:17:24,459 --> 00:17:30,460  
because he was looking for comets so to

378  
00:17:26,769 --> 00:17:33,220  
him he got new science out of a failed

379  
00:17:30,460 --> 00:17:34,059  
product that failed project was finding

380  
00:17:33,220 --> 00:17:37,620  
more comets

381  
00:17:34,059 --> 00:17:43,029  
because he said look it's not a comment

382  
00:17:37,619 --> 00:17:46,209  
not a comment shoot not a comment but

383  
00:17:43,029 --> 00:17:47,920  
for us again his catalog is very

384  
00:17:46,210 --> 00:17:50,410  
important because of some of the near

385  
00:17:47,920 --> 00:17:53,170

sky objects we can actually look at and

386

00:17:50,410 --> 00:17:55,210

see in great detail sometimes we can see

387

00:17:53,170 --> 00:17:57,490

them with our naked eye and sometimes it

388

00:17:55,210 --> 00:18:03,069

takes very little something like

389

00:17:57,490 --> 00:18:06,910

binoculars to actually see this but to

390

00:18:03,069 --> 00:18:09,339

me the actual start of understanding

391

00:18:06,910 --> 00:18:12,310

what the universe was came from this

392

00:18:09,339 --> 00:18:14,799

gentleman right here with his pipe Edwin

393

00:18:12,309 --> 00:18:18,009

Hubble I think you might have heard that

394

00:18:14,799 --> 00:18:19,779

name this gentleman was the namesake and

395

00:18:18,009 --> 00:18:23,440

I was lucky enough when I was a

396

00:18:19,779 --> 00:18:25,869

postdoctoral hubbell fellow at Carnegie

397

00:18:23,440 --> 00:18:27,309

observatories I actually got to work at

398

00:18:25,869 --> 00:18:29,559

the place where Edwin Hubble did his

399

00:18:27,309 --> 00:18:32,289

science which was pretty cool I got to

400  
00:18:29,559 --> 00:18:34,869  
see his office which now the director of

401  
00:18:32,289 --> 00:18:36,940  
Carnegie observatories uses and I

402  
00:18:34,869 --> 00:18:40,029  
actually got to see this which is a

403  
00:18:36,940 --> 00:18:42,400  
plate taken by Edwin Hubble of the

404  
00:18:40,029 --> 00:18:44,349  
Andromeda galaxy where that up there

405  
00:18:42,400 --> 00:18:46,720  
that red bar is Edwin Hubble's

406  
00:18:44,349 --> 00:18:49,809  
handwriting because he found a variable

407  
00:18:46,720 --> 00:18:51,970  
star in the Andromeda galaxy which told

408  
00:18:49,809 --> 00:18:57,190  
him that the universe was beyond the

409  
00:18:51,970 --> 00:18:59,680  
Milky Way so not only did he discover

410  
00:18:57,190 --> 00:19:02,170  
this he actually also put together

411  
00:18:59,680 --> 00:19:04,000  
something that we use today for galaxies

412  
00:19:02,170 --> 00:19:07,570  
which is he put together the Hubble

413  
00:19:04,000 --> 00:19:13,150  
sequence of galaxies so here's the paper

414  
00:19:07,569 --> 00:19:16,179  
from I think this was in 1923 maybe 1926

415  
00:19:13,150 --> 00:19:18,280  
the classification employed is based on

416  
00:19:16,180 --> 00:19:20,740  
the forms of the photographic images

417  
00:19:18,279 --> 00:19:21,670  
about 3% are irregular but the remaining

418  
00:19:20,740 --> 00:19:24,339  
nebula

419  
00:19:21,670 --> 00:19:26,350  
fall into a sequence of type forms

420  
00:19:24,339 --> 00:19:29,319  
characterized by rotational symmetry

421  
00:19:26,349 --> 00:19:31,659  
about dominating nuclei the sequence is

422  
00:19:29,319 --> 00:19:34,480  
composed of two sections the elliptical

423  
00:19:31,660 --> 00:19:38,110  
navilet and the spirals which merge into

424  
00:19:34,480 --> 00:19:40,269  
each other so here is what the Hubble

425  
00:19:38,109 --> 00:19:43,419  
sequence actually looks like in modern

426  
00:19:40,269 --> 00:19:46,089  
times here is a really nice version of

427  
00:19:43,420 --> 00:19:48,910  
it made in part but the help of the of

428

00:19:46,089 --> 00:19:51,759  
the Zooniverse but let me show you what

429  
00:19:48,910 --> 00:19:58,660  
Edwin Hubble published in 1926 in this

430  
00:19:51,759 --> 00:20:02,379  
book 1926 folks I think he did a pretty

431  
00:19:58,660 --> 00:20:04,600  
good job now he accidentally flipped the

432  
00:20:02,380 --> 00:20:06,810  
order he thought that the elliptical

433  
00:20:04,599 --> 00:20:12,099  
galaxies were the ones that morphed into

434  
00:20:06,809 --> 00:20:15,099  
the spiral galaxies but that is all that

435  
00:20:12,099 --> 00:20:20,469  
he got wrong because as I said as I

436  
00:20:15,099 --> 00:20:27,069  
showed you just previously right pretty

437  
00:20:20,470 --> 00:20:28,539  
good so as I've once said in that

438  
00:20:27,069 --> 00:20:31,599  
original paper the Hubble sequence

439  
00:20:28,539 --> 00:20:34,389  
breaks in two types over here you have

440  
00:20:31,599 --> 00:20:37,209  
spirals and over here you have early

441  
00:20:34,390 --> 00:20:39,009  
type galaxies now again early type is an

442  
00:20:37,210 --> 00:20:40,600

old-fashioned nomenclature coming

443

00:20:39,009 --> 00:20:42,490  
originally from that Edwin Hubble

444

00:20:40,599 --> 00:20:45,129  
mistake which we still use today

445

00:20:42,490 --> 00:20:47,230  
- unfortunately confuse the public as

446

00:20:45,130 --> 00:20:49,360  
well as our students but early type

447

00:20:47,230 --> 00:20:52,599  
galaxies are actually the old galaxies

448

00:20:49,359 --> 00:20:55,089  
so a typical spiral is disk-like it has

449

00:20:52,599 --> 00:20:58,689  
spiral structure it's blue in color and

450

00:20:55,089 --> 00:21:01,059  
it's forming stars early types actually

451

00:20:58,690 --> 00:21:02,980  
break into two different types you have

452

00:21:01,059 --> 00:21:06,190  
typical ellipticals and lenticular x'

453

00:21:02,980 --> 00:21:08,529  
this is a lenticular galaxy this is an

454

00:21:06,190 --> 00:21:11,200  
elliptical galaxy the thing that

455

00:21:08,529 --> 00:21:13,029  
differentiates an elliptical or an early

456

00:21:11,200 --> 00:21:15,460  
type but when an elliptical and



457  
00:21:13,029 --> 00:21:17,710  
lenticular slash early type galaxy from

458  
00:21:15,460 --> 00:21:22,420  
a spiral is actually that it lacks that

459  
00:21:17,710 --> 00:21:26,019  
spiral structure so in the sense the

460  
00:21:22,420 --> 00:21:29,650  
smooth structure is what classifies you

461  
00:21:26,019 --> 00:21:31,569  
as an early type galaxy lenticular ZAR

462  
00:21:29,650 --> 00:21:33,980  
disk a ellipticals are ellipsoidal

463  
00:21:31,569 --> 00:21:39,980  
they're reading color

464  
00:21:33,980 --> 00:21:42,079  
and their non star-forming so again we

465  
00:21:39,980 --> 00:21:43,849  
break it down spirals are blue

466  
00:21:42,079 --> 00:21:47,029  
they've destructure visible spiral

467  
00:21:43,849 --> 00:21:49,279  
spiral arms star forming and right now

468  
00:21:47,029 --> 00:21:52,910  
77 percent of the galaxies in the sky

469  
00:21:49,279 --> 00:21:56,869  
are spirals blue star forming again this

470  
00:21:52,910 --> 00:21:58,700  
is typical ellipticals are read their

471  
00:21:56,869 --> 00:22:01,548  
lips swollen structures with light

472  
00:21:58,700 --> 00:22:03,679  
distribution quiescent which basically

473  
00:22:01,548 --> 00:22:05,720  
just means non star forming my accent

474  
00:22:03,679 --> 00:22:07,460  
means quiet so if I slip into

475  
00:22:05,720 --> 00:22:09,500  
astronomers speak I just wanted to make

476  
00:22:07,460 --> 00:22:11,090  
sure when I use the word pious that you

477  
00:22:09,500 --> 00:22:16,640  
know what it means they tend to be more

478  
00:22:11,089 --> 00:22:18,589  
massive why is it that I keep saying the

479  
00:22:16,640 --> 00:22:21,440  
word star farming when I'm talking about

480  
00:22:18,589 --> 00:22:24,439  
blue and I keep saying things like quiet

481  
00:22:21,440 --> 00:22:28,009  
when I talk about red the colors of

482  
00:22:24,440 --> 00:22:30,529  
galaxies for the most part save for dust

483  
00:22:28,009 --> 00:22:33,079  
which is actually important come from

484  
00:22:30,529 --> 00:22:36,379  
the colors of the stars that the galaxy

485

00:22:33,079 --> 00:22:38,569  
is comprised of so a stellar population

486  
00:22:36,380 --> 00:22:41,870  
a young stellar population again

487  
00:22:38,569 --> 00:22:44,990  
something frank said earlier is blue

488  
00:22:41,869 --> 00:22:47,449  
it's coming from young hot rock star

489  
00:22:44,990 --> 00:22:51,740  
stars that are going to live hard rock

490  
00:22:47,450 --> 00:22:53,779  
hard and die young because they are

491  
00:22:51,740 --> 00:22:56,029  
burning up their star forming fuel so

492  
00:22:53,779 --> 00:22:59,808  
fast they get very hot in temperature

493  
00:22:56,029 --> 00:23:03,558  
and that temperature makes them blue on

494  
00:22:59,808 --> 00:23:07,009  
the other hand older younger older

495  
00:23:03,558 --> 00:23:09,379  
smaller stars are red in color like that

496  
00:23:07,009 --> 00:23:11,240  
which is why elliptical galaxies would

497  
00:23:09,380 --> 00:23:12,860  
have a lot more of these stars that have

498  
00:23:11,240 --> 00:23:16,250  
been taking it easy their whole lives

499  
00:23:12,859 --> 00:23:20,418

not really big burning their hydrogen

500

00:23:16,250 --> 00:23:22,069

sort of at a low level it's why these

501

00:23:20,419 --> 00:23:24,440

galaxies are red because they're cooler

502

00:23:22,069 --> 00:23:27,678

which means they can last longer and

503

00:23:24,440 --> 00:23:30,320

they're older the reason this works in

504

00:23:27,679 --> 00:23:33,798

the galaxies is because these blue hot

505

00:23:30,319 --> 00:23:35,960

stars are so dominant to the light in

506

00:23:33,798 --> 00:23:39,019

the galaxy that even if you have a lot

507

00:23:35,960 --> 00:23:40,700

of these older red stars in your galaxy

508

00:23:39,019 --> 00:23:46,009

the second you have blue stars or

509

00:23:40,700 --> 00:23:48,769

galaxies gonna look blue so

510

00:23:46,009 --> 00:23:50,359

when I talk about star formation I also

511

00:23:48,769 --> 00:23:52,730

kind of want to tell you what I mean

512

00:23:50,359 --> 00:23:54,259

because again we're having to get into

513

00:23:52,730 --> 00:23:58,160

the murder mysteries of what kills

514  
00:23:54,259 --> 00:24:00,230  
galaxies so when I observe star

515  
00:23:58,160 --> 00:24:02,450  
formation what you're usually looking at

516  
00:24:00,230 --> 00:24:04,849  
is a hot young new least form star

517  
00:24:02,450 --> 00:24:07,490  
cluster and around that star cluster is

518  
00:24:04,849 --> 00:24:10,548  
all of these clouds these parent clouds

519  
00:24:07,490 --> 00:24:13,910  
that created these stars and what you

520  
00:24:10,548 --> 00:24:16,519  
see is you see this hydrogen and this

521  
00:24:13,910 --> 00:24:19,759  
dust that is reradiating that hot

522  
00:24:16,519 --> 00:24:23,048  
ultraviolet light that hydrogen is now

523  
00:24:19,759 --> 00:24:25,819  
getting is now getting irradiated and is

524  
00:24:23,048 --> 00:24:26,960  
reradiating that's in the optical from

525  
00:24:25,819 --> 00:24:29,298  
h2 regions

526  
00:24:26,960 --> 00:24:32,509  
h2 roman numeral rather than h2

527  
00:24:29,298 --> 00:24:34,609  
subscript and the dust grains where

528  
00:24:32,509 --> 00:24:36,798  
again this they're absorbing this

529  
00:24:34,609 --> 00:24:39,859  
ultraviolet light from these new hot

530  
00:24:36,798 --> 00:24:44,210  
young stars is getting reradiating in

531  
00:24:39,859 --> 00:24:46,308  
the infrared so when you think about how

532  
00:24:44,210 --> 00:24:48,319  
to tell if a galaxy is forming stars you

533  
00:24:46,308 --> 00:24:49,460  
now know that they're blue in color but

534  
00:24:48,319 --> 00:24:51,409  
you also now know that there might be

535  
00:24:49,460 --> 00:24:54,048  
some other signatures for instance you

536  
00:24:51,410 --> 00:24:58,100  
might see these hydrogen lines or you

537  
00:24:54,048 --> 00:24:59,808  
might see dust and on top of that you

538  
00:24:58,099 --> 00:25:05,869  
want to look for things like this that's

539  
00:24:59,808 --> 00:25:09,369  
h2 gas so when we look up in the sky we

540  
00:25:05,869 --> 00:25:11,719  
see this well I should point out from

541  
00:25:09,369 --> 00:25:14,479  
Maryland for a while unfortunately we

542

00:25:11,720 --> 00:25:16,400  
haven't been seeing this we've been

543  
00:25:14,480 --> 00:25:19,130  
seeing a lot of clouds getting a little

544  
00:25:16,400 --> 00:25:21,830  
rain in our faces in Los Angeles where

545  
00:25:19,130 --> 00:25:23,600  
usually it is pretty dry I will say we

546  
00:25:21,829 --> 00:25:27,349  
did not see this we saw a lot of city

547  
00:25:23,599 --> 00:25:29,029  
lights but if we're very lucky and we go

548  
00:25:27,349 --> 00:25:30,980  
out into the desert when we go to a

549  
00:25:29,029 --> 00:25:33,470  
place that's low light we could

550  
00:25:30,980 --> 00:25:35,120  
potentially see this my favorite place

551  
00:25:33,470 --> 00:25:36,950  
to see this is probably the Chilean

552  
00:25:35,119 --> 00:25:38,449  
desert but you don't need to get to the

553  
00:25:36,950 --> 00:25:40,730  
Chilean desert to see it you could see

554  
00:25:38,450 --> 00:25:45,640  
this in Wyoming and on particularly dark

555  
00:25:40,730 --> 00:25:48,230  
nights in Michigan but that's not what

556  
00:25:45,640 --> 00:25:50,419

everything everyone sees when they look

557

00:25:48,230 --> 00:25:52,069

at the Milky Way it's when our eye see

558

00:25:50,419 --> 00:25:54,890

because our eyes process optical light

559

00:25:52,069 --> 00:25:57,740

but our telescopes and our instruments

560

00:25:54,890 --> 00:26:00,440

give us a much greater picture of what

561

00:25:57,740 --> 00:26:02,359

the Milky Way is we know what the Milky

562

00:26:00,440 --> 00:26:04,870

Way looks like in gamma rays x-rays

563

00:26:02,359 --> 00:26:08,119

optical near-infrared mid infrared

564

00:26:04,869 --> 00:26:11,869

infrared molecular hydrogen radio

565

00:26:08,119 --> 00:26:15,408

continuum atomic hydrogen and even lower

566

00:26:11,869 --> 00:26:17,178

frequency radio continuum and the reason

567

00:26:15,409 --> 00:26:19,400

astronomers like to do this is because

568

00:26:17,179 --> 00:26:20,960

each one of these can tell us something

569

00:26:19,400 --> 00:26:22,460

a little bit different about the

570

00:26:20,960 --> 00:26:27,079

universe a little bit different about



571  
00:26:22,460 --> 00:26:29,179  
our world so the ones I think about or I

572  
00:26:27,079 --> 00:26:31,460  
like to think about this one I like to

573  
00:26:29,179 --> 00:26:35,240  
think about where the molecular hydrogen

574  
00:26:31,460 --> 00:26:37,308  
is where the cold dense gases because

575  
00:26:35,240 --> 00:26:38,659  
where the cold dense gases that's

576  
00:26:37,308 --> 00:26:40,099  
actually where you're gonna find your

577  
00:26:38,659 --> 00:26:42,140  
stellar nurseries that's where you're

578  
00:26:40,099 --> 00:26:44,178  
going to find the places that you are

579  
00:26:42,140 --> 00:26:47,179  
birthing new stars and keeping your

580  
00:26:44,179 --> 00:26:52,309  
galaxies blue and vibrant and star

581  
00:26:47,179 --> 00:26:54,500  
forming how we see these different

582  
00:26:52,308 --> 00:26:58,490  
wavelengths is with a lot of really cool

583  
00:26:54,500 --> 00:27:00,859  
telescopes I obviously have not seen all

584  
00:26:58,490 --> 00:27:04,599  
of these in person given that this is in

585  
00:27:00,859 --> 00:27:07,849  
space and I am NOT an astronaut but

586  
00:27:04,599 --> 00:27:10,399  
astronomers get to use an incredible set

587  
00:27:07,849 --> 00:27:12,500  
of tools with which we can actually look

588  
00:27:10,400 --> 00:27:13,790  
at these different wavelengths to

589  
00:27:12,500 --> 00:27:17,990  
understand different things about the

590  
00:27:13,789 --> 00:27:21,769  
universe how do we find star formation

591  
00:27:17,990 --> 00:27:25,659  
well one thing we can look at is the

592  
00:27:21,769 --> 00:27:29,599  
ultraviolet this is the Whirlpool Galaxy

593  
00:27:25,659 --> 00:27:31,159  
this is done by Galax there are images

594  
00:27:29,599 --> 00:27:33,558  
of this with Hubble that are

595  
00:27:31,159 --> 00:27:35,390  
significantly better than this but

596  
00:27:33,558 --> 00:27:37,548  
because ultraviolet light is coming

597  
00:27:35,390 --> 00:27:39,350  
again from very hot very young stars

598  
00:27:37,548 --> 00:27:43,269  
you're able to trace our formation with

599

00:27:39,349 --> 00:27:45,349  
it you can also trace it in H alpha

600  
00:27:43,269 --> 00:27:47,298  
again I can think back to that little

601  
00:27:45,349 --> 00:27:50,418  
diagram I showed you one of the things

602  
00:27:47,298 --> 00:27:52,308  
that these hot stars do is they radiate

603  
00:27:50,419 --> 00:27:55,330  
the gas that is around them and that gas

604  
00:27:52,308 --> 00:27:57,558  
being radiated will re radiate that

605  
00:27:55,329 --> 00:28:02,148  
ultraviolet light that it that it's

606  
00:27:57,558 --> 00:28:06,859  
absorbed in line-in lines including the

607  
00:28:02,148 --> 00:28:09,139  
H alpha line and finally

608  
00:28:06,859 --> 00:28:11,808  
you can see star formation and dust this

609  
00:28:09,140 --> 00:28:13,910  
image being an image of the Whirlpool

610  
00:28:11,808 --> 00:28:15,950  
Galaxy from Herschel and what you can

611  
00:28:13,910 --> 00:28:17,720  
see here is again where you have those

612  
00:28:15,950 --> 00:28:20,120  
those gas envelopes that are around

613  
00:28:17,720 --> 00:28:22,548

those stars you also have dust and the

614

00:28:20,119 --> 00:28:27,409

dust is taking those ultraviolet photons

615

00:28:22,548 --> 00:28:32,298

and reradiating it as well okay that's

616

00:28:27,410 --> 00:28:34,880

great but what about the fuel how do you

617

00:28:32,298 --> 00:28:36,650

form those stars we now know that you

618

00:28:34,880 --> 00:28:38,870

can look at ultraviolet light you can

619

00:28:36,650 --> 00:28:41,210

look at optical light to some degree you

620

00:28:38,869 --> 00:28:42,678

can look at spectra you can look at dust

621

00:28:41,210 --> 00:28:44,960

and you can find where the stars are

622

00:28:42,679 --> 00:28:47,269

actually forming well what if you don't

623

00:28:44,960 --> 00:28:48,350

want to just think about the the product

624

00:28:47,269 --> 00:28:52,308

what if you want to think about the

625

00:28:48,349 --> 00:28:54,439

source well where you see young stars

626

00:28:52,308 --> 00:28:57,440

you have to have fuel that is forming

627

00:28:54,440 --> 00:29:00,880

the young stars so first thing you do is

628  
00:28:57,440 --> 00:29:03,529  
you look at where the young stars are

629  
00:29:00,880 --> 00:29:06,080  
you can also look where the dust is

630  
00:29:03,529 --> 00:29:08,529  
because again the dust is in those

631  
00:29:06,079 --> 00:29:15,139  
envelopes those whole pockets of gas

632  
00:29:08,529 --> 00:29:20,480  
with that gas reradiating and finally

633  
00:29:15,140 --> 00:29:23,870  
you can look at the molecular gas in

634  
00:29:20,480 --> 00:29:29,058  
order to form a star you need to be in

635  
00:29:23,869 --> 00:29:30,949  
gas that is both dense and cold because

636  
00:29:29,058 --> 00:29:34,750  
it has to be dense because you need it

637  
00:29:30,950 --> 00:29:37,400  
to be able to overcome gravity and

638  
00:29:34,750 --> 00:29:40,190  
collapse upon itself to form that star

639  
00:29:37,400 --> 00:29:42,710  
and the thing about hydrogen is you're

640  
00:29:40,190 --> 00:29:44,539  
not going to find hydrogen just atoms of

641  
00:29:42,710 --> 00:29:47,090  
hydrogen in places where you don't have

642  
00:29:44,539 --> 00:29:50,720  
cold gas you need to find molecular

643  
00:29:47,089 --> 00:29:52,789  
hydrogen so molecular hydrogen makes up

644  
00:29:50,720 --> 00:29:55,370  
about 70% of the mass in our universe

645  
00:29:52,789 --> 00:29:57,200  
and this also I guess it's not molecular

646  
00:29:55,369 --> 00:29:59,389  
hydrogen make 70% of the mass every

647  
00:29:57,200 --> 00:30:02,360  
universe molecular hydrogen is where you

648  
00:29:59,390 --> 00:30:06,130  
form stars there's this problem with

649  
00:30:02,359 --> 00:30:09,619  
hydrogen the problem with hydrogen is

650  
00:30:06,130 --> 00:30:12,380  
what it is trying to radiate when its

651  
00:30:09,619 --> 00:30:15,139  
spinning it doesn't have a dipole moment

652  
00:30:12,380 --> 00:30:20,140  
that means that it's really really hard

653  
00:30:15,140 --> 00:30:24,280  
to detect it directly but it has

654  
00:30:20,140 --> 00:30:26,920  
neighbor and I know in our world carbon

655  
00:30:24,279 --> 00:30:30,329  
monoxide is not so great but for radio

656

00:30:26,920 --> 00:30:32,890  
astronomers this is a wonderful molecule

657  
00:30:30,329 --> 00:30:34,809  
it's wonderful because it forms in

658  
00:30:32,890 --> 00:30:37,600  
exactly the same environments that you

659  
00:30:34,809 --> 00:30:39,159  
find molecular hydrogen that is if the

660  
00:30:37,599 --> 00:30:41,079  
conditions are right to form molecular

661  
00:30:39,160 --> 00:30:44,080  
hydrogen the conditions are right to

662  
00:30:41,079 --> 00:30:46,750  
make stars the conditions are also right

663  
00:30:44,079 --> 00:30:48,159  
to form carbon monoxide carbon and

664  
00:30:46,750 --> 00:30:51,130  
oxygen are also two of the first

665  
00:30:48,160 --> 00:30:52,870  
molecules of formed in stars so really

666  
00:30:51,130 --> 00:30:54,450  
early on in the universe you had plenty

667  
00:30:52,869 --> 00:30:56,859  
of carbon and you had plenty of oxygen

668  
00:30:54,450 --> 00:30:59,950  
but the thing about this molecule that's

669  
00:30:56,859 --> 00:31:03,819  
even better is that carbon and oxygen

670  
00:30:59,950 --> 00:31:06,519

have a big dipole moment so the second

671

00:31:03,819 --> 00:31:08,799

they start rotating they radiate and we

672

00:31:06,519 --> 00:31:12,789

can pick that up we can pick that up in

673

00:31:08,799 --> 00:31:14,049

radio telescopes so despite the fact

674

00:31:12,789 --> 00:31:16,109

that unfortunately the thing we would

675

00:31:14,049 --> 00:31:19,419

want to detect most molecular hydrogen

676

00:31:16,109 --> 00:31:21,699

sort of out of our reach carbon monoxide

677

00:31:19,420 --> 00:31:24,840

is not and it is best friends and

678

00:31:21,700 --> 00:31:30,059

neighbors with that molecular hydrogen

679

00:31:24,839 --> 00:31:33,549

so we use radio telescopes for it

680

00:31:30,059 --> 00:31:35,619

carbon monoxide is brightest at a

681

00:31:33,549 --> 00:31:37,149

frequency of about one hundred fifty one

682

00:31:35,619 --> 00:31:40,029

hundred fifteen point two seven one two

683

00:31:37,150 --> 00:31:41,590

oh two gigahertz yes I've had to type

684

00:31:40,029 --> 00:31:43,629

that number into a lot of programs to



685  
00:31:41,589 --> 00:31:45,789  
process data which is why I remember too

686  
00:31:43,630 --> 00:31:47,530  
that many significant figures but the

687  
00:31:45,789 --> 00:31:50,529  
idea is this is something that you can

688  
00:31:47,529 --> 00:31:52,079  
see in in radio and with radio

689  
00:31:50,529 --> 00:31:55,690  
telescopes you're actually able to

690  
00:31:52,079 --> 00:31:57,519  
monitor it this video was taken of

691  
00:31:55,690 --> 00:31:58,779  
unfortunately the now-defunct combined

692  
00:31:57,519 --> 00:32:01,809  
array for research and millimeter

693  
00:31:58,779 --> 00:32:04,000  
astronomy which was in the which was in

694  
00:32:01,809 --> 00:32:07,149  
the desert just outside of Mammoth Lakes

695  
00:32:04,000 --> 00:32:09,910  
in California and Carmel was a great

696  
00:32:07,150 --> 00:32:12,070  
instrument for finding carbon monoxide

697  
00:32:09,910 --> 00:32:13,900  
in galaxies and thus finding molecular

698  
00:32:12,069 --> 00:32:16,960  
hydrogen and just finding star forming

699  
00:32:13,900 --> 00:32:20,170  
fuel and now even better is in the

700  
00:32:16,960 --> 00:32:23,019  
Atacama Desert it all my husband has

701  
00:32:20,170 --> 00:32:25,240  
been out there doing incredibly

702  
00:32:23,019 --> 00:32:26,920  
incredible revolutionary things where

703  
00:32:25,240 --> 00:32:29,349  
it's being able to find carbon monoxide

704  
00:32:26,920 --> 00:32:32,970  
not only in nearby neighbor galaxies but

705  
00:32:29,349 --> 00:32:32,969  
out to the beginnings of the universe

706  
00:32:33,150 --> 00:32:39,110  
so what does this all mean I've not told

707  
00:32:36,089 --> 00:32:43,109  
you about how I like to observe stars

708  
00:32:39,109 --> 00:32:46,229  
stars forming old stars young stars red

709  
00:32:43,109 --> 00:32:47,339  
stars green stars blue stars and I've

710  
00:32:46,230 --> 00:32:48,930  
told you how I wanted to look at the

711  
00:32:47,339 --> 00:32:51,480  
star forming gaps

712  
00:32:48,930 --> 00:32:54,900  
well what do you have to do to see a

713

00:32:51,480 --> 00:33:01,640  
galaxy March from this vibrant spiral

714  
00:32:54,900 --> 00:33:01,640  
like thing to this red and dead thing

715  
00:33:03,170 --> 00:33:08,970  
we've thought of a few ways and like

716  
00:33:06,569 --> 00:33:10,829  
I'll say maybe like galaxy evolution

717  
00:33:08,970 --> 00:33:13,410  
astronomers are some of the most macabre

718  
00:33:10,829 --> 00:33:16,259  
astronomers but I like thinking about

719  
00:33:13,410 --> 00:33:19,019  
this even if it's just to think about

720  
00:33:16,259 --> 00:33:21,179  
how to prevent it so if you're a spiral

721  
00:33:19,019 --> 00:33:23,940  
galaxy how do you become an elliptical

722  
00:33:21,179 --> 00:33:26,040  
how do you lose the ability to form

723  
00:33:23,940 --> 00:33:29,220  
those new young stars how do you lose

724  
00:33:26,039 --> 00:33:31,079  
that star forming fuel you can fall into

725  
00:33:29,220 --> 00:33:33,058  
a cluster you can go through a merger

726  
00:33:31,079 --> 00:33:36,329  
you can be in a Galaxy group you can

727  
00:33:33,058 --> 00:33:37,470

have death by black hole and galaxies

728

00:33:36,329 --> 00:33:40,500

shapes which I don't think I will talk

729

00:33:37,470 --> 00:33:44,400

about today don't worry I will talk

730

00:33:40,500 --> 00:33:46,549

about most of these so death by

731

00:33:44,400 --> 00:33:52,500

strangulation ie

732

00:33:46,549 --> 00:33:55,799

falling into a cluster galaxy clusters

733

00:33:52,500 --> 00:33:57,720

are huge conglomerates of a lot of

734

00:33:55,799 --> 00:34:00,659

galaxies that are in basically a big

735

00:33:57,720 --> 00:34:03,660

pocket of hot gas this represents our

736

00:34:00,660 --> 00:34:05,009

hot cluster x-ray gas and because of the

737

00:34:03,660 --> 00:34:07,170

fact that they are gravitational

738

00:34:05,009 --> 00:34:09,148

sinkholes galaxies that are near

739

00:34:07,170 --> 00:34:12,659

clusters are pretty much doomed to

740

00:34:09,148 --> 00:34:15,779

become part of the clusters so

741

00:34:12,659 --> 00:34:18,090

unfortunately this little guy galaxy has

742  
00:34:15,780 --> 00:34:21,600  
been caught by the cluster is now

743  
00:34:18,090 --> 00:34:24,300  
falling into the cluster gas when it

744  
00:34:21,599 --> 00:34:26,159  
falls into this Ram pressure stripping

745  
00:34:24,300 --> 00:34:28,530  
actually starts to strip all of that

746  
00:34:26,159 --> 00:34:31,398  
nice star forming fuel out of the galaxy

747  
00:34:28,530 --> 00:34:33,899  
and it pulls the gas out of the system

748  
00:34:31,398 --> 00:34:35,878  
without the gas unfortunately for that

749  
00:34:33,898 --> 00:34:37,259  
galaxy it's not going to be forming

750  
00:34:35,878 --> 00:34:39,299  
stars so it's not going to be blue

751  
00:34:37,260 --> 00:34:42,800  
anymore because all of a sudden those

752  
00:34:39,300 --> 00:34:45,780  
yellow and red sort of easygoing stars

753  
00:34:42,800 --> 00:34:48,030  
start to dominate the light in the Gow

754  
00:34:45,780 --> 00:34:52,860  
lexy and to us the galaxy actually looks

755  
00:34:48,030 --> 00:34:56,490  
green and then finally upon losing all

756  
00:34:52,860 --> 00:34:59,550  
of its gas the galaxy stops being able

757  
00:34:56,489 --> 00:35:01,829  
to form stars at all and it becomes red

758  
00:34:59,550 --> 00:35:04,320  
and dead it fades into becoming red

759  
00:35:01,829 --> 00:35:08,090  
where again the only stars you're seeing

760  
00:35:04,320 --> 00:35:11,160  
in it now are those older easygoing

761  
00:35:08,090 --> 00:35:13,800  
smaller stars that are ten billion years

762  
00:35:11,159 --> 00:35:15,929  
old as opposed to those young supernova

763  
00:35:13,800 --> 00:35:18,840  
rock star stars which are going to die

764  
00:35:15,929 --> 00:35:22,619  
and about 50 million years ten million

765  
00:35:18,840 --> 00:35:24,390  
years they don't last long and just in

766  
00:35:22,619 --> 00:35:28,619  
case you wonder if we've ever observed

767  
00:35:24,389 --> 00:35:31,379  
this we have we've actually seen this

768  
00:35:28,619 --> 00:35:32,369  
process taking place I don't know

769  
00:35:31,380 --> 00:35:37,110  
whether you can see these little

770

00:35:32,369 --> 00:35:39,179  
filaments here but those are actually

771  
00:35:37,110 --> 00:35:40,920  
the places that the gas is being

772  
00:35:39,179 --> 00:35:43,230  
stripped out of that galaxy is that

773  
00:35:40,920 --> 00:35:46,079  
galaxy falls into a cluster we call them

774  
00:35:43,230 --> 00:35:49,070  
jellyfish galaxies who said astronomers

775  
00:35:46,079 --> 00:35:51,929  
are not creative in their naming schemes

776  
00:35:49,070 --> 00:35:56,730  
so it's why when you look at a cluster

777  
00:35:51,929 --> 00:35:59,730  
like this most of what you see is are

778  
00:35:56,730 --> 00:36:01,500  
these red and dead galaxies now there's

779  
00:35:59,730 --> 00:36:03,090  
something fairly special about clusters

780  
00:36:01,500 --> 00:36:05,340  
is that you actually get to magnify

781  
00:36:03,090 --> 00:36:06,720  
background galaxies but for the most

782  
00:36:05,340 --> 00:36:10,079  
part the galaxies that are in this

783  
00:36:06,719 --> 00:36:13,649  
cluster have had all of their star

784  
00:36:10,079 --> 00:36:15,449

forming fuel gone they have not been

785

00:36:13,650 --> 00:36:16,860

able to form new stars those new stars

786

00:36:15,449 --> 00:36:18,929

have not been able to turn return the

787

00:36:16,860 --> 00:36:24,890

galaxies to looking blue so those

788

00:36:18,929 --> 00:36:31,379

galaxies now look Brett death by battle

789

00:36:24,889 --> 00:36:33,480

mergers and interactions so let's say

790

00:36:31,380 --> 00:36:36,349

you take two equal mass progenitors

791

00:36:33,480 --> 00:36:38,789

progenitors just means original galaxies

792

00:36:36,349 --> 00:36:41,159

either spirals that are elliptical so

793

00:36:38,789 --> 00:36:43,259

you let them encounter each other their

794

00:36:41,159 --> 00:36:47,309

murder is gonna produce an elliptical

795

00:36:43,260 --> 00:36:50,910

galaxy and the colliding galaxies have

796

00:36:47,309 --> 00:36:52,440

explosions of star formation but in

797

00:36:50,909 --> 00:36:54,329

those explosions of star formation they

798

00:36:52,440 --> 00:36:57,960

basically use up their gas really



799  
00:36:54,329 --> 00:36:59,250  
quickly so this is a simulation done by

800  
00:36:57,960 --> 00:37:01,559  
Phil Hopkins

801  
00:36:59,250 --> 00:37:03,900  
which shows a video of what this process

802  
00:37:01,559 --> 00:37:06,690  
looks like now I should point out up

803  
00:37:03,900 --> 00:37:08,970  
here you can see the time scale one gig

804  
00:37:06,690 --> 00:37:10,769  
a year so unfortunately for us we don't

805  
00:37:08,969 --> 00:37:16,339  
get to watch this fireworks show in real

806  
00:37:10,769 --> 00:37:16,340  
time so this is sped up by well a lot

807  
00:37:26,230 --> 00:37:33,039  
as you saw we started with two disk

808  
00:37:29,650 --> 00:37:34,869  
galaxies this is not looking so disc II

809  
00:37:33,039 --> 00:37:36,340  
anymore is it does it have spiral

810  
00:37:34,869 --> 00:37:38,470  
structure that thing that tells us

811  
00:37:36,340 --> 00:37:42,730  
whether or not we consider it a spiral

812  
00:37:38,469 --> 00:37:45,399  
galaxy not so much there is still a dust

813  
00:37:42,730 --> 00:37:47,949  
line because again we just smashed to

814  
00:37:45,400 --> 00:37:49,750  
gas rich galaxies into each other but

815  
00:37:47,949 --> 00:37:54,730  
slowly but surely that dust is being

816  
00:37:49,750 --> 00:37:58,480  
consumed by star formation and the thing

817  
00:37:54,730 --> 00:38:00,309  
that's great about this is that we know

818  
00:37:58,480 --> 00:38:02,679  
what we know what we think we should see

819  
00:38:00,309 --> 00:38:05,230  
again you just saw the simulation and we

820  
00:38:02,679 --> 00:38:09,879  
see this in the real world when we look

821  
00:38:05,230 --> 00:38:11,949  
at galaxies we see absolutely beautiful

822  
00:38:09,880 --> 00:38:13,960  
images of galaxies as they're colliding

823  
00:38:11,949 --> 00:38:16,329  
with one another you see the explosions

824  
00:38:13,960 --> 00:38:17,740  
of their star formation and again you

825  
00:38:16,329 --> 00:38:24,130  
see them at all different stages

826  
00:38:17,739 --> 00:38:26,979  
thank you Hubble so why is it

827

00:38:24,130 --> 00:38:29,019  
that's colliding these two galaxies you

828  
00:38:26,980 --> 00:38:31,570  
know that how pop gas they're exploding

829  
00:38:29,019 --> 00:38:33,670  
their star formation for a while why is

830  
00:38:31,570 --> 00:38:38,440  
it that they turn into this red and dead

831  
00:38:33,670 --> 00:38:40,750  
galaxies what has to do with gas so I'm

832  
00:38:38,440 --> 00:38:42,190  
playing the same movie again but this

833  
00:38:40,750 --> 00:38:44,170  
time I'm showing you two images I'm

834  
00:38:42,190 --> 00:38:46,090  
showing you the one that if we were you

835  
00:38:44,170 --> 00:38:47,858  
know omniscient energy creatures who

836  
00:38:46,090 --> 00:38:49,740  
lived for billions and billions of years

837  
00:38:47,858 --> 00:38:51,789  
we might be able to see in real time

838  
00:38:49,739 --> 00:38:53,889  
unfortunately for you and me that is not

839  
00:38:51,789 --> 00:38:55,779  
the case and over here I'm actually

840  
00:38:53,889 --> 00:38:57,339  
showing what would happen if you had

841  
00:38:55,780 --> 00:39:00,040

eyes that could look at the gas in the

842

00:38:57,340 --> 00:39:03,039

galaxies the hot gas that is gas that is

843

00:39:00,039 --> 00:39:05,170

traced by x-rays the warm gas which is

844

00:39:03,039 --> 00:39:09,579

traced by things like ionized gas and

845

00:39:05,170 --> 00:39:11,108

again the cold gas that blue gas is the

846

00:39:09,579 --> 00:39:12,909

most important gas in this system

847

00:39:11,108 --> 00:39:15,909

because that's the gas it's forming

848

00:39:12,909 --> 00:39:18,460

stars and what you can see is as this

849

00:39:15,909 --> 00:39:19,868

merger keeps going on yes you're getting

850

00:39:18,460 --> 00:39:23,500

these little explosions of star

851

00:39:19,869 --> 00:39:26,170

formation but all of a sudden all of

852

00:39:23,500 --> 00:39:28,630

that warm and cold gas now you're seeing

853

00:39:26,170 --> 00:39:30,700

is really either concentrated in the

854

00:39:28,630 --> 00:39:34,090

very center as it's forming more stars

855

00:39:30,699 --> 00:39:36,730

and just finishing off but mostly it's

856  
00:39:34,090 --> 00:39:37,850  
becoming hot gas and unfortunately for

857  
00:39:36,730 --> 00:39:43,940  
star

858  
00:39:37,849 --> 00:39:45,559  
hot gas is not forming stars so what

859  
00:39:43,940 --> 00:39:46,179  
actually happens here why does it happen

860  
00:39:45,559 --> 00:39:50,409  
like that

861  
00:39:46,179 --> 00:39:53,480  
well I have a handy-dandy schematic here

862  
00:39:50,409 --> 00:39:55,369  
first you have your isolated disks you

863  
00:39:53,480 --> 00:39:57,079  
go through the first interaction there's

864  
00:39:55,369 --> 00:39:59,059  
a coalescence that is when the two

865  
00:39:57,079 --> 00:40:02,539  
galaxies finding smooth into each other

866  
00:39:59,059 --> 00:40:04,820  
there's a gas blowout phase a quasar

867  
00:40:02,539 --> 00:40:07,099  
phase which might be previewing till the

868  
00:40:04,820 --> 00:40:09,559  
next part of my talk once the quasar

869  
00:40:07,099 --> 00:40:11,539  
phase has removed all the gas you get to

870  
00:40:09,559 --> 00:40:13,960  
the decay slash of dying phase that is

871  
00:40:11,539 --> 00:40:16,969  
the post starburst phase until

872  
00:40:13,960 --> 00:40:25,940  
inevitably you march into the run and

873  
00:40:16,969 --> 00:40:28,399  
dead face death by melee so we've now

874  
00:40:25,940 --> 00:40:30,559  
talked about clusters which is hundreds

875  
00:40:28,400 --> 00:40:32,539  
of galaxies and one galaxy falling into

876  
00:40:30,559 --> 00:40:34,639  
that and being doomed to lose all of its

877  
00:40:32,539 --> 00:40:36,409  
gas we've talked about a pair of

878  
00:40:34,639 --> 00:40:38,480  
galaxies having a battle to the death

879  
00:40:36,409 --> 00:40:41,029  
for their gas now we're going to talk

880  
00:40:38,480 --> 00:40:42,740  
about something right in between the fun

881  
00:40:41,030 --> 00:40:44,990  
thing about the right in-between for

882  
00:40:42,739 --> 00:40:47,569  
astronomers is it's actually one of the

883  
00:40:44,989 --> 00:40:49,250  
most complicated things to model because

884

00:40:47,570 --> 00:40:51,769  
the two galaxies you can kind of model

885  
00:40:49,250 --> 00:40:53,570  
together a really big massive cluster

886  
00:40:51,769 --> 00:40:55,750  
can actually be modeled as just that one

887  
00:40:53,570 --> 00:40:58,519  
little dinky galaxy and the big cluster

888  
00:40:55,750 --> 00:41:00,289  
unfortunately this galaxy doesn't just

889  
00:40:58,519 --> 00:41:02,030  
care about that galaxy this galaxy cares

890  
00:41:00,289 --> 00:41:06,590  
about that galaxy and this galaxy and

891  
00:41:02,030 --> 00:41:08,750  
that galaxy in that galaxy so when we

892  
00:41:06,590 --> 00:41:11,030  
say compact group because we're

893  
00:41:08,750 --> 00:41:13,400  
astronomers the first way we actually

894  
00:41:11,030 --> 00:41:15,440  
define this like that when Hubble was a

895  
00:41:13,400 --> 00:41:17,750  
small relatively isolated system of

896  
00:41:15,440 --> 00:41:20,329  
typically four or five galaxies in close

897  
00:41:17,750 --> 00:41:23,090  
proximity to one another when Paul

898  
00:41:20,329 --> 00:41:25,130

Hickson actually did this he was not

899

00:41:23,090 --> 00:41:26,240

looking at spectra he was not comparing

900

00:41:25,130 --> 00:41:28,099

redshifts you did not have

901

00:41:26,239 --> 00:41:31,399

three-dimensional information on these

902

00:41:28,099 --> 00:41:32,929

galaxies he had images and from those

903

00:41:31,400 --> 00:41:34,730

images he basically looked at places

904

00:41:32,929 --> 00:41:36,349

where he saw a few galaxies that were

905

00:41:34,730 --> 00:41:38,719

close to each other and then he

906

00:41:36,349 --> 00:41:40,460

carefully calculated the brightnesses of

907

00:41:38,719 --> 00:41:42,529

those galaxies to see if they were

908

00:41:40,460 --> 00:41:45,590

pretty much as bright as each other and

909

00:41:42,530 --> 00:41:47,630

he came up with a list of 100 compact

910

00:41:45,590 --> 00:41:49,789

groups which we now call Hicks and

911

00:41:47,630 --> 00:41:50,869

compact groups and of those 100 I think

912

00:41:49,789 --> 00:41:53,029

that 90



913  
00:41:50,869 --> 00:41:55,309  
three of them when we went back and took

914  
00:41:53,030 --> 00:41:57,820  
spectra so that we had their distances

915  
00:41:55,309 --> 00:42:00,019  
we found to actually be correctly

916  
00:41:57,820 --> 00:42:01,880  
identified as compact groups that were

917  
00:42:00,019 --> 00:42:05,199  
together so I think that's pretty good

918  
00:42:01,880 --> 00:42:07,340  
for somebody having just you know images

919  
00:42:05,199 --> 00:42:09,679  
they have a high fraction of dead

920  
00:42:07,340 --> 00:42:12,980  
galaxies they have evidence of tidal

921  
00:42:09,679 --> 00:42:15,769  
interactions and again the high density

922  
00:42:12,980 --> 00:42:17,690  
means they have lots and lots and lots

923  
00:42:15,769 --> 00:42:19,400  
of interactions with each other they get

924  
00:42:17,690 --> 00:42:21,619  
the worst of both worlds

925  
00:42:19,400 --> 00:42:23,059  
there's hot gas in those systems so

926  
00:42:21,619 --> 00:42:24,920  
they're getting that hot gas dripping

927

00:42:23,059 --> 00:42:26,690

away some of their gas and they're also

928

00:42:24,920 --> 00:42:29,539

having interaction after interaction

929

00:42:26,690 --> 00:42:32,000

after interaction which is again pulling

930

00:42:29,539 --> 00:42:35,329

it they're pulling their gas away from

931

00:42:32,000 --> 00:42:37,219

them so they start as a loose group at

932

00:42:35,329 --> 00:42:39,259

some point they become a compact group

933

00:42:37,219 --> 00:42:41,089

the star formation fuels starts to be

934

00:42:39,260 --> 00:42:42,770

dispersed again when you have an

935

00:42:41,090 --> 00:42:44,930

interaction a lot of your cold gas

936

00:42:42,769 --> 00:42:47,719

starts being being heated and becoming

937

00:42:44,929 --> 00:42:49,190

part of that hot gas halo the galaxies

938

00:42:47,719 --> 00:42:52,879

evolve into ellipticals and lenticular

939

00:42:49,190 --> 00:42:57,820

x' again a big extra gas bubbles is

940

00:42:52,880 --> 00:43:00,140

shown and maybe we're not sure but maybe

941

00:42:57,820 --> 00:43:02,690  
compact groups can actually make giant

942  
00:43:00,139 --> 00:43:04,699  
ellipticals most of the time when we see

943  
00:43:02,690 --> 00:43:06,380  
the ultra massive elliptical galaxies

944  
00:43:04,699 --> 00:43:08,389  
those are the ultra big red and dead

945  
00:43:06,380 --> 00:43:11,869  
galaxies we see them in the center of

946  
00:43:08,389 --> 00:43:13,789  
clusters but once in a while you

947  
00:43:11,869 --> 00:43:15,769  
actually find these very rare things in

948  
00:43:13,789 --> 00:43:17,809  
the field that is not around these big

949  
00:43:15,769 --> 00:43:19,639  
hundred galaxy clusters but by

950  
00:43:17,809 --> 00:43:21,440  
themselves and so one of the big

951  
00:43:19,639 --> 00:43:23,690  
questions we've asked is how do they get

952  
00:43:21,440 --> 00:43:25,789  
there and it looks like it's very

953  
00:43:23,690 --> 00:43:30,250  
possible that these compact groups are

954  
00:43:25,789 --> 00:43:35,269  
one of the ways to do it again

955  
00:43:30,250 --> 00:43:42,050

death by black hole which we call a GN

956

00:43:35,269 --> 00:43:45,409

feedback so I can't help this this is my

957

00:43:42,050 --> 00:43:49,870

favorite galaxy I was a graduate student

958

00:43:45,409 --> 00:43:53,710

when this galaxy appeared in my life and

959

00:43:49,869 --> 00:43:56,359

it was super weird which is both

960

00:43:53,710 --> 00:43:59,510

wonderful and terrible for a graduate

961

00:43:56,360 --> 00:44:03,610

student especially one as stubborn as I

962

00:43:59,510 --> 00:44:05,710

am because again from

963

00:44:03,610 --> 00:44:09,010

picture you're seeing it it doesn't look

964

00:44:05,710 --> 00:44:11,470

all that interesting but it was a

965

00:44:09,010 --> 00:44:12,910

mystery that all of these different

966

00:44:11,469 --> 00:44:16,419

things were happening in it that were

967

00:44:12,909 --> 00:44:19,239

very very hard to explain again it's a

968

00:44:16,420 --> 00:44:23,320

treasure but it's also a Pandora's box

969

00:44:19,239 --> 00:44:25,899

and I bought it hook line and sinker and

970  
00:44:23,320 --> 00:44:27,789  
said okay I am going to learn why this

971  
00:44:25,900 --> 00:44:31,450  
galaxy is doing the things this galaxy

972  
00:44:27,789 --> 00:44:34,389  
is doing so one of the first things I

973  
00:44:31,449 --> 00:44:38,559  
did is I took a picture I managed to

974  
00:44:34,389 --> 00:44:40,629  
convince the scientists who determine

975  
00:44:38,559 --> 00:44:41,500  
what Hubble is going to look at to look

976  
00:44:40,630 --> 00:44:45,700  
at it for me

977  
00:44:41,500 --> 00:44:48,489  
and luckily for me the little graduate

978  
00:44:45,699 --> 00:44:51,250  
student they said yes so again let's go

979  
00:44:48,489 --> 00:44:53,559  
back to this picture this is NGC 1266

980  
00:44:51,250 --> 00:44:56,050  
taken from the ground with a really good

981  
00:44:53,559 --> 00:44:59,860  
ground-based telescope in the optical

982  
00:44:56,050 --> 00:45:03,010  
with really deep observations and this

983  
00:44:59,860 --> 00:45:04,780  
is what Hubble showed us so yes this is

984  
00:45:03,010 --> 00:45:07,600  
a non photoshopped version

985  
00:45:04,780 --> 00:45:09,460  
I'm very sad Zoltan Levay has retired

986  
00:45:07,599 --> 00:45:12,039  
because I can just imagine how beautiful

987  
00:45:09,460 --> 00:45:14,949  
this would be with results incredible

988  
00:45:12,039 --> 00:45:17,349  
image processing mastery but instead of

989  
00:45:14,949 --> 00:45:19,210  
just seeing this kind of amorphous blob

990  
00:45:17,349 --> 00:45:22,089  
maybe a little bit bright in the middle

991  
00:45:19,210 --> 00:45:23,800  
maybe a little bit weird you see that

992  
00:45:22,090 --> 00:45:25,870  
this thing is really bright in the

993  
00:45:23,800 --> 00:45:27,070  
center and you can actually see a dust

994  
00:45:25,869 --> 00:45:30,579  
cone now coming out of it

995  
00:45:27,070 --> 00:45:33,780  
that's because NGC 1266 was one of the

996  
00:45:30,579 --> 00:45:36,309  
first galaxies we discovered that had a

997  
00:45:33,780 --> 00:45:38,650  
supermassive black hole that was

998

00:45:36,309 --> 00:45:41,889  
actively removing the gas from the

999  
00:45:38,650 --> 00:45:44,230  
system a lot of it we're not talking

1000  
00:45:41,889 --> 00:45:45,909  
about one solar mass per year here which

1001  
00:45:44,230 --> 00:45:47,889  
is about the star formation rate of the

1002  
00:45:45,909 --> 00:45:49,509  
Milky Way we're talking about the fact

1003  
00:45:47,889 --> 00:45:51,909  
that this little black hole is doing

1004  
00:45:49,510 --> 00:45:54,190  
some work this is a hundred solar masses

1005  
00:45:51,909 --> 00:45:59,019  
per year that is managing to move around

1006  
00:45:54,190 --> 00:46:01,000  
in the center of this thing so the next

1007  
00:45:59,019 --> 00:46:03,429  
thing you do again another gorgeous

1008  
00:46:01,000 --> 00:46:05,710  
Hubble image this time I took it in the

1009  
00:46:03,429 --> 00:46:09,190  
near-infrared which is a very good way

1010  
00:46:05,710 --> 00:46:10,809  
to trace stars in particular to look and

1011  
00:46:09,190 --> 00:46:13,240  
see if I could find any signatures of

1012  
00:46:10,809 --> 00:46:14,920

some massive interactions some big

1013

00:46:13,239 --> 00:46:17,419

battle that took place with another

1014

00:46:14,920 --> 00:46:23,059

galaxy like those those simulations I

1015

00:46:17,420 --> 00:46:24,980

you know not really but then when you

1016

00:46:23,059 --> 00:46:27,980

look at it and you combine not only the

1017

00:46:24,980 --> 00:46:29,990

Hubble imaging with the radio telescope

1018

00:46:27,980 --> 00:46:32,659

imaging which was able to show me the

1019

00:46:29,989 --> 00:46:38,509

carbon monoxide thus the star forming

1020

00:46:32,659 --> 00:46:41,719

gas I saw this so radio astronomers like

1021

00:46:38,510 --> 00:46:43,940

contours I'll just warn you this is very

1022

00:46:41,719 --> 00:46:47,509

red shifted yes so this is gas this red

1023

00:46:43,940 --> 00:46:51,619

blob here is gas going 400 kilometers

1024

00:46:47,510 --> 00:46:53,990

per second away from this point and the

1025

00:46:51,619 --> 00:46:58,730

gas here is going 400 kilometers per

1026

00:46:53,989 --> 00:47:01,969

second away towards us and that's in the



1027  
00:46:58,730 --> 00:47:03,108  
middle so when you see this this tells

1028  
00:47:01,969 --> 00:47:05,689  
you you're actually looking at an

1029  
00:47:03,108 --> 00:47:08,509  
outflow we were looking at an outflow in

1030  
00:47:05,690 --> 00:47:11,298  
the cold star forming gas there was cold

1031  
00:47:08,510 --> 00:47:13,069  
star forming gas that this a GN /

1032  
00:47:11,298 --> 00:47:18,460  
supermassive black hole was picking up

1033  
00:47:13,068 --> 00:47:21,710  
and throwing out of the galaxy so again

1034  
00:47:18,460 --> 00:47:24,199  
this picture I hope you can also see

1035  
00:47:21,710 --> 00:47:26,449  
where this Hubble image is showing you

1036  
00:47:24,199 --> 00:47:28,399  
dust that's telling you that there is

1037  
00:47:26,449 --> 00:47:29,960  
cold gas at the core of a dust cone

1038  
00:47:28,400 --> 00:47:35,650  
which again Hubble's image for us

1039  
00:47:29,960 --> 00:47:40,909  
beautifully so that's really interesting

1040  
00:47:35,650 --> 00:47:44,269  
we've now found a way to take gas that

1041  
00:47:40,909 --> 00:47:46,039  
is right in the center of a galaxy throw

1042  
00:47:44,269 --> 00:47:49,759  
it out of that galaxy so that galaxy is

1043  
00:47:46,039 --> 00:47:52,308  
done it might not be a case that gas way

1044  
00:47:49,760 --> 00:47:54,619  
out here this black hole can do much to

1045  
00:47:52,309 --> 00:47:57,260  
it has to be a really really bright

1046  
00:47:54,619 --> 00:47:59,210  
terrible thing to affect gas out here

1047  
00:47:57,260 --> 00:48:01,790  
this should also make you feel pretty

1048  
00:47:59,210 --> 00:48:03,619  
safe we are eight kiloparsecs that is

1049  
00:48:01,789 --> 00:48:06,409  
like way out here compared to the center

1050  
00:48:03,619 --> 00:48:08,059  
of the Milky Way so it would take a lot

1051  
00:48:06,409 --> 00:48:09,889  
of really crazy stuff to happen at

1052  
00:48:08,059 --> 00:48:11,960  
Sagittarius a star the center of our own

1053  
00:48:09,889 --> 00:48:14,210  
galaxy in the supermassive black hole

1054  
00:48:11,960 --> 00:48:17,420  
there to do anything really significant

1055

00:48:14,210 --> 00:48:20,389  
and terrible to us so that's again great

1056  
00:48:17,420 --> 00:48:22,190  
for us annoying for astronomers because

1057  
00:48:20,389 --> 00:48:23,989  
their astronomers you want to get rid of

1058  
00:48:22,190 --> 00:48:26,389  
gas here because again we know these

1059  
00:48:23,989 --> 00:48:28,519  
galaxies are red and dead you can't do

1060  
00:48:26,389 --> 00:48:30,759  
it with something there if you move the

1061  
00:48:28,519 --> 00:48:33,730  
gas in to there

1062  
00:48:30,760 --> 00:48:36,700  
we now know even a little wimpy not

1063  
00:48:33,730 --> 00:48:43,210  
super powerful blackhole can do a huge

1064  
00:48:36,699 --> 00:48:44,439  
amount so that's great it's wonderful

1065  
00:48:43,210 --> 00:48:45,960  
when you find a thing that starts to

1066  
00:48:44,440 --> 00:48:49,050  
answer some of the questions you have

1067  
00:48:45,960 --> 00:48:54,250  
but there's a problem

1068  
00:48:49,050 --> 00:48:56,880  
like any case study it's one thing has

1069  
00:48:54,250 --> 00:49:00,599

anyone ever fit a line to a single point

1070

00:48:56,880 --> 00:49:03,309

you should not do that that's bad

1071

00:49:00,599 --> 00:49:06,159

because you can fit an infinite number

1072

00:49:03,309 --> 00:49:08,440

of lines to that point that means to us

1073

00:49:06,159 --> 00:49:10,299

yes we found one way one thing to do a

1074

00:49:08,440 --> 00:49:11,920

thing and that's great that means

1075

00:49:10,300 --> 00:49:13,780

probably in the universe there are more

1076

00:49:11,920 --> 00:49:15,460

galaxies like this more places that

1077

00:49:13,780 --> 00:49:17,890

dinky little black holes are able to

1078

00:49:15,460 --> 00:49:21,280

remove their gas and effectively kill

1079

00:49:17,889 --> 00:49:23,379

off their galaxies but I kind of want to

1080

00:49:21,280 --> 00:49:25,450

know if that's really common is it

1081

00:49:23,380 --> 00:49:28,300

something you see all the time if you

1082

00:49:25,449 --> 00:49:30,009

look at the early universe when all of

1083

00:49:28,300 --> 00:49:32,530

the star formation seems to be falling

1084  
00:49:30,010 --> 00:49:35,680  
off at the same time is that kind of

1085  
00:49:32,530 --> 00:49:37,810  
thing happening there too is it rare and

1086  
00:49:35,679 --> 00:49:40,299  
I just got really lucky as a graduate

1087  
00:49:37,809 --> 00:49:42,039  
student or is it common and I just

1088  
00:49:40,300 --> 00:49:44,380  
happen to be one of the first people who

1089  
00:49:42,039 --> 00:49:45,070  
had instruments available to me to put

1090  
00:49:44,380 --> 00:49:49,030  
it all together

1091  
00:49:45,070 --> 00:49:51,010  
is there a circle of life in the

1092  
00:49:49,030 --> 00:49:52,680  
galaxies is it a case that these

1093  
00:49:51,010 --> 00:49:54,760  
galaxies are gonna come back someday

1094  
00:49:52,679 --> 00:49:55,389  
well it turns out to do any of that

1095  
00:49:54,760 --> 00:49:58,119  
stuff

1096  
00:49:55,389 --> 00:50:00,309  
ya actually need to find more you can't

1097  
00:49:58,119 --> 00:50:03,309  
just make all of the answers up with one

1098  
00:50:00,309 --> 00:50:08,199  
thing unfortunately as much as poor

1099  
00:50:03,309 --> 00:50:10,929  
graduate student may wish you could so I

1100  
00:50:08,199 --> 00:50:12,368  
wanted to find new ones of these and

1101  
00:50:10,929 --> 00:50:16,179  
that's actually a part of the reason I'm

1102  
00:50:12,369 --> 00:50:18,730  
now here is how do you find and the way

1103  
00:50:16,179 --> 00:50:21,940  
we did it was we looked at special

1104  
00:50:18,730 --> 00:50:24,849  
things about NGC 1266 I told you really

1105  
00:50:21,940 --> 00:50:27,250  
early on about ionized gas in star

1106  
00:50:24,849 --> 00:50:29,469  
forming regions the hot ultraviolet

1107  
00:50:27,250 --> 00:50:32,409  
light and stars are able to irradiate

1108  
00:50:29,469 --> 00:50:35,439  
the gas and that gas is going to rear 88

1109  
00:50:32,409 --> 00:50:37,690  
out in lines it turns out there are

1110  
00:50:35,440 --> 00:50:40,300  
other things that can do that if for

1111  
00:50:37,690 --> 00:50:42,980  
instance you shock the gas that is you

1112

00:50:40,300 --> 00:50:44,570  
collide the gas into itself your

1113  
00:50:42,980 --> 00:50:47,590  
also going to heat up that gas and that

1114  
00:50:44,570 --> 00:50:51,019  
gas is also going to radiate and finally

1115  
00:50:47,590 --> 00:50:53,600  
when a galaxy has stopped has stopped

1116  
00:50:51,019 --> 00:50:55,670  
forming stars there is a period of time

1117  
00:50:53,599 --> 00:50:57,799  
that's a little bit special because that

1118  
00:50:55,670 --> 00:51:00,320  
galaxy is still going to have some young

1119  
00:50:57,800 --> 00:51:04,700  
stars but it's no longer gonna have

1120  
00:51:00,320 --> 00:51:07,340  
infinite stars and because maybe you can

1121  
00:51:04,699 --> 00:51:09,679  
find that snapshot on time you can find

1122  
00:51:07,340 --> 00:51:11,240  
more of these things when we looked we

1123  
00:51:09,679 --> 00:51:14,868  
found these were two things that NGC

1124  
00:51:11,239 --> 00:51:17,449  
1266 had it had shocked gas and we were

1125  
00:51:14,869 --> 00:51:19,730  
able to tell because the energy coming

1126  
00:51:17,449 --> 00:51:21,858

out of a shock makes the gas emission

1127

00:51:19,730 --> 00:51:23,090

lines look a little bit different than

1128

00:51:21,858 --> 00:51:25,489

it does when it's coming from star

1129

00:51:23,090 --> 00:51:29,570

formation and we could find through

1130

00:51:25,489 --> 00:51:32,149

absorption of the through a spectral

1131

00:51:29,570 --> 00:51:35,090

absorption that is certain kinds of

1132

00:51:32,150 --> 00:51:38,119

stars have certain gas that's absorbing

1133

00:51:35,090 --> 00:51:41,059

different different lines different

1134

00:51:38,119 --> 00:51:44,840

radiation you find young but not infant

1135

00:51:41,059 --> 00:51:47,769

stars and so we formed a team and an

1136

00:51:44,840 --> 00:51:50,210

acronym which in astronomy is a big deal

1137

00:51:47,769 --> 00:51:54,949

we were looking for shock to post

1138

00:51:50,210 --> 00:51:56,869

starburst galaxies or Sparks and I will

1139

00:51:54,949 --> 00:51:59,299

warn you you might not take much from my

1140

00:51:56,869 --> 00:52:02,539

talk today you will probably remember



1141  
00:51:59,300 --> 00:52:04,519  
this acronym that's what makes it good

1142  
00:52:02,539 --> 00:52:09,829  
not that it's creative not that it makes

1143  
00:52:04,519 --> 00:52:12,820  
you smile it's sticks in your brain and

1144  
00:52:09,829 --> 00:52:16,009  
so that's what I did is I looked at a

1145  
00:52:12,820 --> 00:52:18,200  
survey of millions of galaxies spectra

1146  
00:52:16,010 --> 00:52:21,040  
and I looked for that special

1147  
00:52:18,199 --> 00:52:24,469  
combination that we found in NGC 1266 I

1148  
00:52:21,039 --> 00:52:26,329  
looked for the special spectral

1149  
00:52:24,469 --> 00:52:28,250  
signatures that told me there was gas in

1150  
00:52:26,329 --> 00:52:31,429  
those galaxies but that gas was not

1151  
00:52:28,250 --> 00:52:34,190  
forming stars that gas was shocked and I

1152  
00:52:31,429 --> 00:52:37,549  
looked for signs in the spectra of young

1153  
00:52:34,190 --> 00:52:39,409  
stars but not infant stars so not the

1154  
00:52:37,550 --> 00:52:41,210  
ones that are gonna supernova right now

1155  
00:52:39,409 --> 00:52:44,059  
because they're still actively forming

1156  
00:52:41,210 --> 00:52:46,070  
and we found out of millions of galaxies

1157  
00:52:44,059 --> 00:52:47,659  
we had to cut it down to about a hundred

1158  
00:52:46,070 --> 00:52:49,220  
thousand that had high enough

1159  
00:52:47,659 --> 00:52:50,690  
signal-to-noise that is they were bright

1160  
00:52:49,219 --> 00:52:53,659  
enough for us to actually do the search

1161  
00:52:50,690 --> 00:52:55,729  
we found over about a thousand galaxies

1162  
00:52:53,659 --> 00:53:01,338  
that were

1163  
00:52:55,728 --> 00:53:06,088  
1266 they were kind of galactic zombies

1164  
00:53:01,338 --> 00:53:08,998  
and because astronomers actually tried

1165  
00:53:06,088 --> 00:53:10,619  
like to share their knowledge you can

1166  
00:53:08,998 --> 00:53:14,788  
actually go and look at the catalog of

1167  
00:53:10,619 --> 00:53:16,318  
all 1067 of these galaxies on a little

1168  
00:53:14,789 --> 00:53:18,359  
website and again

1169

00:53:16,318 --> 00:53:20,728  
luckily the acronym fog will stick in

1170  
00:53:18,358 --> 00:53:22,708  
your head so that website might - and

1171  
00:53:20,728 --> 00:53:24,778  
again this is just fun this is all

1172  
00:53:22,708 --> 00:53:26,578  
science there's nothing on there to buy

1173  
00:53:24,778 --> 00:53:28,619  
nothing like that you just basically go

1174  
00:53:26,579 --> 00:53:30,809  
get get to go look at like thumbnails of

1175  
00:53:28,619 --> 00:53:35,969  
cool galaxies for a while because some

1176  
00:53:30,809 --> 00:53:39,778  
of them look pretty wild then comes the

1177  
00:53:35,969 --> 00:53:41,039  
final phase so I've told you some of the

1178  
00:53:39,778 --> 00:53:43,768  
ways that we have figured out how

1179  
00:53:41,039 --> 00:53:46,799  
galaxies trigger their transition and

1180  
00:53:43,768 --> 00:53:49,108  
become dead I talked to you about the

1181  
00:53:46,798 --> 00:53:51,179  
ways that something inside of the galaxy

1182  
00:53:49,108 --> 00:53:53,728  
itself can actually cause this these

1183  
00:53:51,179 --> 00:53:56,338

galaxies to die and I've talked to you

1184

00:53:53,728 --> 00:53:58,438

about how maybe we can find more that

1185

00:53:56,338 --> 00:54:01,739

are just on this cusp of death where we

1186

00:53:58,438 --> 00:54:03,389

can learn a lot but there's something

1187

00:54:01,739 --> 00:54:05,458

cool about the ones that are the walking

1188

00:54:03,389 --> 00:54:07,708

dead the ellipticals and the lenticular

1189

00:54:05,458 --> 00:54:09,448

x' those that have already gone through

1190

00:54:07,708 --> 00:54:12,208

all of these processes are done with

1191

00:54:09,449 --> 00:54:17,809

their star forming gaps and really just

1192

00:54:12,208 --> 00:54:20,188

are red don't have young stars so again

1193

00:54:17,809 --> 00:54:22,169

the murder takes the gas out of the

1194

00:54:20,188 --> 00:54:24,149

ghoul the murderer puts the gas into the

1195

00:54:22,168 --> 00:54:26,038

middle of the galaxy the black hole does

1196

00:54:24,150 --> 00:54:30,209

the rest and gets the gas out of the

1197

00:54:26,039 --> 00:54:32,369

galaxy then because at some point you

1198  
00:54:30,208 --> 00:54:34,139  
can't recover that gas be fell into a

1199  
00:54:32,369 --> 00:54:38,130  
cluster that gas is gone it's all part

1200  
00:54:34,139 --> 00:54:42,658  
of the hot cluster halo you end with

1201  
00:54:38,130 --> 00:54:45,539  
just this big bright thing these are

1202  
00:54:42,659 --> 00:54:47,640  
interesting too because just because

1203  
00:54:45,539 --> 00:54:49,140  
it's red doesn't mean there is not

1204  
00:54:47,639 --> 00:54:53,989  
something interesting going on in it

1205  
00:54:49,139 --> 00:54:56,219  
because those stars are old stars and

1206  
00:54:53,989 --> 00:54:59,458  
their stars that have been around a

1207  
00:54:56,219 --> 00:55:01,438  
really long time so it turns out if we

1208  
00:54:59,458 --> 00:55:02,998  
look at those kinds of stars the stars

1209  
00:55:01,438 --> 00:55:04,558  
we see that make up these red and dead

1210  
00:55:02,998 --> 00:55:06,928  
galaxies for instance in the Bulge of

1211  
00:55:04,559 --> 00:55:07,530  
our own galaxy we're starting to learn

1212  
00:55:06,929 --> 00:55:10,260  
things

1213  
00:55:07,530 --> 00:55:12,510  
stars that formed towards the beginning

1214  
00:55:10,260 --> 00:55:15,780  
of the universe as opposed to these

1215  
00:55:12,510 --> 00:55:17,700  
young rock star supernova stars that are

1216  
00:55:15,780 --> 00:55:19,019  
there and gone but they're not telling

1217  
00:55:17,699 --> 00:55:25,379  
us about the beginning of the universe

1218  
00:55:19,019 --> 00:55:27,239  
where some of these can so here are some

1219  
00:55:25,380 --> 00:55:28,849  
of the galaxies these are again NGC

1220  
00:55:27,239 --> 00:55:31,529  
numbers which is new galactic catalog

1221  
00:55:28,849 --> 00:55:33,509  
some of these red and galaxies got into

1222  
00:55:31,530 --> 00:55:36,390  
mezes catalog and maybe seven is a

1223  
00:55:33,510 --> 00:55:37,890  
really good example of one Messier 807

1224  
00:55:36,389 --> 00:55:42,719  
is at the center of the Coma Cluster

1225  
00:55:37,889 --> 00:55:44,519  
which is a very nearby cluster to us and

1226

00:55:42,719 --> 00:55:47,519

I guess I leave with the more

1227

00:55:44,519 --> 00:55:51,659

philosophical question here which is

1228

00:55:47,519 --> 00:55:53,670

what will become of us so you might have

1229

00:55:51,659 --> 00:55:55,739

seen that murder those two beautiful gas

1230

00:55:53,670 --> 00:55:58,680

rich discs that I showed and talk to

1231

00:55:55,739 --> 00:56:00,119

yourself huh we have a gas rich disk

1232

00:55:58,679 --> 00:56:04,440

that's kind of next door

1233

00:56:00,119 --> 00:56:08,250

I wonder what's gonna happen well I will

1234

00:56:04,440 --> 00:56:12,269

say this is a visualization an artist's

1235

00:56:08,250 --> 00:56:15,449

rendition not a simulation but let's say

1236

00:56:12,269 --> 00:56:18,119

in the billion year future future

1237

00:56:15,449 --> 00:56:20,069

Earthlings who have evolved beyond

1238

00:56:18,119 --> 00:56:23,489

bodies and now can live sort of

1239

00:56:20,070 --> 00:56:26,039

immortally we're sitting on earth what

1240

00:56:23,489 --> 00:56:29,359

would it look like to them as time

1241

00:56:26,039 --> 00:56:36,239

marched on and we met our friend

1242

00:56:29,360 --> 00:56:39,690

Andromeda usually this comes with music

1243

00:56:36,239 --> 00:56:44,309

we could not make it work so I shall

1244

00:56:39,690 --> 00:56:47,820

narrate so again when you look up in the

1245

00:56:44,309 --> 00:56:49,980

sky this is kind of what you see you see

1246

00:56:47,820 --> 00:56:58,260

that right there I bet you can guess

1247

00:56:49,980 --> 00:57:00,690

what that is that's Andromeda so we're

1248

00:56:58,260 --> 00:57:02,790

going around again this is supposed to

1249

00:57:00,690 --> 00:57:05,579

be from the perspective of an earthling

1250

00:57:02,789 --> 00:57:09,239

sitting on earth moving around the

1251

00:57:05,579 --> 00:57:11,719

galaxy because we orbit the Sun the Sun

1252

00:57:09,239 --> 00:57:14,609

also is orbiting the whole galaxy and

1253

00:57:11,719 --> 00:57:16,889

watching as we get closer and closer

1254

00:57:14,610 --> 00:57:18,900

because of the inevitable pull of



1255  
00:57:16,889 --> 00:57:21,019  
gravity between the Milky Way and

1256  
00:57:18,900 --> 00:57:21,019  
Andromeda

1257  
00:57:26,780 --> 00:57:31,380  
yeah

1258  
00:57:28,139 --> 00:57:33,599  
now again they don't just come together

1259  
00:57:31,380 --> 00:57:38,039  
and smash into each other we're on

1260  
00:57:33,599 --> 00:57:39,889  
orbits but this probably looks like that

1261  
00:57:38,039 --> 00:57:46,349  
nice photos on the sheet that you have

1262  
00:57:39,889 --> 00:57:48,359  
that's again our future maybe but you

1263  
00:57:46,349 --> 00:57:51,089  
can also see that now there's a lot more

1264  
00:57:48,360 --> 00:57:53,730  
blue because as these two things collide

1265  
00:57:51,090 --> 00:57:55,769  
into each other the gas is starting to

1266  
00:57:53,730 --> 00:57:57,990  
compress it starting to shock it's

1267  
00:57:55,769 --> 00:58:01,019  
starting to make super star starbursts

1268  
00:57:57,989 --> 00:58:03,599  
but also unfortunately that gravity

1269  
00:58:01,019 --> 00:58:06,599  
coming from that pesky Andromeda has now

1270  
00:58:03,599 --> 00:58:09,089  
thrown us into a really really bad orbit

1271  
00:58:06,599 --> 00:58:11,819  
we are no longer safely in the disk of

1272  
00:58:09,090 --> 00:58:17,850  
the galaxy we are now getting shot off

1273  
00:58:11,820 --> 00:58:25,860  
all over the place in our orbit it's

1274  
00:58:17,849 --> 00:58:35,009  
great for the view but maybe not so much

1275  
00:58:25,860 --> 00:58:39,150  
for us so again I turn to my little

1276  
00:58:35,010 --> 00:58:40,800  
summary of the different ways you can

1277  
00:58:39,150 --> 00:58:44,670  
die in the universe I know I promised

1278  
00:58:40,800 --> 00:58:47,880  
you a hundred ways I apologize I was

1279  
00:58:44,670 --> 00:58:55,490  
going for the gimmick but I've given you

1280  
00:58:47,880 --> 00:58:55,490  
five ways and now the observers Creed

1281  
00:58:56,510 --> 00:59:02,910  
obviously even though we have thousands

1282  
00:59:01,170 --> 00:59:04,800  
of galaxies even though Hubble has

1283

00:59:02,909 --> 00:59:07,109  
revolutionized our world even though the

1284  
00:59:04,800 --> 00:59:09,420  
launch of James Webb is going to do

1285  
00:59:07,110 --> 00:59:12,920  
these in gorgeous Hubble images but even

1286  
00:59:09,420 --> 00:59:15,530  
further back in the universe and in time

1287  
00:59:12,920 --> 00:59:18,750  
we still don't have all the answers

1288  
00:59:15,530 --> 00:59:21,900  
we found one galaxy like NGC we found

1289  
00:59:18,750 --> 00:59:24,690  
one NGC 1266 that is teaching us a huge

1290  
00:59:21,900 --> 00:59:26,700  
amount about what happens after the

1291  
00:59:24,690 --> 00:59:29,429  
galaxy is dying and after that galaxy

1292  
00:59:26,699 --> 00:59:32,769  
has stopped has been doomed to stop

1293  
00:59:29,429 --> 00:59:35,618  
forming stars and yet

1294  
00:59:32,769 --> 00:59:36,730  
we don't know how common that is we

1295  
00:59:35,619 --> 00:59:39,100  
don't know if that's the way all

1296  
00:59:36,730 --> 00:59:41,769  
galaxies across all of the universe have

1297  
00:59:39,099 --> 00:59:43,779

died we do not know if falling into the

1298

00:59:41,769 --> 00:59:46,780

cluster is the most important part

1299

00:59:43,780 --> 00:59:49,080

or if galaxies merge and die in groups

1300

00:59:46,780 --> 00:59:55,150

before they fall into those clusters and

1301

00:59:49,079 --> 01:00:15,819

so again I have to say as an observer we

1302

00:59:55,150 --> 01:00:18,250

always need more data Thank You microns

1303

01:00:15,820 --> 01:00:20,740

on good alright so we are now at

1304

01:00:18,250 --> 01:00:23,940

questions so who has a question and

1305

01:00:20,739 --> 01:00:25,899

we'll bring the microphone to you I

1306

01:00:23,940 --> 01:00:35,440

guess somebody's phoning in with a

1307

01:00:25,900 --> 01:00:38,590

question you should an example of the

1308

01:00:35,440 --> 01:00:40,329

jellyfish galaxies so my question was

1309

01:00:38,590 --> 01:00:42,100

what would cause the gas to be siphoned

1310

01:00:40,329 --> 01:00:43,779

off and multiple distinct tendrils

1311

01:00:42,099 --> 01:00:49,179

rather than being siphoned off uniformly

1312  
01:00:43,780 --> 01:00:50,800  
all around oh that's actually so I'm

1313  
01:00:49,179 --> 01:00:52,659  
gonna assume everyone heard the question

1314  
01:00:50,800 --> 01:00:55,300  
because of that awesome cute microphone

1315  
01:00:52,659 --> 01:00:56,469  
so that's because gas and galaxies does

1316  
01:00:55,300 --> 01:00:58,600  
not look uniform

1317  
01:00:56,469 --> 01:01:00,639  
if the galaxies if the gas at the

1318  
01:00:58,599 --> 01:01:02,739  
galaxy's falling into is completely

1319  
01:01:00,639 --> 01:01:04,480  
uniform and smooth and the gas in the

1320  
01:01:02,739 --> 01:01:06,909  
galaxy was completely uniform and smooth

1321  
01:01:04,480 --> 01:01:09,579  
you might expect that but in both cases

1322  
01:01:06,909 --> 01:01:12,039  
we know that the gas is extremely clumpy

1323  
01:01:09,579 --> 01:01:14,650  
so the fact that you're falling you're a

1324  
01:01:12,039 --> 01:01:16,599  
clumpy thing that's falling into kind of

1325  
01:01:14,650 --> 01:01:18,369  
a clumpy thing though the gas in the

1326  
01:01:16,599 --> 01:01:19,989  
galaxy is probably clunkier than the gas

1327  
01:01:18,369 --> 01:01:26,410  
in the cluster that's why there are

1328  
01:01:19,989 --> 01:01:28,809  
tendrils yeah in front of what structure

1329  
01:01:26,409 --> 01:01:32,230  
are you standing and where is it oh um

1330  
01:01:28,809 --> 01:01:34,570  
again this is unfortunately the Karma

1331  
01:01:32,230 --> 01:01:36,789  
array up in Owens Valley California

1332  
01:01:34,570 --> 01:01:41,800  
which is now in the valley and has been

1333  
01:01:36,789 --> 01:01:44,679  
decommissioned yeah there is Alma which

1334  
01:01:41,800 --> 01:01:46,210  
is at 16,000 feet in the Atacama Desert

1335  
01:01:44,679 --> 01:01:49,269  
of Chile but I have never

1336  
01:01:46,210 --> 01:01:53,559  
myself up enough to go so really that's

1337  
01:01:49,269 --> 01:01:57,219  
that's high-altitude but there's a there

1338  
01:01:53,559 --> 01:01:58,929  
telescopes like this in on Mauna Kea

1339  
01:01:57,219 --> 01:02:00,669  
called the submillimetre array for

1340

01:01:58,929 --> 01:02:02,829  
anyone who's ever thought to go to Mauna

1341  
01:02:00,670 --> 01:02:07,059  
Kea you can actually see structures like

1342  
01:02:02,829 --> 01:02:11,289  
this in the case there of the the

1343  
01:02:07,059 --> 01:02:13,630  
collision scenarios do we ever get

1344  
01:02:11,289 --> 01:02:16,809  
relativistic effects general relativity

1345  
01:02:13,630 --> 01:02:19,450  
effects you talked about the gradients

1346  
01:02:16,809 --> 01:02:21,849  
the contour lines are their

1347  
01:02:19,449 --> 01:02:24,730  
gravitational contour lines as we get

1348  
01:02:21,849 --> 01:02:27,400  
closer to the center as they begin to

1349  
01:02:24,730 --> 01:02:29,079  
intersect I realized that these are

1350  
01:02:27,400 --> 01:02:31,240  
clusters and I realized that the

1351  
01:02:29,079 --> 01:02:35,440  
majority of the mass is actually dust

1352  
01:02:31,239 --> 01:02:37,629  
not solid objects would spill right so I

1353  
01:02:35,440 --> 01:02:39,429  
will say that ideal on the meso scale so

1354  
01:02:37,630 --> 01:02:40,990

most of the scales I'm working on are

1355

01:02:39,429 --> 01:02:45,368

Killip hundreds of parsecs to

1356

01:02:40,989 --> 01:02:47,199

kiloparsecs so 300 light years to 3,000

1357

01:02:45,369 --> 01:02:48,700

light years I'm on those scales you

1358

01:02:47,199 --> 01:02:51,368

don't really see those relativistic

1359

01:02:48,699 --> 01:02:53,319

effects that being said there are a

1360

01:02:51,369 --> 01:02:55,869

couple of very cool scenarios and things

1361

01:02:53,320 --> 01:02:58,150

that do have relativistic effects first

1362

01:02:55,869 --> 01:02:59,890

is in some of these kinds of galaxies

1363

01:02:58,150 --> 01:03:02,559

there seemed to be relativistic radio

1364

01:02:59,889 --> 01:03:05,500

jets that can form that they're called

1365

01:03:02,559 --> 01:03:08,500

radio galaxies and in those cases you

1366

01:03:05,500 --> 01:03:10,769

actually have such a big black hole that

1367

01:03:08,500 --> 01:03:13,659

you have basically high-powered radio

1368

01:03:10,769 --> 01:03:15,550

plasmas coming out and you can see it



1369  
01:03:13,659 --> 01:03:17,710  
really really far away from the galaxies

1370  
01:03:15,550 --> 01:03:19,570  
the other place that relativistic

1371  
01:03:17,710 --> 01:03:21,639  
effects are sort of interesting is that

1372  
01:03:19,570 --> 01:03:24,338  
in some of these mergers and these

1373  
01:03:21,639 --> 01:03:26,289  
galaxies that are very post-merger those

1374  
01:03:24,338 --> 01:03:28,809  
are actually the galaxies that have such

1375  
01:03:26,289 --> 01:03:30,880  
a wacky gravitational torques in the

1376  
01:03:28,809 --> 01:03:32,920  
centres you can actually get tidal

1377  
01:03:30,880 --> 01:03:38,019  
disruption events which is where stars

1378  
01:03:32,920 --> 01:03:40,659  
fall directly into the black holes yeah

1379  
01:03:38,019 --> 01:03:42,880  
so I mean the the relativistic effects

1380  
01:03:40,659 --> 01:03:44,739  
are really strong around the

1381  
01:03:42,880 --> 01:03:46,210  
supermassive black holes and you get

1382  
01:03:44,739 --> 01:03:49,709  
that but that's much smaller scale than

1383  
01:03:46,210 --> 01:03:49,710  
she usually deals with here yes

1384  
01:03:51,248 --> 01:03:56,718  
it is and we learned we actually have

1385  
01:03:54,798 --> 01:03:58,788  
learned a lot from a couple of these

1386  
01:03:56,719 --> 01:04:00,949  
tidal disruption events we've seen I'm

1387  
01:03:58,789 --> 01:04:02,390  
again the thing the super cool is we

1388  
01:04:00,949 --> 01:04:04,909  
keep seeing these tidal disruption

1389  
01:04:02,389 --> 01:04:07,159  
events in these weird types of galaxies

1390  
01:04:04,909 --> 01:04:10,548  
these galaxies are rare the kind of

1391  
01:04:07,159 --> 01:04:13,578  
zombie galaxies I study are 1% of modern

1392  
01:04:10,548 --> 01:04:15,170  
galaxies and yet in in these events

1393  
01:04:13,579 --> 01:04:16,548  
where you're finding these stars that

1394  
01:04:15,170 --> 01:04:18,318  
are actually starting to give you an

1395  
01:04:16,548 --> 01:04:20,748  
idea of what the black hole spin is

1396  
01:04:18,318 --> 01:04:21,829  
because you can actually model it you're

1397

01:04:20,748 --> 01:04:23,958  
finding them in these weird

1398  
01:04:21,829 --> 01:04:27,410  
one-percenters and not really finding

1399  
01:04:23,958 --> 01:04:30,618  
them as much in other things when when

1400  
01:04:27,409 --> 01:04:32,719  
the galaxies collide do you and the

1401  
01:04:30,619 --> 01:04:35,358  
actually do the actually form new

1402  
01:04:32,719 --> 01:04:37,639  
molecular structure when when they

1403  
01:04:35,358 --> 01:04:40,278  
actually come together to the what

1404  
01:04:37,639 --> 01:04:44,298  
actually does collide um for the most

1405  
01:04:40,278 --> 01:04:45,679  
part gas so the the actual stars for the

1406  
01:04:44,298 --> 01:04:47,688  
most part don't collide with one another

1407  
01:04:45,679 --> 01:04:49,969  
there's probably I don't know what the

1408  
01:04:47,688 --> 01:04:51,288  
chances are there's like a 1% chance in

1409  
01:04:49,969 --> 01:04:54,829  
one of these collisions you have one

1410  
01:04:51,289 --> 01:04:57,079  
star hit one star yeah lower it's very

1411  
01:04:54,829 --> 01:04:58,519

very small the gas on the other hand

1412

01:04:57,079 --> 01:05:01,369

actually does collide with each other

1413

01:04:58,518 --> 01:05:03,889

and it shocks and when it shocks it

1414

01:05:01,369 --> 01:05:05,809

turns out you do actually sometimes form

1415

01:05:03,889 --> 01:05:07,518

different molecular structures but

1416

01:05:05,809 --> 01:05:10,489

that's because the gas is being heated

1417

01:05:07,518 --> 01:05:12,228

so much that things like the dust which

1418

01:05:10,489 --> 01:05:15,228

has you know the dust which was normally

1419

01:05:12,228 --> 01:05:17,028

pretty happy is sublimated and so all of

1420

01:05:15,228 --> 01:05:20,298

a sudden the sublimated dust is now

1421

01:05:17,028 --> 01:05:22,969

gaseous and so for instance in some of

1422

01:05:20,298 --> 01:05:24,978

these galaxies uh but even closer to

1423

01:05:22,969 --> 01:05:27,559

home things like star protostars

1424

01:05:24,978 --> 01:05:29,958

you see things like silicon oxide in the

1425

01:05:27,559 --> 01:05:32,869

radio spectra because the dust has been

1426  
01:05:29,958 --> 01:05:35,808  
destroyed in them from these shocks okay

1427  
01:05:32,869 --> 01:05:39,048  
we have a comment from online while dare

1428  
01:05:35,809 --> 01:05:44,410  
grant given that your title is actually

1429  
01:05:39,048 --> 01:05:44,409  
correct because 1 0 0 in binary is 5

1430  
01:05:44,739 --> 01:05:54,348  
whoever that is like cannot attend man

1431  
01:05:49,009 --> 01:05:57,769  
well I got to it's gotta to you

1432  
01:05:54,349 --> 01:06:01,278  
characterize the little galaxies is

1433  
01:05:57,768 --> 01:06:04,578  
sighing and but they seem to live live

1434  
01:06:01,278 --> 01:06:06,798  
long lives out of house their lifespan

1435  
01:06:04,579 --> 01:06:09,859  
on average compared with those of the

1436  
01:06:06,798 --> 01:06:13,250  
spiral galaxies um

1437  
01:06:09,858 --> 01:06:14,750  
I think the thing that oh wait was the

1438  
01:06:13,250 --> 01:06:20,750  
way that I always like to think about it

1439  
01:06:14,750 --> 01:06:23,630  
is galaxies are like cities so in let's

1440  
01:06:20,750 --> 01:06:25,190  
say New York City you have a set of

1441  
01:06:23,630 --> 01:06:26,660  
people who have been living you know a

1442  
01:06:25,190 --> 01:06:28,400  
nice life that are getting towards

1443  
01:06:26,659 --> 01:06:30,528  
retirement age and are pretty happy and

1444  
01:06:28,400 --> 01:06:32,869  
pretty calm but then you also have like

1445  
01:06:30,528 --> 01:06:35,690  
the young rock stars and like things

1446  
01:06:32,869 --> 01:06:38,298  
going on in those cities and so in in

1447  
01:06:35,690 --> 01:06:40,099  
disk galaxies um you still have those

1448  
01:06:38,298 --> 01:06:42,170  
star formation events but that city

1449  
01:06:40,099 --> 01:06:43,880  
could be very old and you just have like

1450  
01:06:42,170 --> 01:06:45,200  
the people who have been watching you

1451  
01:06:43,880 --> 01:06:46,730  
know on their balconies and like

1452  
01:06:45,199 --> 01:06:48,469  
smelling the fresh air and thinking

1453  
01:06:46,730 --> 01:06:50,630  
about how things were which is these red

1454

01:06:48,469 --> 01:06:52,788  
stars are like looking down and seeing

1455  
01:06:50,630 --> 01:06:55,880  
the frenetic frantic activities of the

1456  
01:06:52,789 --> 01:06:57,380  
younger supernovae in stars whereas in

1457  
01:06:55,880 --> 01:06:59,000  
the elliptical galaxies you're basically

1458  
01:06:57,380 --> 01:07:00,710  
living in a place where all of the stars

1459  
01:06:59,000 --> 01:07:03,798  
are are old

1460  
01:07:00,710 --> 01:07:05,389  
so again Edwin Hubble had it wrong when

1461  
01:07:03,798 --> 01:07:07,400  
Edwin put together the sequence

1462  
01:07:05,389 --> 01:07:09,469  
he thought early types became late types

1463  
01:07:07,400 --> 01:07:11,088  
which is what we call them spiral

1464  
01:07:09,469 --> 01:07:12,739  
galaxies are late types I tried very

1465  
01:07:11,088 --> 01:07:18,440  
hard not to say it because I think it is

1466  
01:07:12,739 --> 01:07:21,348  
confusing but even in our Milky Way the

1467  
01:07:18,440 --> 01:07:22,670  
Bulge of our Milky Way is quite old even

1468  
01:07:21,349 --> 01:07:26,150

though the disk of our Milky Way on

1469

01:07:22,670 --> 01:07:28,250

average is young so it just comes down

1470

01:07:26,150 --> 01:07:31,460

to the proportion of old to young they

1471

01:07:28,250 --> 01:07:33,108

can both have around the same age but

1472

01:07:31,460 --> 01:07:35,059

they just have been living and acting

1473

01:07:33,108 --> 01:07:36,558

differently in those ages because again

1474

01:07:35,059 --> 01:07:40,609

they're not people they're cities in

1475

01:07:36,559 --> 01:07:42,829

this case so it's the populations okay

1476

01:07:40,608 --> 01:07:45,440

we have a question from online why do

1477

01:07:42,829 --> 01:07:49,150

most young stars appear in the galaxy

1478

01:07:45,440 --> 01:07:49,150

arms instead of the nucleus

1479

01:07:49,989 --> 01:07:57,679

well I want to think about that because

1480

01:07:54,289 --> 01:07:59,780

in my systems they're all of the nucleus

1481

01:07:57,679 --> 01:08:02,298

because that's where the gas is and I

1482

01:07:59,780 --> 01:08:05,569

think for the most part the start the



1483  
01:08:02,298 --> 01:08:07,759  
young stars follow where the gases so it

1484  
01:08:05,568 --> 01:08:09,889  
turns out in the center of the Milky Way

1485  
01:08:07,760 --> 01:08:11,329  
there is a lot of star information going

1486  
01:08:09,889 --> 01:08:13,788  
on it's called the central molecular

1487  
01:08:11,329 --> 01:08:15,410  
zone there's dense gas there's but the

1488  
01:08:13,789 --> 01:08:21,640  
arms is where you're seeing the majority

1489  
01:08:15,409 --> 01:08:38,000  
of it um so the answer is follow the gas

1490  
01:08:21,640 --> 01:08:41,750  
okay do all galaxies die eventually yeah

1491  
01:08:38,000 --> 01:08:45,560  
so our universe seems to show a

1492  
01:08:41,750 --> 01:08:47,479  
hierarchy the bigger a galaxy is the

1493  
01:08:45,560 --> 01:08:50,359  
more likely the galaxy is to be dead

1494  
01:08:47,479 --> 01:08:53,568  
which is what caused the pause so if

1495  
01:08:50,359 --> 01:08:56,539  
you're a small small galaxy you probably

1496  
01:08:53,569 --> 01:08:58,548  
have had the supply of gas available to

1497  
01:08:56,539 --> 01:09:00,079  
you for longer and it's going to be

1498  
01:08:58,548 --> 01:09:02,649  
available to you for longer than a

1499  
01:09:00,079 --> 01:09:06,048  
really big galaxy eventually yes

1500  
01:09:02,649 --> 01:09:07,849  
eventually it's likely all gas is going

1501  
01:09:06,048 --> 01:09:09,140  
to be consumed in galaxies all stars are

1502  
01:09:07,850 --> 01:09:10,429  
going to become white works and then

1503  
01:09:09,140 --> 01:09:15,980  
they're all going to fall into black

1504  
01:09:10,429 --> 01:09:18,380  
holes but right so that to me doesn't

1505  
01:09:15,979 --> 01:09:22,309  
seem like quite the answer you want the

1506  
01:09:18,380 --> 01:09:25,039  
answer is yes all galaxies probably will

1507  
01:09:22,310 --> 01:09:27,650  
die and the bigger more massive galaxies

1508  
01:09:25,039 --> 01:09:29,829  
seem to have died first and like

1509  
01:09:27,649 --> 01:09:34,278  
unfortunately for us in the Milky Way

1510  
01:09:29,829 --> 01:09:36,289  
we're coming soon another way to look at

1511

01:09:34,279 --> 01:09:38,000  
it is if you look at the star formation

1512  
01:09:36,289 --> 01:09:39,528  
history of the universe it's sort of

1513  
01:09:38,000 --> 01:09:41,659  
Peaks about two to three billion years

1514  
01:09:39,529 --> 01:09:44,359  
into the universe and has been declining

1515  
01:09:41,659 --> 01:09:46,939  
ever since so the maximum amount of star

1516  
01:09:44,359 --> 01:09:49,489  
formation occurred about ten billion

1517  
01:09:46,939 --> 01:09:53,500  
years ago in the universe if I remember

1518  
01:09:49,488 --> 01:09:53,500  
correctly yes it would you remember

1519  
01:09:53,680 --> 01:10:00,650  
right so so peaked and then it's falling

1520  
01:09:58,069 --> 01:10:02,899  
ever since so yeah we're on the decline

1521  
01:10:00,649 --> 01:10:06,529  
yeah at least from a universal

1522  
01:10:02,899 --> 01:10:08,889  
perspective all right other questions

1523  
01:10:06,529 --> 01:10:15,289  
[Music]

1524  
01:10:08,890 --> 01:10:19,070  
all right let's check online there's

1525  
01:10:15,289 --> 01:10:20,869

something about will the you talked

1526

01:10:19,069 --> 01:10:23,569

about birth and they're saying you made

1527

01:10:20,869 --> 01:10:26,119

a doomsday prediction for Earth during

1528

01:10:23,569 --> 01:10:28,189

the Milky Way Andromeda collision but

1529

01:10:26,119 --> 01:10:30,019

then the question is of course will

1530

01:10:28,189 --> 01:10:39,799

earth still be here during that

1531

01:10:30,020 --> 01:10:41,930

collision poofed up big enough that it

1532

01:10:39,800 --> 01:10:45,440

basically fries us and maybe even in

1533

01:10:41,930 --> 01:10:46,670

develops us the stellar winds that are

1534

01:10:45,439 --> 01:10:49,369

going to be coming off of it at that

1535

01:10:46,670 --> 01:10:53,869

time will have absolutely crushed us so

1536

01:10:49,369 --> 01:10:55,670

no it will have to be new earth or you

1537

01:10:53,869 --> 01:10:58,220

know will have to be a Star Trek society

1538

01:10:55,670 --> 01:11:00,079

by then and wrists around the galaxy to

1539

01:10:58,220 --> 01:11:02,119

look for places hopefully by then we'll

1540  
01:11:00,079 --> 01:11:04,159  
have like super wormhole networks that

1541  
01:11:02,119 --> 01:11:07,789  
can connect us to a galaxy that's not

1542  
01:11:04,159 --> 01:11:09,380  
about to collide with Andromeda a really

1543  
01:11:07,789 --> 01:11:12,409  
long time from now we have a lot of

1544  
01:11:09,380 --> 01:11:13,760  
times the first pass of the collision is

1545  
01:11:12,409 --> 01:11:16,670  
gonna be about four billion years from

1546  
01:11:13,760 --> 01:11:18,170  
now and the final merger is about six

1547  
01:11:16,670 --> 01:11:21,350  
and a half seven billion years from now

1548  
01:11:18,170 --> 01:11:23,690  
yeah once the Milky Way and Andromeda

1549  
01:11:21,350 --> 01:11:26,750  
become an elliptical it'll you about six

1550  
01:11:23,689 --> 01:11:29,569  
seven billion years from now and our Sun

1551  
01:11:26,750 --> 01:11:33,439  
will have yeah it'll it'll have done its

1552  
01:11:29,569 --> 01:11:35,289  
own dying thing alright any last

1553  
01:11:33,439 --> 01:11:40,399  
questions from the audience

1554  
01:11:35,289 --> 01:11:43,489  
all right next month star is chasing

1555  
01:11:40,399 --> 01:11:47,089  
supernova with Kepler okay

1556  
01:11:43,489 --> 01:11:49,670  
in October arena stand up and wave

1557  
01:11:47,090 --> 01:11:51,400  
everyone say hi we haven't seen before

1558  
01:11:49,670 --> 01:11:53,569  
once

1559  
01:11:51,399 --> 01:11:54,979  
if you would like to go across the

1560  
01:11:53,569 --> 01:11:57,769  
street and look out through the

1561  
01:11:54,979 --> 01:12:00,579  
telescope in the observatory follow her

1562  
01:11:57,770 --> 01:12:00,580  
how many can you take

1563  
01:12:04,060 --> 01:12:08,900  
okay there are no there are safety

1564  
01:12:07,369 --> 01:12:11,720  
regulations there's only so many people

1565  
01:12:08,899 --> 01:12:15,109  
and they once we got a little bit too

1566  
01:12:11,720 --> 01:12:17,030  
much yet so uh thank you all for coming

1567  
01:12:15,109 --> 01:12:19,359  
let's give Katie one more big round and

1568

01:12:17,029 --> 01:12:19,359  
have fun

1569  
01:12:27,988 --> 01:12:40,919  
we had coming over it's been months and

1570  
01:12:38,829 --> 01:12:40,920  
months

1571  
01:12:45,238 --> 01:12:49,709  
yeah watching wait over there can slow