PUBLIC LECTURE SERIES

# Rubin's Galaxy: A Gentle Giant Spiral Galaxy

Featuring Guest Speaker :

**Benne Holwerda**

1
00:00:05,499 --> 00:00:02,960
welcome to the Space Telescope public

2
00:00:09,500 --> 00:00:05,509
lecture series in our very first

3
00:00:12,470 --> 00:00:09,510
online-only edition today we have Benny

4
00:00:14,330 --> 00:00:12,480
hall where Duff speaking on from the

5
00:00:18,160 --> 00:00:14,340
University of Louisville speaking on

6
00:00:21,500 --> 00:00:18,170
Rubens galaxy gentle giant spiral galaxy

7
00:00:23,920 --> 00:00:21,510
I'm your host dr. Frank summers of the

8
00:00:27,019 --> 00:00:23,930
Space Telescope Science Institute and

9
00:00:29,419 --> 00:00:27,029
I'm the Space Telescope public lecture

10
00:00:33,260 --> 00:00:29,429
series will be online only for the rest

11
00:00:36,920 --> 00:00:33,270
of 2020 and I want to thank the amazing

12
00:00:40,190 --> 00:00:36,930
team at Space Telescope for producing

13
00:00:42,260 --> 00:00:40,200

all of this in special our thanks to the

14
00:00:44,840 --> 00:00:42,270
amazing tech team Thomas Maroof ooh and

15
00:00:47,529 --> 00:00:44,850
grant justice without whom this special

16
00:00:50,209 --> 00:00:47,539
online-only edition wouldn't be possible

17
00:00:54,229 --> 00:00:50,219
so we have speakers lined up for the

18
00:00:57,290 --> 00:00:54,239
rest of a twenty twenty next month in

19
00:01:00,170 --> 00:00:57,300
July will mi Amoro Martin will be

20
00:01:02,959 --> 00:01:00,180
speaking on interstellar comets these

21
00:01:05,929 --> 00:01:02,969
are comets that have come from other

22
00:01:07,850 --> 00:01:05,939
solar systems and entered into our

23
00:01:08,929 --> 00:01:07,860
planetary system you're really gonna

24
00:01:11,030 --> 00:01:08,939
want to hear that that's gonna be

25
00:01:13,640 --> 00:01:11,040
fantastic in August

26
00:01:16,789 --> 00:01:13,650
Quinn heart will be talking about the

27
00:01:18,050 --> 00:01:16,799
physics of astrophysics and I know that

28
00:01:19,700 --> 00:01:18,060
sounds really geeky but she actually

29
00:01:20,990 --> 00:01:19,710
said you know that's sort of the topic

30
00:01:22,910 --> 00:01:21,000
that I'm gonna talk about but I'll give

31
00:01:24,560 --> 00:01:22,920
you a really cool title so next month

32
00:01:26,899 --> 00:01:24,570
we'll have a really cool title that

33
00:01:29,840 --> 00:01:26,909
won't sound so so geeky but actually

34
00:01:32,120 --> 00:01:29,850
it's really interesting how how much

35
00:01:34,340 --> 00:01:32,130
physics is there is underlying the

36
00:01:37,910 --> 00:01:34,350
astrophysics and how that the two things

37
00:01:39,890 --> 00:01:37,920
work back and forth in September will

38
00:01:43,069 --> 00:01:39,900

fish will be speaking on the lyses

39
00:01:47,210 --> 00:01:43,079
project which is a grand ultraviolet

40
00:01:49,730 --> 00:01:47,220
survey of stars and it's one of the big

41
00:01:51,920 --> 00:01:49,740
really big legacy projects from Hubble

42
00:01:54,679 --> 00:01:51,930
and he'll be able to tell you all about

43
00:01:57,649 --> 00:01:54,689
that in September if you would like to

44
00:02:02,300 --> 00:01:57,659
learn about of these events you go to

45
00:02:05,060 --> 00:02:02,310
our website which is at WWSD SEI tu /

46
00:02:08,029 --> 00:02:05,070
public - lectures and you will get this

47
00:02:12,050 --> 00:02:08,039
webpage and we have just updated it for

48
00:02:13,790 --> 00:02:12,060
our online only version the webcasts

49
00:02:18,230 --> 00:02:13,800
we've been doing webcasts

50
00:02:20,480 --> 00:02:18,240
so off gosh back to 2005 so that's 15

51
00:02:23,300 --> 00:02:20,490
years of webcasts we've been doing we've

52
00:02:27,410 --> 00:02:23,310
been doing YouTube webcasts since the

53
00:02:29,330 --> 00:02:27,420
about 2013-2014 timeframe so there are

54
00:02:31,760 --> 00:02:29,340
links on the left side of this page to

55
00:02:33,740 --> 00:02:31,770
our YouTube playlist as well as our

56
00:02:36,620 --> 00:02:33,750
webcast archives here at the Space

57
00:02:38,780 --> 00:02:36,630
Telescope Science Institute and on the

58
00:02:40,670 --> 00:02:38,790
right you can sign up for email you can

59
00:02:43,070 --> 00:02:40,680
put in your email address and subscribe

60
00:02:45,410 --> 00:02:43,080
and you'll get an email once or twice a

61
00:02:46,790 --> 00:02:45,420
month telling you when our lectures are

62
00:02:50,270 --> 00:02:46,800
going to be and when they have been

63
00:02:52,280 --> 00:02:50,280

posted on our YouTube channel lower down

64
00:02:54,440 --> 00:02:52,290
on that same page you will find a list

65
00:02:58,310 --> 00:02:54,450
of the upcoming lectures and their

66
00:03:00,380 --> 00:02:58,320
details the details of each lecture tell

67
00:03:02,390 --> 00:03:00,390
you not only the speaker and the

68
00:03:05,030 --> 00:03:02,400
abstract of the description of what's

69
00:03:07,580 --> 00:03:05,040
going on but also after they are posted

70
00:03:09,710 --> 00:03:07,590
we have links to the stsci version of

71
00:03:11,810 --> 00:03:09,720
the webcast as well as the YouTube

72
00:03:13,850 --> 00:03:11,820
webcast of course for this year for the

73
00:03:18,680 --> 00:03:13,860
rest of this year the stsci webcast will

74
00:03:20,900 --> 00:03:18,690
not be there the email as I said if you

75
00:03:23,090 --> 00:03:20,910
can just sign up at our website to get

76
00:03:26,270 --> 00:03:23,100
announcements an alternate way to get

77
00:03:27,229 --> 00:03:26,280
notified is to subscribe to our YouTube

78
00:03:29,810 --> 00:03:27,239
channel

79
00:03:32,690 --> 00:03:29,820
it is youtube.com slash Hubble Space

80
00:03:35,060 --> 00:03:32,700
Telescope all one word and that if you

81
00:03:37,010 --> 00:03:35,070
sign up a subscribe to that you will get

82
00:03:39,530 --> 00:03:37,020
not only the reminders of these live

83
00:03:42,620 --> 00:03:39,540
events but also notices of the new

84
00:03:44,240 --> 00:03:42,630
videos that we post there finally if you

85
00:03:47,300 --> 00:03:44,250
have comments I have questions you can

86
00:03:50,540 --> 00:03:47,310
send them to public lecture at STScI dot

87
00:03:53,050 --> 00:03:50,550
edu if you'd like to follow our

88
00:03:55,340 --> 00:03:53,060

Institute on social media we have

89
00:03:57,199 --> 00:03:55,350
channels for our Institute as well as

90
00:03:59,690 --> 00:03:57,209
for the Hubble and James Webb Space

91
00:04:03,350 --> 00:03:59,700
Telescope's they're on Facebook Twitter

92
00:04:05,510 --> 00:04:03,360
YouTube and Instagram I myself do a

93
00:04:07,460 --> 00:04:05,520
little bit of a social media on Facebook

94
00:04:09,560 --> 00:04:07,470
and Twitter and you can follow that if

95
00:04:14,150 --> 00:04:09,570
you'd like to know my thoughts on the

96
00:04:17,380 --> 00:04:14,160
world okay now my favorite part the news

97
00:04:20,720 --> 00:04:17,390
from the universe for June 2020 our

98
00:04:23,120 --> 00:04:20,730
first story tonight and what was going

99
00:04:27,680 --> 00:04:23,130
to be the topic of our public lecture in

100
00:04:31,650 --> 00:04:27,690
April is Hubble's 30th anniversary

101
00:04:33,480 --> 00:04:31,660
it was 30 years ago I mean wow it's just

102
00:04:35,430 --> 00:04:33,490
hard to think about it being that long

103
00:04:37,830 --> 00:04:35,440
ago but it was 30 years ago that the

104
00:04:41,640 --> 00:04:37,840
Hubble Space Telescope launched into

105
00:04:43,920 --> 00:04:41,650
orbit on the space shuttle and each year

106
00:04:47,220 --> 00:04:43,930
we challenge ourselves to come up with a

107
00:04:50,160 --> 00:04:47,230
really cool image to celebrate what are

108
00:04:52,380 --> 00:04:50,170
we gonna do to top ourselves well this

109
00:04:54,840 --> 00:04:52,390
year we came up with an amazing image

110
00:04:58,710 --> 00:04:54,850
and this was the image that we came up

111
00:05:02,370 --> 00:04:58,720
with it's a picture of the red nebula

112
00:05:06,920 --> 00:05:02,380
which is NGC 2014 and the smaller blue

113
00:05:09,540 --> 00:05:06,930

nebula which is NGC 2020 and this is

114
00:05:12,410 --> 00:05:09,550
really gorgeous it's you know hundreds

115
00:05:15,300 --> 00:05:12,420
of megapixels all sorts of detailed and

116
00:05:17,250 --> 00:05:15,310
- when we were first looking at it it

117
00:05:19,920 --> 00:05:17,260
sort of had this you know brain coral

118
00:05:22,080 --> 00:05:19,930
type feel to it and we sort of got that

119
00:05:23,730 --> 00:05:22,090
oh well maybe the NGC 2020 is this

120
00:05:27,360 --> 00:05:23,740
little jellyfish dancing around on a

121
00:05:31,650 --> 00:05:27,370
coral reef and so the nickname came up

122
00:05:34,950 --> 00:05:31,660
to call it the cosmic reef and I would

123
00:05:38,250 --> 00:05:34,960
tell you all about this image but I'm

124
00:05:41,220 --> 00:05:38,260
not because I've already done it on the

125
00:05:43,650 --> 00:05:41,230
30th anniversary we did a YouTube

126
00:05:47,370 --> 00:05:43,660
webcast of the Hubble Space Telescope

127
00:05:51,210 --> 00:05:47,380
30th anniversary image unveiling with me

128
00:05:54,810 --> 00:05:51,220
and Allen asabi describing Hubble and

129
00:05:57,630 --> 00:05:54,820
the 30 years and the details of this new

130
00:06:00,960 --> 00:05:57,640
image so if you go to youtube and type

131
00:06:04,320 --> 00:06:00,970
in Hubble 30 image unveiling this will

132
00:06:06,570 --> 00:06:04,330
be your first hit and you can watch a 30

133
00:06:08,370 --> 00:06:06,580
minute presentation on the 30th

134
00:06:10,890 --> 00:06:08,380
anniversary image which saves me from

135
00:06:14,990 --> 00:06:10,900
having to repeat all that during my news

136
00:06:18,930 --> 00:06:15,000
from the universe today our second story

137
00:06:20,490 --> 00:06:18,940
baitul juice is back to normal if you

138
00:06:23,490 --> 00:06:20,500

were here in March

139
00:06:26,700 --> 00:06:23,500
you saw that I talked about the super

140
00:06:28,770 --> 00:06:26,710
red supergiant star bail juice most of

141
00:06:31,200 --> 00:06:28,780
you may know that it is the right

142
00:06:33,570 --> 00:06:31,210
shoulder of Orion it's on the top left

143
00:06:36,840 --> 00:06:33,580
and this image it's a red supergiant

144
00:06:38,600 --> 00:06:36,850
star and what I talked about then was

145
00:06:40,230 --> 00:06:38,610
the fact that bail juice has been

146
00:06:41,820 --> 00:06:40,240
dimming okay

147
00:06:44,700 --> 00:06:41,830
on the left you see a picture from

148
00:06:47,040 --> 00:06:44,710
February 2016 which is its normal

149
00:06:49,170 --> 00:06:47,050
brightness and on the right you see a

150
00:06:51,920 --> 00:06:49,180
picture from December 2019 which is

151
00:06:54,600 --> 00:06:51,930
aimed greatly reduced brightness and so

152
00:06:56,430 --> 00:06:54,610
fatal Jews had been dimming and people

153
00:06:59,249 --> 00:06:56,440
going oh my gosh is it gonna explode is

154
00:07:00,480 --> 00:06:59,259
it going to explode and no it's not

155
00:07:03,059 --> 00:07:00,490
gonna explode

156
00:07:06,029 --> 00:07:03,069
it didn't explode I showed at the time

157
00:07:09,570 --> 00:07:06,039
this graph here which has brightness on

158
00:07:11,490 --> 00:07:09,580
the y-axis and time on the x-axis and

159
00:07:14,309 --> 00:07:11,500
the green dots indicate the visible

160
00:07:18,210 --> 00:07:14,319
light observations of baitul Jews and it

161
00:07:21,029 --> 00:07:18,220
does vary up and down but in 2019 to

162
00:07:24,540 --> 00:07:21,039
2020 it drops significantly it dropped a

163
00:07:26,129 --> 00:07:24,550

full magnitude okay that's a factor of

164
00:07:29,430 --> 00:07:26,139
at least two and a half so it was down

165
00:07:32,100 --> 00:07:29,440
you know for T less than 40% of its

166
00:07:34,559 --> 00:07:32,110
normal brightness and at the time I said

167
00:07:36,719 --> 00:07:34,569
well you know it looks like it's a giant

168
00:07:39,450 --> 00:07:36,729
dust cloud that's blocking it and this

169
00:07:42,510 --> 00:07:39,460
should go away well just to update you

170
00:07:45,870 --> 00:07:42,520
on that here is the current plot and it

171
00:07:47,939 --> 00:07:45,880
shows that veil juice has indeed risen

172
00:07:51,149 --> 00:07:47,949
back up to its normal brightness okay so

173
00:07:53,310 --> 00:07:51,159
bail juice is back to normal it's not

174
00:07:57,020 --> 00:07:53,320
going supernova but when it does it's

175
00:07:59,010 --> 00:07:57,030
gonna be fantastic so stay tuned

176
00:08:04,379 --> 00:07:59,020
eventually we'll get to see Betelgeuse

177
00:08:08,040 --> 00:08:04,389
go supernova just not in 2020 our third

178
00:08:11,459 --> 00:08:08,050
story is also about a star it's our star

179
00:08:16,920 --> 00:08:11,469
the Sun and how it is actually arousing

180
00:08:19,980 --> 00:08:16,930
from its hibernation now the Sun usually

181
00:08:22,200 --> 00:08:19,990
has sun spots on it right and on the

182
00:08:24,629 --> 00:08:22,210
left side of this video you can see the

183
00:08:27,659 --> 00:08:24,639
Sun during the month of November 2011

184
00:08:29,370 --> 00:08:27,669
and it has a large number of spots on it

185
00:08:32,100 --> 00:08:29,380
this is sort of what we expect out of

186
00:08:35,310 --> 00:08:32,110
the Sun to have a lot of sunspots on the

187
00:08:37,139 --> 00:08:35,320
right is the Sun from February 2019 and

188
00:08:39,180 --> 00:08:37,149

I know it doesn't look like it's

189
00:08:41,550 --> 00:08:39,190
actually a movie but it is it's actually

190
00:08:44,840 --> 00:08:41,560
rotating just like the one on the left

191
00:08:49,199 --> 00:08:44,850
but during February 2019 there were no

192
00:08:52,949 --> 00:08:49,209
sunspots at all for the entire month the

193
00:08:54,020 --> 00:08:52,959
Sun has been quiet right and this is

194
00:08:56,840 --> 00:08:54,030
normal because

195
00:08:58,760 --> 00:08:56,850
the Sun goes through a solar cycle it

196
00:09:00,500 --> 00:08:58,770
goes from minimum where it has no

197
00:09:03,380 --> 00:09:00,510
sunspots to maximum where it has its

198
00:09:07,040 --> 00:09:03,390
greatest number of sunspots this image

199
00:09:10,490 --> 00:09:07,050
is from the Soho satellite and it shows

200
00:09:13,190 --> 00:09:10,500
the Sun in ultraviolet from 1996 every

201
00:09:16,220 --> 00:09:13,200
year through 2006 and you can see the

202
00:09:19,760 --> 00:09:16,230
amount of solar activity rises and falls

203
00:09:22,330 --> 00:09:19,770
over this 11-year cycle well here's a

204
00:09:24,680 --> 00:09:22,340
plot to show you where we are in 2020

205
00:09:27,500 --> 00:09:24,690
we're just finishing what's called solar

206
00:09:30,740 --> 00:09:27,510
cycle 24 and you can see the number of

207
00:09:32,750 --> 00:09:30,750
sunspots peaked somewhere around 2014

208
00:09:36,290 --> 00:09:32,760
and has been falling ever since

209
00:09:39,640 --> 00:09:36,300
matter of fact 2019 was a very very

210
00:09:43,100 --> 00:09:39,650
quiet year in the Sun there were over

211
00:09:46,040 --> 00:09:43,110
100 days recently where the Sun did not

212
00:09:48,500 --> 00:09:46,050
have a single sunspot and so this is

213
00:09:50,420 --> 00:09:48,510

what we call solar minimum and we're

214
00:09:54,890 --> 00:09:50,430
waiting for the Sun to come out of the

215
00:09:58,100 --> 00:09:54,900
solar minimum this cycle however was

216
00:10:00,170 --> 00:09:58,110
also a relatively low cycle on the

217
00:10:02,720 --> 00:10:00,180
series of cycles so we've been following

218
00:10:05,870 --> 00:10:02,730
sunspots for hundreds of years and you

219
00:10:08,560 --> 00:10:05,880
can see that current lately the highest

220
00:10:12,500 --> 00:10:08,570
cycle is around what about 1960 or so

221
00:10:15,920 --> 00:10:12,510
there was a cyclo menace number of

222
00:10:18,590 --> 00:10:15,930
sunspots but cycle 24 doesn't seem to be

223
00:10:20,660 --> 00:10:18,600
that great and their red line by the way

224
00:10:24,410 --> 00:10:20,670
is the prediction that they expect for

225
00:10:26,570 --> 00:10:24,420
cycle 25 so we're waiting for it

226
00:10:31,130 --> 00:10:26,580
watching it to see is it going to come

227
00:10:34,040 --> 00:10:31,140
out and on May 29th of this year the

228
00:10:38,720 --> 00:10:34,050
Solar Dynamics Observatory got these

229
00:10:41,150 --> 00:10:38,730
images showing activity on the left on

230
00:10:43,490 --> 00:10:41,160
the upper left here of the Sun and you

231
00:10:45,920 --> 00:10:43,500
can see that there's a wonderful amount

232
00:10:48,140 --> 00:10:45,930
of magnetic activity showing that hey

233
00:10:50,600 --> 00:10:48,150
the Sun might be starting to come out of

234
00:10:52,790 --> 00:10:50,610
it does this mean that it's going to

235
00:10:55,460 --> 00:10:52,800
come out of it no it could just be an

236
00:10:58,250 --> 00:10:55,470
isolated region that go that comes and

237
00:11:00,920 --> 00:10:58,260
goes away um or it could be the start of

238
00:11:02,180 --> 00:11:00,930

cycle 25 which should begin relatively

239
00:11:04,520 --> 00:11:02,190
soon

240
00:11:07,639 --> 00:11:04,530
it's just goes to show you that the Sun

241
00:11:11,119 --> 00:11:07,649
is not static the Sun goes through

242
00:11:13,670 --> 00:11:11,129
Changez and it's a wonderful process of

243
00:11:16,460 --> 00:11:13,680
science being able to sit and watch and

244
00:11:22,460 --> 00:11:16,470
study and explore those changes in our

245
00:11:25,609 --> 00:11:22,470
own star and now bring you to our

246
00:11:27,859 --> 00:11:25,619
featured speaker Benny Hill Huerta is

247
00:11:29,809 --> 00:11:27,869
currently at the Department of physics

248
00:11:33,530 --> 00:11:29,819
and astronomy at the University of

249
00:11:36,049 --> 00:11:33,540
Louisville he got his PhD at the

250
00:11:38,929 --> 00:11:36,059
University of Groningen in the

251
00:11:40,280 --> 00:11:38,939
Netherlands and then he came to our

252
00:11:43,160 --> 00:11:40,290
institution at the Space Telescope

253
00:11:46,819 --> 00:11:43,170
Science Institute and did a postdoc here

254
00:11:48,639 --> 00:11:46,829
for several years he has kind of been a

255
00:11:51,799 --> 00:11:48,649
world traveler in what he's done

256
00:11:52,549 --> 00:11:51,809
after the Netherlands and the United

257
00:11:55,819 --> 00:11:52,559
States

258
00:11:59,359 --> 00:11:55,829
he went to Cape Town he went to work for

259
00:12:02,989 --> 00:11:59,369
the European Space Agency he worked at

260
00:12:05,480 --> 00:12:02,999
the Leiden University and then finally

261
00:12:07,040 --> 00:12:05,490
he came back to the United States to his

262
00:12:09,470 --> 00:12:07,050
job at the University of Louisville

263
00:12:11,090 --> 00:12:09,480

about three years ago

264
00:12:13,129 --> 00:12:11,100
Bennie and I worked together a little

265
00:12:16,309 --> 00:12:13,139
bit while he was here he's a wonderful

266
00:12:18,079 --> 00:12:16,319
guy and I asked him for something

267
00:12:21,559 --> 00:12:18,089
interesting and fun to tell about him

268
00:12:24,049 --> 00:12:21,569
and he said that he learned to fly a

269
00:12:27,590 --> 00:12:24,059
plane he has this pilot's license from

270
00:12:30,110 --> 00:12:27,600
another astronomer so he may exceed in

271
00:12:32,689 --> 00:12:30,120
flights of fancy not just in science but

272
00:12:37,100 --> 00:12:32,699
also actual flights so ladies and

273
00:12:40,759 --> 00:12:37,110
gentlemen dr. Benny Hill Huerta thank

274
00:12:44,960 --> 00:12:40,769
you thank you very much

275
00:12:48,009 --> 00:12:44,970
I I'm trying to shift gears really

276
00:12:50,749 --> 00:12:48,019
quickly here thank you for having me I

277
00:12:55,489 --> 00:12:50,759
know Frank for a long time so as soon as

278
00:12:57,110 --> 00:12:55,499
he said any volunteers me so I'm very

279
00:13:00,350 --> 00:12:57,120
glad to be talking to you here about

280
00:13:04,759 --> 00:13:00,360
Vera Rubin skelux see the phone number

281
00:13:07,489 --> 00:13:04,769
for that is UGC to 885 but we've been

282
00:13:10,879 --> 00:13:07,499
calling it Reubens galaxy since since

283
00:13:11,480 --> 00:13:10,889
January and I don't do this alone far

284
00:13:14,030 --> 00:13:11,490
from it

285
00:13:15,559 --> 00:13:14,040
I do this with Polly Chandra Pauline

286
00:13:18,019 --> 00:13:15,569
Barbie sat at Ford

287
00:13:20,569 --> 00:13:18,029
Jeremy Balin and Molly Peebles those are

288
00:13:21,380 --> 00:13:20,579

my collaborators at the beginning for

289
00:13:23,269 --> 00:13:21,390
this project

290
00:13:25,579 --> 00:13:23,279
and then we have a bunch of students

291
00:13:27,769 --> 00:13:25,589
working on this comics and bio show

292
00:13:30,110 --> 00:13:27,779
inaudible Alice Jack's and Ren Mullins

293
00:13:31,040 --> 00:13:30,120
so it's it's a team effort that we've

294
00:13:32,120 --> 00:13:31,050
been working with and I'm going to

295
00:13:35,509 --> 00:13:32,130
working with the Space Telescope Science

296
00:13:37,940 --> 00:13:35,519
Institute so the talk is kind of a

297
00:13:40,160 --> 00:13:37,950
two-parter one I'll explain to you who

298
00:13:42,769 --> 00:13:40,170
the sphere Aruban person is first and

299
00:13:45,380 --> 00:13:42,779
then why we hopefully become clear why

300
00:13:46,850 --> 00:13:45,390
we wanted to name a galaxy we didn't

301
00:13:48,259 --> 00:13:46,860
officially name it because there are no

302
00:13:51,560 --> 00:13:48,269
official names but there are lots of

303
00:13:53,750 --> 00:13:51,570
nicknames for galaxies so it's kind of

304
00:13:56,150 --> 00:13:53,760
now the unofficial nickname for this

305
00:13:58,670 --> 00:13:56,160
particular galaxy and if you actually

306
00:14:01,699 --> 00:13:58,680
want to talk to me later have a question

307
00:14:05,060 --> 00:14:01,709
feel free to either you know use Twitter

308
00:14:08,060 --> 00:14:05,070
or email to send me a question later so

309
00:14:13,449 --> 00:14:08,070
who is Vera Rubin via Rubin was one of

310
00:14:16,389 --> 00:14:13,459
the first was was an astronomer in

311
00:14:19,340 --> 00:14:16,399
California and she published one of two

312
00:14:21,829 --> 00:14:19,350
major findings that showed that dark

313
00:14:24,199 --> 00:14:21,839

matter in galaxies actually exists she

314
00:14:29,509 --> 00:14:24,209
looked at the rotation how fast galaxies

315
00:14:31,490 --> 00:14:29,519
rotate around using spectroscopy and she

316
00:14:34,689 --> 00:14:31,500
was one of the two people that advocated

317
00:14:37,310 --> 00:14:34,699
that these that these galaxies had

318
00:14:39,019 --> 00:14:37,320
things other than the stars that we can

319
00:14:41,180 --> 00:14:39,029
see and in the picture here you can see

320
00:14:42,889 --> 00:14:41,190
and I always look at these things and go

321
00:14:44,630 --> 00:14:42,899
like they must be staged because the

322
00:14:47,600 --> 00:14:44,640
Lighting's so good and they're clearly

323
00:14:50,740 --> 00:14:47,610
not working in a shadowy observatory but

324
00:14:53,840 --> 00:14:50,750
you can watch her here look examine

325
00:14:55,819 --> 00:14:53,850
photographs here but what she was mostly

326
00:14:58,189 --> 00:14:55,829
used for mostly known for a spectroscopy

327
00:15:00,680 --> 00:14:58,199
and the second thing and this is

328
00:15:02,840 --> 00:15:00,690
something that is really I've

329
00:15:04,639 --> 00:15:02,850
encountered her one time she was

330
00:15:07,370 --> 00:15:04,649
incredibly encouraging this is back in

331
00:15:09,439 --> 00:15:07,380
2005 I was finishing my PhD and so

332
00:15:12,350 --> 00:15:09,449
you're nervous and I was talking about

333
00:15:14,689 --> 00:15:12,360
my my topic and she goes oh wait hang on

334
00:15:16,939 --> 00:15:14,699
as she did dives into her bookcase comes

335
00:15:19,400 --> 00:15:16,949
back out and says look Hubble was

336
00:15:21,740 --> 00:15:19,410
struggling with the same thing and I

337
00:15:25,100 --> 00:15:21,750
don't know just that's a that little

338
00:15:28,189 --> 00:15:25,110

push kind of really gets you through the

339
00:15:31,519 --> 00:15:28,199
last bits of a PhD and so she was and

340
00:15:33,800 --> 00:15:31,529
and my story is far from unique in fact

341
00:15:35,360 --> 00:15:33,810
everybody I've talked to said that she

342
00:15:39,220 --> 00:15:35,370
was invariably

343
00:15:44,269 --> 00:15:39,230
encouraging and supportive of young

344
00:15:48,070 --> 00:15:44,279
young astronomers of any stripe to go go

345
00:15:52,310 --> 00:15:48,080
do science and she was a very impressive

346
00:15:54,380 --> 00:15:52,320
scientist and for these two

347
00:15:56,269 --> 00:15:54,390
characteristics so she was known for the

348
00:15:58,040 --> 00:15:56,279
spectroscopy and I love this it's kind

349
00:16:00,829 --> 00:15:58,050
of like a more candid shot where they're

350
00:16:03,200 --> 00:16:00,839
they're debugging their spectrograph at

351
00:16:07,430 --> 00:16:03,210
the back end of this large Lowell

352
00:16:10,220 --> 00:16:07,440
telescope and what she did mostly was

353
00:16:12,560 --> 00:16:10,230
take spectra like these in spectra or

354
00:16:14,480 --> 00:16:12,570
the fact that you take a point of light

355
00:16:16,550 --> 00:16:14,490
and you spread it around in wavelength

356
00:16:19,160 --> 00:16:16,560
so then you can see the fingerprints of

357
00:16:21,350 --> 00:16:19,170
various chemical elements so for example

358
00:16:24,590 --> 00:16:21,360
at the bottom you see H which is

359
00:16:27,800 --> 00:16:24,600
hydrogen and then alpha and beta I mean

360
00:16:30,500 --> 00:16:27,810
that they are different kinds of lines

361
00:16:34,220 --> 00:16:30,510
but the fingerprint of hydrogen is

362
00:16:36,860 --> 00:16:34,230
pretty clearly visible as is oxygen in

363
00:16:39,440 --> 00:16:36,870

some of these some of these spectra that

364
00:16:41,329 --> 00:16:39,450
she's taken and the or I want to take

365
00:16:42,980 --> 00:16:41,339
take you to the orange line the orange

366
00:16:45,230 --> 00:16:42,990
line is where we expect hydrogen to have

367
00:16:47,180 --> 00:16:45,240
made a lot light and then you'll notice

368
00:16:48,829 --> 00:16:47,190
that some of the smudges are a little

369
00:16:50,990 --> 00:16:48,839
bit to the right they're red shifted

370
00:16:52,220 --> 00:16:51,000
they're in longer wavelengths and some

371
00:16:54,410 --> 00:16:52,230
of them are a little bit to the blue

372
00:16:55,640 --> 00:16:54,420
side they're blue shifted so this is

373
00:16:59,150 --> 00:16:55,650
what happens when the Doppler effect

374
00:17:00,650 --> 00:16:59,160
takes effect if something's moving if

375
00:17:03,740 --> 00:17:00,660
it's moving towards you the wavelength

376
00:17:06,350 --> 00:17:03,750
gets shorter the pitch gets higher you

377
00:17:08,360 --> 00:17:06,360
there blue shifted and if they're moving

378
00:17:10,549 --> 00:17:08,370
away from you the pitch gets lower their

379
00:17:13,990 --> 00:17:10,559
red shifted so we've been looking you

380
00:17:17,120 --> 00:17:14,000
can see movement using spectroscopy and

381
00:17:20,090 --> 00:17:17,130
very carefully they did this for our

382
00:17:21,500 --> 00:17:20,100
nearest neighboring galaxy Andromeda you

383
00:17:23,540 --> 00:17:21,510
can see the photographic plates on the

384
00:17:27,319 --> 00:17:23,550
left here with all the points that they

385
00:17:29,690 --> 00:17:27,329
took a velocity measure of and then on

386
00:17:33,710 --> 00:17:29,700
the right you can see the distance to

387
00:17:36,710 --> 00:17:33,720
the center of Andromeda and how fast

388
00:17:39,320 --> 00:17:36,720

it's moving away from us it's all moving

389
00:17:41,030 --> 00:17:39,330
away from us but it's moving at relative

390
00:17:42,590 --> 00:17:41,040
speeds so some of them are moving

391
00:17:44,780 --> 00:17:42,600
towards us and some of them are moving

392
00:17:47,270 --> 00:17:44,790
away from us in fact as you plot

393
00:17:48,750 --> 00:17:47,280
everything along this line you'll notice

394
00:17:50,700 --> 00:17:48,760
that all of on once

395
00:17:52,919 --> 00:17:50,710
of the galaxy our redshift they're

396
00:17:55,200 --> 00:17:52,929
moving away and on the other side

397
00:17:57,990 --> 00:17:55,210
they're all moving towards us so

398
00:18:00,419 --> 00:17:58,000
Andromeda is rotating and not only is

399
00:18:03,570 --> 00:18:00,429
Andromeda rotating you sort of expected

400
00:18:06,930 --> 00:18:03,580
that but it's an it's rotating and the

401
00:18:10,980 --> 00:18:06,940
speed that which all the bits are going

402
00:18:12,990 --> 00:18:10,990
are is roughly the same this no matter

403
00:18:14,909 --> 00:18:13,000
how far out from the centre you go

404
00:18:17,940 --> 00:18:14,919
you'll notice that it's fairly flat

405
00:18:21,480 --> 00:18:17,950
they're all kind of going at the 300

406
00:18:22,950 --> 00:18:21,490
kilometers a second speed in the

407
00:18:26,100 --> 00:18:22,960
redshift and they're all going to match

408
00:18:28,230 --> 00:18:26,110
to between two and 300 in the blue shift

409
00:18:30,330 --> 00:18:28,240
but it doesn't quite matter how far away

410
00:18:31,830 --> 00:18:30,340
from the centre you are now if you find

411
00:18:33,630 --> 00:18:31,840
this in one galaxy if you find something

412
00:18:36,210 --> 00:18:33,640
strange in one galaxy you can kind of

413
00:18:38,520 --> 00:18:36,220

write it off and say I guess that

414
00:18:41,520 --> 00:18:38,530
galaxy's just strange and move on with

415
00:18:42,950 --> 00:18:41,530
your life and because you know that all

416
00:18:47,970 --> 00:18:42,960
the galaxies don't behave like that

417
00:18:49,380 --> 00:18:47,980
however at the same time and these the

418
00:18:50,100 --> 00:18:49,390
groups were definitely talking to each

419
00:18:52,500 --> 00:18:50,110
other

420
00:18:56,010 --> 00:18:52,510
the Westerbork radio telescope was taken

421
00:18:57,750 --> 00:18:56,020
into operation Ron Allen my PhD

422
00:19:00,810 --> 00:18:57,760
supervisor was intimately involved in

423
00:19:02,880 --> 00:19:00,820
that and they were also looking for

424
00:19:04,950 --> 00:19:02,890
hydrogen the imprint of hydrogen but in

425
00:19:07,409 --> 00:19:04,960
the radio and in the radio you can meet

426
00:19:09,930 --> 00:19:07,419
but you can also measure Doppler shifts

427
00:19:12,299 --> 00:19:09,940
so they did the exact same experiment on

428
00:19:14,430 --> 00:19:12,309
different galaxies so here's an example

429
00:19:17,100 --> 00:19:14,440
NGC 47:36

430
00:19:19,830 --> 00:19:17,110
another phone number we haven't named

431
00:19:21,780 --> 00:19:19,840
this one but as you go further and

432
00:19:24,630 --> 00:19:21,790
further out from the center of the

433
00:19:26,970 --> 00:19:24,640
galaxy you'll notice that the gas moves

434
00:19:30,060 --> 00:19:26,980
with about the same speed in this case

435
00:19:32,730 --> 00:19:30,070
it's almost 200 kilometres a second and

436
00:19:38,159 --> 00:19:32,740
it roughly stays pretty flat no matter

437
00:19:40,200 --> 00:19:38,169
how far out you go and that is kind of

438
00:19:43,049 --> 00:19:40,210

surprising because if you put if you

439
00:19:44,310 --> 00:19:43,059
assume that all the mass is associated

440
00:19:46,860 --> 00:19:44,320
with all the stuff that gives off a

441
00:19:49,650 --> 00:19:46,870
light which it is true in our own solar

442
00:19:52,590 --> 00:19:49,660
system for example you'd expect the

443
00:19:56,250 --> 00:19:52,600
dashed line here if we just say all the

444
00:19:57,539 --> 00:19:56,260
mass that's in there that's although

445
00:19:59,430 --> 00:19:57,549
that's all the stuff that's in this

446
00:20:01,560 --> 00:19:59,440
galaxy and if I'm looking at something

447
00:20:02,500 --> 00:20:01,570
that's orbiting around it it can't go

448
00:20:04,780 --> 00:20:02,510
any faster

449
00:20:06,760 --> 00:20:04,790
than say on 30,000 light years out it

450
00:20:08,530 --> 00:20:06,770
can't go any faster than 50 kilometres a

451
00:20:10,480 --> 00:20:08,540
second because otherwise it would fly

452
00:20:13,450 --> 00:20:10,490
off otherwise there's just not enough

453
00:20:15,580 --> 00:20:13,460
stuff within it to keep it pulling into

454
00:20:17,380 --> 00:20:15,590
its orbit and yet we look at the

455
00:20:19,420 --> 00:20:17,390
observations we look at the blue points

456
00:20:22,960 --> 00:20:19,430
for example from Radio and we look at

457
00:20:25,570 --> 00:20:22,970
the yellow points from starlight they're

458
00:20:28,000 --> 00:20:25,580
going much faster than they should be

459
00:20:30,340 --> 00:20:28,010
able to and this flat the fact that it's

460
00:20:31,960 --> 00:20:30,350
flat means that there is more and more

461
00:20:33,940 --> 00:20:31,970
things despite the fact that the amount

462
00:20:36,790 --> 00:20:33,950
of stars seem to drop off pretty quickly

463
00:20:39,550 --> 00:20:36,800

there has to be more stuff there just to

464
00:20:42,000 --> 00:20:39,560
keep the gas from you wrote from flying

465
00:20:44,500 --> 00:20:42,010
off as it's rotating around the disk and

466
00:20:46,120 --> 00:20:44,510
so that's a bit of a mystery you have to

467
00:20:50,410 --> 00:20:46,130
have something that isn't stars isn't

468
00:20:51,000 --> 00:20:50,420
gas isn't giving off light and we don't

469
00:20:53,740 --> 00:20:51,010
know what it is

470
00:20:57,310 --> 00:20:53,750
hence dark matter and this was the best

471
00:21:01,090 --> 00:20:57,320
evidence for dark matter and as we just

472
00:21:02,980 --> 00:21:01,100
to compare if like we look at our own

473
00:21:06,280 --> 00:21:02,990
solar system 90% of all the masses in

474
00:21:08,350 --> 00:21:06,290
the Sun so everything rotates around the

475
00:21:10,510 --> 00:21:08,360
main mass which is essentially all in

476
00:21:12,850 --> 00:21:10,520
the Sun and so if you're close by you

477
00:21:15,190 --> 00:21:12,860
whip around it and as you go further and

478
00:21:18,370 --> 00:21:15,200
further out you go slower and longer

479
00:21:20,890 --> 00:21:18,380
orbits so in Pluto take is only going at

480
00:21:23,830 --> 00:21:20,900
10 kilometers a second or less and then

481
00:21:27,310 --> 00:21:23,840
mercury is whipping around there with 45

482
00:21:31,150 --> 00:21:27,320
kilometers a second so and even if you

483
00:21:34,120 --> 00:21:31,160
look at the top here so you can go look

484
00:21:35,590 --> 00:21:34,130
from above you see like the solar system

485
00:21:37,720 --> 00:21:35,600
you see the movement going on the

486
00:21:39,670 --> 00:21:37,730
left-hand side and like the way the

487
00:21:42,880 --> 00:21:39,680
galaxies move is on the right-hand side

488
00:21:45,040 --> 00:21:42,890

and you can see that galaxies don't move

489
00:21:48,370 --> 00:21:45,050
like the solar system does we are

490
00:21:51,870 --> 00:21:48,380
definitely in trouble our galaxy despite

491
00:21:54,490 --> 00:21:51,880
looking like a giant ball of stars with

492
00:21:57,700 --> 00:21:54,500
just some stuff swirling around it is

493
00:22:00,880 --> 00:21:57,710
not moving like the solar system is so

494
00:22:03,040 --> 00:22:00,890
the mass is distributed differently so

495
00:22:07,720 --> 00:22:03,050
galaxies don't rotate like a solid disc

496
00:22:10,540 --> 00:22:07,730
I love the example of a clay spinner

497
00:22:12,550 --> 00:22:10,550
because we used to say record-player but

498
00:22:14,380 --> 00:22:12,560
I don't think anybody knows where the

499
00:22:15,970 --> 00:22:14,390
record player is anymore except for some

500
00:22:19,360 --> 00:22:15,980
audio files

501
00:22:20,890 --> 00:22:19,370
and so maybe you've done this and you'll

502
00:22:24,280 --> 00:22:20,900
notice that if you put the clay further

503
00:22:26,350 --> 00:22:24,290
out it'll definitely spin off the of the

504
00:22:28,090 --> 00:22:26,360
wheel so a pottery wheel you have to put

505
00:22:31,210 --> 00:22:28,100
it right in the center but as you go

506
00:22:33,550 --> 00:22:31,220
further out it's moving quicker and if

507
00:22:35,080 --> 00:22:33,560
you they don't grow tracked like the

508
00:22:36,580 --> 00:22:35,090
planets around her son either so

509
00:22:39,130 --> 00:22:36,590
something in between it's something

510
00:22:41,260 --> 00:22:39,140
between a solid disc and putting

511
00:22:44,740 --> 00:22:41,270
everything in the center which is

512
00:22:47,050 --> 00:22:44,750
strange right so this was a this was

513
00:22:48,790 --> 00:22:47,060

definitely a bold claim to say like well

514
00:22:52,420 --> 00:22:48,800
most of the mass doesn't glow up isn't

515
00:22:58,840 --> 00:22:52,430
sitting in stars and this is the seminal

516
00:23:01,870 --> 00:22:58,850
study from Rubin in 1980 the 1977 or 78

517
00:23:03,730 --> 00:23:01,880
78 Albert boss ma produced something

518
00:23:06,280 --> 00:23:03,740
very similar so basically these both

519
00:23:08,380 --> 00:23:06,290
these groups had plots like this where

520
00:23:10,630 --> 00:23:08,390
you go from the center of the galaxy and

521
00:23:12,790 --> 00:23:10,640
each line here is a galaxy so instead of

522
00:23:15,640 --> 00:23:12,800
saying well I guess Andromeda is just

523
00:23:17,080 --> 00:23:15,650
strange let's go check it in other

524
00:23:19,210 --> 00:23:17,090
galaxies and see if they do the same

525
00:23:21,340 --> 00:23:19,220
thing and they do they all sort of

526
00:23:25,000 --> 00:23:21,350
flatten out to further out you go they

527
00:23:27,340 --> 00:23:25,010
go up really steeply the velocity whips

528
00:23:29,710 --> 00:23:27,350
up and then it just flattens out and

529
00:23:32,500 --> 00:23:29,720
stays there and and the further out you

530
00:23:34,870 --> 00:23:32,510
go you just it still stays at pretty

531
00:23:36,610 --> 00:23:34,880
much the lot of the rotational or the

532
00:23:38,470 --> 00:23:36,620
velocity here that you see so they're

533
00:23:39,790 --> 00:23:38,480
all flat and one of them kind of sticks

534
00:23:43,690 --> 00:23:39,800
out because it's right at the top and

535
00:23:46,000 --> 00:23:43,700
that's you GC to 885 other than that the

536
00:23:47,770 --> 00:23:46,010
fact that it has the fastest rotation in

537
00:23:50,350 --> 00:23:47,780
her study it doesn't really stand out

538
00:23:53,260 --> 00:23:50,360

it's a normal spiral galaxy it's got

539
00:23:54,480 --> 00:23:53,270
that lovely flat rotation curve and

540
00:23:57,400 --> 00:23:54,490
that's it

541
00:24:00,400 --> 00:23:57,410
of course we check each other's work

542
00:24:03,220 --> 00:24:00,410
we're good good conscientious scientists

543
00:24:05,890 --> 00:24:03,230
so as soon as one group claimed hey this

544
00:24:07,690 --> 00:24:05,900
galaxies rotating flatly we'll going to

545
00:24:09,280 --> 00:24:07,700
go check that with the radio telescopes

546
00:24:11,290 --> 00:24:09,290
and the radio telescope results were

547
00:24:13,510 --> 00:24:11,300
checked with spectroscopy so the

548
00:24:15,520 --> 00:24:13,520
rotation curves were confirmed for this

549
00:24:19,180 --> 00:24:15,530
particular galaxy right after well

550
00:24:21,190 --> 00:24:19,190
pretty quickly after 1980 and so they're

551
00:24:23,710 --> 00:24:21,200
all agreeing that yes this galaxy

552
00:24:25,570 --> 00:24:23,720
rotates between 250 and 300 kilometers a

553
00:24:27,190 --> 00:24:25,580
second doesn't matter how far out you go

554
00:24:28,270 --> 00:24:27,200
you can keep going keep going keep going

555
00:24:31,600 --> 00:24:28,280
it's just

556
00:24:35,110 --> 00:24:31,610
locates at that speed so very

557
00:24:37,390 --> 00:24:35,120
interesting cool result galaxies don't

558
00:24:41,080 --> 00:24:37,400
grow Tate like solid disks they don't

559
00:24:43,350 --> 00:24:41,090
grow Tate like our solar system and that

560
00:24:45,640 --> 00:24:43,360
comes to the spiderman rule of science

561
00:24:48,430 --> 00:24:45,650
extraordinary claims basically saying

562
00:24:49,570 --> 00:24:48,440
all the mass isn't sitting in stars it's

563
00:24:52,030 --> 00:24:49,580

sitting somewhere else

564
00:24:54,940 --> 00:24:52,040
they require extraordinary evidence not

565
00:24:57,490 --> 00:24:54,950
a single galaxy multiple galaxies not a

566
00:24:59,740 --> 00:24:57,500
single kind of telescopes multiple

567
00:25:02,290 --> 00:24:59,750
different telescopes not a single group

568
00:25:05,460 --> 00:25:02,300
both groups find the same thing and so

569
00:25:07,690 --> 00:25:05,470
it's an amazing discovery by the various

570
00:25:11,740 --> 00:25:07,700
scientists of the time like this was

571
00:25:13,780 --> 00:25:11,750
this took very careful work and so that

572
00:25:16,180 --> 00:25:13,790
finally cleared the threshold of saying

573
00:25:19,710 --> 00:25:16,190
like yes there has to be some additional

574
00:25:23,410 --> 00:25:19,720
ingredient whenever we bake a galaxy so

575
00:25:25,210 --> 00:25:23,420
the spider-man rule was a was it here

576
00:25:27,940 --> 00:25:25,220
too but what he says all have to do with

577
00:25:30,580 --> 00:25:27,950
the Hubble Space Telescope nothing so

578
00:25:32,280 --> 00:25:30,590
far all of this was done in the 1970s

579
00:25:36,160 --> 00:25:32,290
when the Hubble Space Telescope was a

580
00:25:39,490 --> 00:25:36,170
was a dream of the early of the early

581
00:25:41,590 --> 00:25:39,500
pioneers like Nancy Roman and they were

582
00:25:44,320 --> 00:25:41,600
looking at how to build one of these

583
00:25:46,540 --> 00:25:44,330
things and I one of my favorite things

584
00:25:48,880 --> 00:25:46,550
of the Hubble Space Telescope history is

585
00:25:50,830 --> 00:25:48,890
they used to have a drawing with a

586
00:25:51,340 --> 00:25:50,840
little astronaut in the back of this

587
00:25:54,190 --> 00:25:51,350
thing

588
00:25:57,210 --> 00:25:54,200

changing out photographic plates like he

589
00:25:59,500 --> 00:25:57,220
is you know Vera Rubin but now in space

590
00:26:01,390 --> 00:25:59,510
I'm so glad they don't do that because

591
00:26:03,340 --> 00:26:01,400
we don't visit the Space Telescope

592
00:26:08,140 --> 00:26:03,350
anymore and that would be very unhappy

593
00:26:10,030 --> 00:26:08,150
astronaut but there's a Hubble Space

594
00:26:12,790 --> 00:26:10,040
Telescope this is where it comes in

595
00:26:16,510 --> 00:26:12,800
because Vera Rubin wrote two papers in

596
00:26:18,430 --> 00:26:16,520
1980 and I read the second one and so

597
00:26:19,870 --> 00:26:18,440
the one is on the rotation curves in

598
00:26:23,470 --> 00:26:19,880
dark matter it's the one that we all

599
00:26:25,000 --> 00:26:23,480
look at and it's the seminal result and

600
00:26:27,670 --> 00:26:25,010
the other one kind of just notes that

601
00:26:29,500 --> 00:26:27,680
this particular galaxy is really big

602
00:26:32,920 --> 00:26:29,510
compared to all the others that we know

603
00:26:37,510 --> 00:26:32,930
of and so this is a picture from that

604
00:26:39,580 --> 00:26:37,520
other 1980 paper where you see m81

605
00:26:41,230 --> 00:26:39,590
that's a very well known spiral galaxy

606
00:26:41,770 --> 00:26:41,240
our own Milky Way the roots back

607
00:26:44,410 --> 00:26:41,780
twenty-five

608
00:26:47,200 --> 00:26:44,420
kiloparsecs in diameter and 51 it's a

609
00:26:51,010 --> 00:26:47,210
bit bigger 35 kiloparsecs in diameter

610
00:26:53,560 --> 00:26:51,020
mm 104 is to sombrero galaxy it's 40

611
00:26:55,930 --> 00:26:53,570
kiloparsecs in diameter and 31 the one

612
00:26:59,880 --> 00:26:55,940
Andromeda galaxy 50 kilobytes in

613
00:27:03,430 --> 00:26:59,890

diameter and M 101 is our is another

614
00:27:06,940 --> 00:27:03,440
crowd pleaser this lovely face on spiral

615
00:27:09,580 --> 00:27:06,950
galaxy and it's 65 kiloparsecs roughly

616
00:27:11,680 --> 00:27:09,590
in diameter what she noted was that it's

617
00:27:15,220 --> 00:27:11,690
joining 50 kilometer field parsecs in

618
00:27:18,520 --> 00:27:15,230
diameter for UGC 285 so that galaxy is

619
00:27:20,710 --> 00:27:18,530
really really big except that it looks

620
00:27:23,380 --> 00:27:20,720
like it's rotating like any other galaxy

621
00:27:26,260 --> 00:27:23,390
it's just all the way at the top it just

622
00:27:31,600 --> 00:27:26,270
seems to be well-behaved spiral galaxy

623
00:27:33,310 --> 00:27:31,610
just really really large and so what I

624
00:27:35,560 --> 00:27:33,320
noticed when I was looking at this idly

625
00:27:38,680 --> 00:27:35,570
and like huh well we've got a nice

626
00:27:41,710 --> 00:27:38,690
Hubble picture for M 81 and 51 m 104

627
00:27:44,200 --> 00:27:41,720
we've got like a third of him 31 and we

628
00:27:46,030 --> 00:27:44,210
got all of them 101 so we have beautiful

629
00:27:51,160 --> 00:27:46,040
Hubble pictures for all of these

630
00:27:53,350 --> 00:27:51,170
galaxies except for UGC 8 to 885 so why

631
00:27:55,080 --> 00:27:53,360
wouldn't it be a good idea to go look at

632
00:27:57,850 --> 00:27:55,090
the biggest spiral in the local universe

633
00:27:59,830 --> 00:27:57,860
let's go have a look at that and see if

634
00:28:02,020 --> 00:27:59,840
we can figure out how you make something

635
00:28:04,030 --> 00:28:02,030
that big how you make a disk that big so

636
00:28:07,270 --> 00:28:04,040
that's the that's the result that we did

637
00:28:10,450 --> 00:28:07,280
this is the this is the Hubble picture

638
00:28:12,190 --> 00:28:10,460

of Rubens galaxy and the other idea was

639
00:28:15,820 --> 00:28:12,200
to use it as a little tribute picture

640
00:28:19,510 --> 00:28:15,830
for Vera Rubin who passed away in 2016

641
00:28:21,700 --> 00:28:19,520
so you can see a lot more detail of

642
00:28:24,880 --> 00:28:21,710
course in the Hubble picture we have we

643
00:28:28,690 --> 00:28:24,890
opted for a color option and and so you

644
00:28:30,760 --> 00:28:28,700
can see all the the various yeah the

645
00:28:32,770 --> 00:28:30,770
components for a spiral galaxy you see

646
00:28:36,340 --> 00:28:32,780
the Bulge in the center you see the disk

647
00:28:37,840 --> 00:28:36,350
you see the spiral arms and yeah I'll

648
00:28:43,930 --> 00:28:37,850
just take you through this Hubble

649
00:28:47,740 --> 00:28:43,940
picture now first oh where can you find

650
00:28:49,390 --> 00:28:47,750
this and this isn't a question I always

651
00:28:50,820 --> 00:28:49,400
get from the amateur astronomers here in

652
00:28:54,340 --> 00:28:50,830
Louisville we have a very active group

653
00:28:55,549 --> 00:28:54,350
and you can see this with binoculars or

654
00:28:58,279 --> 00:28:55,559
a decent

655
00:29:04,370 --> 00:28:58,289
amateur telescope or enthusiastic

656
00:29:05,750 --> 00:29:04,380
telescope and it's in Percy's and so you

657
00:29:08,240 --> 00:29:05,760
see all the stuff all the Milky Way

658
00:29:12,310 --> 00:29:08,250
stars here there's a there's a warrior

659
00:29:15,830 --> 00:29:12,320
and I should go through words whose foot

660
00:29:18,350 --> 00:29:15,840
you can start seeing some smudges and

661
00:29:22,640 --> 00:29:18,360
then they did this lovely fade here as

662
00:29:24,500 --> 00:29:22,650
we go to a modern picture and here we

663
00:29:27,680 --> 00:29:24,510

are with the Hubble picture so it's a

664
00:29:29,510 --> 00:29:27,690
pretty small smudge on the sky but you

665
00:29:31,580 --> 00:29:29,520
can't actually see it and you can

666
00:29:33,230 --> 00:29:31,590
actually see the house blue edges it's a

667
00:29:35,840 --> 00:29:33,240
little trickier to see because of that

668
00:29:38,690 --> 00:29:35,850
bright star and a floor ground there but

669
00:29:40,880 --> 00:29:38,700
you can definitely find it with with the

670
00:29:43,010 --> 00:29:40,890
telescope and binoculars so how do we

671
00:29:45,169 --> 00:29:43,020
grow giant like this big

672
00:29:49,399 --> 00:29:45,179
Ruben's galaxy is so much more massive

673
00:29:52,039 --> 00:29:49,409
it's 10 to 12 so a trillion solar mass

674
00:29:54,169 --> 00:29:52,049
and stars and it's much more extended

675
00:29:56,419 --> 00:29:54,179
than any typical spiral galaxy certainly

676
00:29:58,880 --> 00:29:56,429
the ones that we typically look at with

677
00:30:00,350 --> 00:29:58,890
Hubble or other other telescopes the

678
00:30:03,649 --> 00:30:00,360
question now is like how do you grow

679
00:30:07,610 --> 00:30:03,659
this disk so large typically if we want

680
00:30:09,409 --> 00:30:07,620
to get a trillion solar mass galaxies we

681
00:30:11,480 --> 00:30:09,419
just smash two smaller galaxies and

682
00:30:13,460 --> 00:30:11,490
maybe throw a third one in and then we

683
00:30:16,000 --> 00:30:13,470
end up with within two small solar

684
00:30:20,270 --> 00:30:16,010
masses and usually they're in a giant

685
00:30:22,990 --> 00:30:20,280
blob they're an elliptical and mergers

686
00:30:27,500 --> 00:30:23,000
leave a mark and this is such a regular

687
00:30:30,289 --> 00:30:27,510
undisturbed looking galaxy that we would

688
00:30:32,450 --> 00:30:30,299

it's strange to not see any merger

689
00:30:34,279 --> 00:30:32,460
remnants but maybe we can see that in

690
00:30:36,890 --> 00:30:34,289
the population of globular clusters in

691
00:30:38,600 --> 00:30:36,900
around this galaxy and so that's the one

692
00:30:42,380 --> 00:30:38,610
that we that's the science we wanted to

693
00:30:44,360 --> 00:30:42,390
do with this picture and so I stuck the

694
00:30:45,620 --> 00:30:44,370
the result in because I'm gonna tell you

695
00:30:46,940 --> 00:30:45,630
about the result and then could tell you

696
00:30:49,940 --> 00:30:46,950
how we got there and then I'm going to

697
00:30:52,010 --> 00:30:49,950
tell you the result again we see very

698
00:30:53,750 --> 00:30:52,020
few globular clusters for galaxies this

699
00:30:56,240 --> 00:30:53,760
size so it actually implies that it

700
00:31:00,020 --> 00:30:56,250
didn't do any merging dude didn't do

701
00:31:02,060 --> 00:31:00,030
much mergers I love the fact that as

702
00:31:05,899 --> 00:31:02,070
soon as Hubble releases a picture people

703
00:31:08,940 --> 00:31:05,909
have have a go at doing creative things

704
00:31:11,430 --> 00:31:08,950
with it and so with this picture

705
00:31:15,029 --> 00:31:11,440
love this 3d issue view I've no idea how

706
00:31:16,350 --> 00:31:15,039
people did this but it does kind of show

707
00:31:18,990 --> 00:31:16,360
you that we're looking at a

708
00:31:20,940 --> 00:31:19,000
three-dimensional structure we are not

709
00:31:22,620 --> 00:31:20,950
just looking at the stars at which the

710
00:31:24,419 --> 00:31:22,630
bright stars are all in the Milky Way

711
00:31:26,519 --> 00:31:24,429
anything with those DOS those

712
00:31:29,759 --> 00:31:26,529
diffraction spikes those spiky things

713
00:31:32,009 --> 00:31:29,769

are coming out they are definitely in

714
00:31:33,960 --> 00:31:32,019
our own Milky Way and then we get this

715
00:31:36,060 --> 00:31:33,970
big galaxy and then in the background

716
00:31:39,419 --> 00:31:36,070
you see these only smaller galaxies and

717
00:31:42,899 --> 00:31:39,429
so you kind of see the whole universe in

718
00:31:44,759 --> 00:31:42,909
a little slice there and so here we were

719
00:31:47,220 --> 00:31:44,769
back at the actual picture and I'll take

720
00:31:49,440 --> 00:31:47,230
you through the various components so

721
00:31:52,169 --> 00:31:49,450
I'll start with the center and so the

722
00:31:55,259 --> 00:31:52,179
center is it's quite interesting because

723
00:31:58,889 --> 00:31:55,269
we see a lot of dust here and brown

724
00:32:01,409 --> 00:31:58,899
stuff that those dark veiny looking

725
00:32:04,740 --> 00:32:01,419
things that are spiral that are swirling

726
00:32:08,250 --> 00:32:04,750
throughout this disk they are their

727
00:32:10,080 --> 00:32:08,260
their molecular gas and dust and I

728
00:32:11,970 --> 00:32:10,090
started my career studying dust in

729
00:32:13,560 --> 00:32:11,980
galaxies so I'm super excited to see a

730
00:32:15,240 --> 00:32:13,570
beautiful example like this you see that

731
00:32:17,789 --> 00:32:15,250
I kind of Tiger stripy pattern in

732
00:32:19,769 --> 00:32:17,799
between there's clearly a lot going on

733
00:32:22,139 --> 00:32:19,779
here but not only that we can see the

734
00:32:24,990 --> 00:32:22,149
blue peeking in between and the blue

735
00:32:27,419 --> 00:32:25,000
means young recently formed massive

736
00:32:29,970 --> 00:32:27,429
stars so we see that this galaxy is

737
00:32:33,539 --> 00:32:29,980
forming stars almost all the way to the

738
00:32:35,580 --> 00:32:33,549

center of it and it has gas reserves to

739
00:32:38,519 --> 00:32:35,590
do that and it's so you see blue new

740
00:32:40,710 --> 00:32:38,529
young blue stars and new gas sitting

741
00:32:43,710 --> 00:32:40,720
ready to go and so you've got both of

742
00:32:47,009 --> 00:32:43,720
those mixed together throughout the disk

743
00:32:49,110 --> 00:32:47,019
so there's star formation isn't going on

744
00:32:51,720 --> 00:32:49,120
at any particular point it is just

745
00:32:55,259 --> 00:32:51,730
spread out through of this entire giant

746
00:32:58,110 --> 00:32:55,269
disk of gal this galaxies no particulars

747
00:33:01,639 --> 00:32:58,120
a lot of star formation but almost all

748
00:33:05,909 --> 00:33:01,649
parts of the disk seems to have some and

749
00:33:08,519 --> 00:33:05,919
there's our it does make the picture

750
00:33:11,070 --> 00:33:08,529
quite photogenic but as an astronomer I

751
00:33:13,889 --> 00:33:11,080
kind of wish that I could wipe this

752
00:33:15,000 --> 00:33:13,899
thing off for a little bit because we

753
00:33:17,279 --> 00:33:15,010
kind of would like to see what's

754
00:33:18,180 --> 00:33:17,289
underneath but unfortunately we can't do

755
00:33:20,310 --> 00:33:18,190
that

756
00:33:22,470 --> 00:33:20,320
there's there's no information below

757
00:33:24,120 --> 00:33:22,480
this this really bright star

758
00:33:25,950 --> 00:33:24,130
and I think that's the reason why we

759
00:33:27,600 --> 00:33:25,960
didn't look at it before with Hubble

760
00:33:29,970 --> 00:33:27,610
because we're a little nervous

761
00:33:33,030 --> 00:33:29,980
pointing Hubble at bright things just in

762
00:33:35,070 --> 00:33:33,040
case we damaged their camera but I want

763
00:33:37,740 --> 00:33:35,080

to point out that these spiral arms are

764
00:33:40,700 --> 00:33:37,750
made out of still more blue stars still

765
00:33:43,140 --> 00:33:40,710
the occasional oh and B type star

766
00:33:45,419 --> 00:33:43,150
brightly shining as it's just been

767
00:33:47,970 --> 00:33:45,429
formed and there's these little clusters

768
00:33:50,820 --> 00:33:47,980
of them all throughout these spiral arms

769
00:33:52,380 --> 00:33:50,830
there's they're beautiful but it also

770
00:33:55,260 --> 00:33:52,390
means that this galaxy it's never really

771
00:33:59,880 --> 00:33:55,270
stopped forming new stars but it does it

772
00:34:01,549 --> 00:33:59,890
at a very gentle pace and whipping

773
00:34:03,990 --> 00:34:01,559
around to the other side of the image

774
00:34:06,510 --> 00:34:04,000
these are the background of galaxies so

775
00:34:10,200 --> 00:34:06,520
we see the front foreground elliptical I

776
00:34:12,899 --> 00:34:10,210
started the foreground Milky Way stars

777
00:34:15,240 --> 00:34:12,909
with the spikes and in the background

778
00:34:17,490 --> 00:34:15,250
objects like this elliptical galaxies

779
00:34:20,430 --> 00:34:17,500
kind of lurking in the corner that

780
00:34:24,840 --> 00:34:20,440
galaxies very far away it has nothing to

781
00:34:26,609 --> 00:34:24,850
do with Rubens galaxy at all and there's

782
00:34:28,139 --> 00:34:26,619
even more distant galaxies that you

783
00:34:31,320 --> 00:34:28,149
could kind of spot here throughout the

784
00:34:33,030 --> 00:34:31,330
image and I started again started my

785
00:34:35,220 --> 00:34:33,040
career looking at dust started my career

786
00:34:36,840 --> 00:34:35,230
looking at the background images this is

787
00:34:39,060 --> 00:34:36,850
what I was looking for these tiny little

788
00:34:41,220 --> 00:34:39,070

smudges so every time I get a Hubble

789
00:34:42,810 --> 00:34:41,230
image I I again go there's one there's

790
00:34:46,440 --> 00:34:42,820
one I'm not gonna do anything but

791
00:34:48,599 --> 00:34:46,450
there's one but what we were looking for

792
00:34:52,590 --> 00:34:48,609
here you see a few of these little red

793
00:34:54,210 --> 00:34:52,600
dots those are the some of them are

794
00:34:56,250 --> 00:34:54,220
still foreground stars so we have to

795
00:34:58,349 --> 00:34:56,260
select those out some of them are back

796
00:35:02,040 --> 00:34:58,359
are parts of background galaxies but

797
00:35:03,960 --> 00:35:02,050
really there is a few round you see a

798
00:35:05,250 --> 00:35:03,970
few round dots here and those are the

799
00:35:08,910 --> 00:35:05,260
globe of the clusters floating around

800
00:35:11,220 --> 00:35:08,920
this giant spiral so there's lots of

801
00:35:14,390 --> 00:35:11,230
detail there's lots of information in

802
00:35:17,760 --> 00:35:14,400
apart from just being a gorgeous picture

803
00:35:19,620 --> 00:35:17,770
we can see the four spiral arms we can

804
00:35:21,240 --> 00:35:19,630
see that the star formation happening

805
00:35:23,849 --> 00:35:21,250
throughout the disk we see that it has

806
00:35:26,640 --> 00:35:23,859
lots of fuel to keep doing this and we

807
00:35:28,920 --> 00:35:26,650
can see that it has costs are floating

808
00:35:30,000 --> 00:35:28,930
around it and so the clusters is the

809
00:35:32,820 --> 00:35:30,010
ones that are the things that were after

810
00:35:35,160 --> 00:35:32,830
I'll give you a quick look because the

811
00:35:36,120 --> 00:35:35,170
picture does not come off looking like

812
00:35:39,450 --> 00:35:36,130
that

813
00:35:42,620 --> 00:35:39,460

it comes off as black-and-white pictures

814
00:35:45,390 --> 00:35:42,630
and here's the our observation design

815
00:35:48,180 --> 00:35:45,400
Hubble has two main cameras the Wide

816
00:35:49,710 --> 00:35:48,190
Field Camera 3 and the advanced camera

817
00:35:53,760 --> 00:35:49,720
for surveys the advanced camera for

818
00:35:57,240 --> 00:35:53,770
surveys went on in 2005 so it is now 15

819
00:35:57,840 --> 00:35:57,250
years old and with the three is a little

820
00:35:59,970 --> 00:35:57,850
younger

821
00:36:04,170 --> 00:35:59,980
it went on the last servicing mission so

822
00:36:06,150 --> 00:36:04,180
you can take pictures at the same time

823
00:36:08,190 --> 00:36:06,160
so we took the the main picture that's

824
00:36:10,530 --> 00:36:08,200
the green triangle so this is a great

825
00:36:12,750 --> 00:36:10,540
Green Square here that's that's where

826
00:36:14,730 --> 00:36:12,760
the the galaxy is but we also are

827
00:36:16,380 --> 00:36:14,740
looking for love of the clusters very

828
00:36:18,660 --> 00:36:16,390
much further away from the galaxy itself

829
00:36:21,200 --> 00:36:18,670
using the advanced camera for surveys so

830
00:36:23,550 --> 00:36:21,210
we have more information on this galaxy

831
00:36:26,250 --> 00:36:23,560
it doesn't come out very pretty the

832
00:36:29,280 --> 00:36:26,260
first time I tried to do this the camera

833
00:36:31,200 --> 00:36:29,290
is still quite a line I got diffraction

834
00:36:33,360 --> 00:36:31,210
spikes from the bright stars I've got

835
00:36:35,910 --> 00:36:33,370
secondary reflections mirror there's a

836
00:36:37,770 --> 00:36:35,920
chip gap so with the help from the

837
00:36:40,230 --> 00:36:37,780
wonderful people at Space Telescope we

838
00:36:42,210 --> 00:36:40,240

cleaned it up some and they and they

839
00:36:44,010 --> 00:36:42,220
just get the stretch just right so that

840
00:36:46,140 --> 00:36:44,020
you can see that both the bright stuff

841
00:36:50,310 --> 00:36:46,150
and the faint stuff at the same time I

842
00:36:52,290 --> 00:36:50,320
do kind of love how you can stretch that

843
00:36:54,270 --> 00:36:52,300
right and so this is a black-and-white

844
00:36:57,300 --> 00:36:54,280
picture you get and you get that in

845
00:36:59,160 --> 00:36:57,310
three filters so you get it in blue you

846
00:37:01,530 --> 00:36:59,170
get it in green and you get it in red

847
00:37:06,300 --> 00:37:01,540
and then you combine the three of them

848
00:37:08,120 --> 00:37:06,310
two into a red green blue RGB image and

849
00:37:12,570 --> 00:37:08,130
so that's how you can get a color image

850
00:37:14,490 --> 00:37:12,580
so we have blue isn't quite blue green

851
00:37:17,370 --> 00:37:14,500
isn't quite green and red is a little

852
00:37:20,340 --> 00:37:17,380
bit near-infrared but they are as close

853
00:37:23,550 --> 00:37:20,350
as our eye perceives these colors so

854
00:37:27,600 --> 00:37:23,560
they're real - as real as I can make

855
00:37:30,330 --> 00:37:27,610
them and so we have the big image

856
00:37:33,180 --> 00:37:30,340
release at the American Astronomical

857
00:37:34,740 --> 00:37:33,190
Society meeting in January this is back

858
00:37:38,880 --> 00:37:34,750
when they still let us out of the house

859
00:37:41,130 --> 00:37:38,890
and it was quite exciting to share this

860
00:37:44,760 --> 00:37:41,140
with the world and share just something

861
00:37:46,080 --> 00:37:44,770
pretty and but we also talked some

862
00:37:47,730 --> 00:37:46,090
science and all the things that we can

863
00:37:49,560 --> 00:37:47,740

do with it and it's really fun when you

864
00:37:52,050 --> 00:37:49,570
actually meet people in person

865
00:37:54,870 --> 00:37:52,060
then class are collaborating with them

866
00:37:58,260 --> 00:37:54,880
however this project got started on

867
00:37:59,820 --> 00:37:58,270
Twitter I just chatted to a couple of

868
00:38:02,040 --> 00:37:59,830
people on Twitter about they sent before

869
00:38:05,220 --> 00:38:02,050
we know it we had a public proposal bit

870
00:38:07,140 --> 00:38:05,230
so you can do things in person you can

871
00:38:08,790 --> 00:38:07,150
do things online and I guess I'm showing

872
00:38:10,440 --> 00:38:08,800
that but here's back in person this is

873
00:38:15,090 --> 00:38:10,450
some of the people that I started this

874
00:38:19,730 --> 00:38:15,100
project with jerem left is my student

875
00:38:23,610 --> 00:38:19,740
Sean all the peoples probably barneby

876
00:38:25,770 --> 00:38:23,620
jeremy Baylin and myself because the

877
00:38:28,650 --> 00:38:25,780
Space Telescope at this up at a

878
00:38:31,350 --> 00:38:28,660
life-size pictures and that was just too

879
00:38:33,930 --> 00:38:31,360
cool not to take a picture of and then

880
00:38:37,710 --> 00:38:33,940
of course if you have something like

881
00:38:40,560 --> 00:38:37,720
this it goes and goes into the various

882
00:38:42,930 --> 00:38:40,570
media and you obsessively check and

883
00:38:45,660 --> 00:38:42,940
refresh things until you realize that

884
00:38:47,460 --> 00:38:45,670
it's all over and you can get to see

885
00:38:50,640 --> 00:38:47,470
your end picture back and not be able to

886
00:38:52,290 --> 00:38:50,650
read anything except Hubble in the the

887
00:38:57,630 --> 00:38:52,300
press releases so that was kind of cool

888
00:39:00,390 --> 00:38:57,640

and and when I was a undergrad in 1995

889
00:39:02,460 --> 00:39:00,400
the NASA started the astronomic

890
00:39:04,860 --> 00:39:02,470
Astronomy Picture of the Day and it

891
00:39:05,790 --> 00:39:04,870
hasn't really changed format it looks

892
00:39:08,520 --> 00:39:05,800
exactly the same

893
00:39:12,330 --> 00:39:08,530
it just publishes a very neat as from

894
00:39:14,220 --> 00:39:12,340
Astronomy Picture every day and starting

895
00:39:16,440 --> 00:39:14,230
as a student of astronomy I was like

896
00:39:18,360 --> 00:39:16,450
well maybe one day when I grow up I'll

897
00:39:22,230 --> 00:39:18,370
have my own Astronomy Picture of the Day

898
00:39:26,180 --> 00:39:22,240
and lo I do finally have one 25 years

899
00:39:31,440 --> 00:39:26,190
later so cross that off past self so

900
00:39:33,360 --> 00:39:31,450
that was really really fun so I talked

901
00:39:37,440 --> 00:39:33,370
about the fact that this is galaxies so

902
00:39:39,720 --> 00:39:37,450
big for a spiral galaxy and this is the

903
00:39:43,100 --> 00:39:39,730
Hubble tuning fork this is the way that

904
00:39:45,270 --> 00:39:43,110
Edwin Hubble back in nineteen the 1920s

905
00:39:48,690 --> 00:39:45,280
classified the galaxies that he saw on

906
00:39:51,410 --> 00:39:48,700
those photographs and so on the left

907
00:39:54,240 --> 00:39:51,420
hand side are the ellipticals they are

908
00:39:56,310 --> 00:39:54,250
basically giant American footballs or

909
00:40:01,530 --> 00:39:56,320
rugby balls to spending where you are in

910
00:40:03,450 --> 00:40:01,540
the continent they are flattened ellipse

911
00:40:05,100 --> 00:40:03,460
elliptical things and it really did

912
00:40:07,020 --> 00:40:05,110
how you look at them that's that's

913
00:40:08,910 --> 00:40:07,030

that's those are the left red dead

914
00:40:11,910 --> 00:40:08,920
galaxies there oranjee they're made out

915
00:40:13,770 --> 00:40:11,920
of old stars and as you go further to

916
00:40:15,450 --> 00:40:13,780
the right you get more things that are

917
00:40:18,030 --> 00:40:15,460
made there and basically flatter and

918
00:40:20,850 --> 00:40:18,040
they are disk galaxies and rubens

919
00:40:23,900 --> 00:40:20,860
galaxies is essentially an SC galaxy so

920
00:40:26,730 --> 00:40:23,910
at the top right it doesn't have a giant

921
00:40:30,030 --> 00:40:26,740
central bulge it just is mostly made out

922
00:40:32,940 --> 00:40:30,040
of discs and arms but if you are looking

923
00:40:35,010 --> 00:40:32,950
for the biggest galaxies we typically

924
00:40:36,900 --> 00:40:35,020
find them on the left so hand side there

925
00:40:39,120 --> 00:40:36,910
are litical pick up the biggest galaxies

926
00:40:42,800 --> 00:40:39,130
are elliptical so how do you get an SC

927
00:40:45,090 --> 00:40:42,810
to compete in the same weight class as

928
00:40:48,210 --> 00:40:45,100
ellipticals that's so that was kind of

929
00:40:50,910 --> 00:40:48,220
the question so I looked at this is a

930
00:40:55,530 --> 00:40:50,920
plot of all the nearby galaxies from the

931
00:40:57,990 --> 00:40:55,540
two micron all-sky survey and there are

932
00:41:00,840 --> 00:40:58,000
star-forming ones and there is quiescent

933
00:41:04,230 --> 00:41:00,850
quiescent means not doing very much star

934
00:41:05,730 --> 00:41:04,240
forming wise and they are there there's

935
00:41:07,950 --> 00:41:05,740
kind of two groupings here you can kind

936
00:41:09,630 --> 00:41:07,960
of see that there's there's a line of

937
00:41:12,060 --> 00:41:09,640
star-forming galaxies and there's a line

938
00:41:14,040 --> 00:41:12,070

of guessing galaxies start forming

939
00:41:15,720 --> 00:41:14,050
galaxies are mostly spiral galaxies the

940
00:41:18,180 --> 00:41:15,730
quiescent ones are mostly elliptical

941
00:41:19,980 --> 00:41:18,190
galaxies and so if you as you go along

942
00:41:21,480 --> 00:41:19,990
the spiral galaxies you certainly kind

943
00:41:24,810 --> 00:41:21,490
of peter out and then there's a few

944
00:41:27,090 --> 00:41:24,820
really big tend to be 11 solar mass

945
00:41:29,160 --> 00:41:27,100
galaxies like they we call those super

946
00:41:31,440 --> 00:41:29,170
spirals so there's you know that's as

947
00:41:34,470 --> 00:41:31,450
big as we can grow them except that you

948
00:41:37,500 --> 00:41:34,480
then how can do another step of ten and

949
00:41:41,520 --> 00:41:37,510
get ten through the 12 a trillion solar

950
00:41:45,330 --> 00:41:41,530
masses of stars and then you you get a

951
00:41:47,760 --> 00:41:45,340
Rubens galaxy so it's even big for a

952
00:41:50,820 --> 00:41:47,770
super spiral it's a super super spiral

953
00:41:53,340 --> 00:41:50,830
and then at the but it's not making

954
00:41:55,770 --> 00:41:53,350
stars exactly like you expect the spiral

955
00:41:59,190 --> 00:41:55,780
galaxies to do it's just sort of

956
00:42:01,710 --> 00:41:59,200
underperforming a little bit there but

957
00:42:04,380 --> 00:42:01,720
still it's got ten times more stars than

958
00:42:07,100 --> 00:42:04,390
the typical super spiral so how do you

959
00:42:09,810 --> 00:42:07,110
get there how did it make so many stars

960
00:42:12,600 --> 00:42:09,820
the super spirals look like this and

961
00:42:15,030 --> 00:42:12,610
most of them I think the technical term

962
00:42:16,900 --> 00:42:15,040
is trainwreck it's really when one a

963
00:42:18,790 --> 00:42:16,910

galaxy has smashed into

964
00:42:21,790 --> 00:42:18,800
the other one you can see on the

965
00:42:24,450 --> 00:42:21,800
left-hand side for example two two

966
00:42:27,280 --> 00:42:24,460
bulges essentially that's two galaxies

967
00:42:29,290 --> 00:42:27,290
as they are smashing together in the

968
00:42:31,360 --> 00:42:29,300
middle you can see well if that's a disk

969
00:42:33,910 --> 00:42:31,370
galaxy I have to squint a little bit

970
00:42:36,340 --> 00:42:33,920
because you know it's it's all twisted

971
00:42:37,000 --> 00:42:36,350
and and strange looking and even on the

972
00:42:39,010 --> 00:42:37,010
right-hand side

973
00:42:41,410 --> 00:42:39,020
despite that looking a lot more like a

974
00:42:43,450 --> 00:42:41,420
normal spiral galaxy it doesn't have

975
00:42:45,700 --> 00:42:43,460
really the spiral arms that in a regular

976
00:42:48,700 --> 00:42:45,710
regular pattern that definitely has been

977
00:42:51,760 --> 00:42:48,710
perturbed by some nearby companions or

978
00:42:53,650 --> 00:42:51,770
after eating a big meal basically

979
00:42:57,490 --> 00:42:53,660
merging with another galaxy and that

980
00:43:01,150 --> 00:42:57,500
seems to be a pattern super spirals tend

981
00:43:02,980 --> 00:43:01,160
to be survivors of a of a recent merger

982
00:43:05,440 --> 00:43:02,990
and the only reason that they're there

983
00:43:07,300 --> 00:43:05,450
pumping at so much new stars is because

984
00:43:11,560 --> 00:43:07,310
they've just swallowed a companion

985
00:43:14,260 --> 00:43:11,570
galaxy so the super spirals it doesn't

986
00:43:16,870 --> 00:43:14,270
seem to belong to it doesn't it's not

987
00:43:19,330 --> 00:43:16,880
forming the amount of stars as the super

988
00:43:21,310 --> 00:43:19,340

spirals do is much bigger than the super

989
00:43:23,170 --> 00:43:21,320
spirals everything else seemed even

990
00:43:26,560 --> 00:43:23,180
remotely in its weight class is an

991
00:43:29,380 --> 00:43:26,570
elliptical so how do you do this how do

992
00:43:31,480 --> 00:43:29,390
you make a giant disk galaxies how do we

993
00:43:35,920 --> 00:43:31,490
how did you get there

994
00:43:37,780 --> 00:43:35,930
and so I go back to what we know about

995
00:43:40,210 --> 00:43:37,790
how galaxies formed we know that

996
00:43:42,880 --> 00:43:40,220
galaxies forming giant Dark Matter halos

997
00:43:45,130 --> 00:43:42,890
so as soon as we learned from Reubens

998
00:43:48,190 --> 00:43:45,140
results and other boss wants results

999
00:43:50,470 --> 00:43:48,200
that galaxies have dark matter in them

1000
00:43:52,720 --> 00:43:50,480
we started making universes in the

1001
00:43:55,210 --> 00:43:52,730
computer that have dark matter in them

1002
00:43:56,410 --> 00:43:55,220
so we start with a giant amount of dark

1003
00:43:58,090 --> 00:43:56,420
matter you see that on the right hand

1004
00:44:00,070 --> 00:43:58,100
side that's what the dark matter lives

1005
00:44:02,020 --> 00:44:00,080
and then you start following where the

1006
00:44:04,510 --> 00:44:02,030
stars are and you see that the galaxies

1007
00:44:06,910 --> 00:44:04,520
sit in the same position as where all

1008
00:44:09,400 --> 00:44:06,920
the dark matter is coming together but u

1009
00:44:12,460 --> 00:44:09,410
s-- notice something else as well if you

1010
00:44:14,620 --> 00:44:12,470
have a big thing of dark matter smaller

1011
00:44:17,400 --> 00:44:14,630
bits of dark matter fall into it and

1012
00:44:22,240 --> 00:44:17,410
they are taking their stars with them so

1013
00:44:26,680 --> 00:44:22,250

stars if you have a big galaxy it should

1014
00:44:28,900 --> 00:44:26,690
be eating and should be acquiring all

1015
00:44:30,640 --> 00:44:28,910
these smaller galaxies and then

1016
00:44:32,890 --> 00:44:30,650
encountering other galaxies

1017
00:44:35,080 --> 00:44:32,900
and then smashing into them like it's a

1018
00:44:37,960 --> 00:44:35,090
very violent process you're the life of

1019
00:44:40,780 --> 00:44:37,970
the galaxy it seems to be so how do you

1020
00:44:42,630 --> 00:44:40,790
make a galaxy of a disk which doesn't

1021
00:44:45,160 --> 00:44:42,640
seem to have been troubled by anybody

1022
00:44:49,090 --> 00:44:45,170
doesn't seem to have eaten many smaller

1023
00:44:51,700 --> 00:44:49,100
galaxies in recently either one this is

1024
00:44:57,310 --> 00:44:51,710
how you know galaxies form you know that

1025
00:44:59,620 --> 00:44:57,320
they start as as separate blobs of self

1026
00:45:02,590 --> 00:44:59,630
dark matter and they come together and

1027
00:45:06,490 --> 00:45:02,600
small a bigger and bigger chunks so this

1028
00:45:11,620 --> 00:45:06,500
is maybe this is an exception remember

1029
00:45:14,110 --> 00:45:11,630
we only have the one so maybe it's just

1030
00:45:15,520 --> 00:45:14,120
eaten lots of really really small

1031
00:45:17,050 --> 00:45:15,530
galaxies and this is what you then

1032
00:45:19,570 --> 00:45:17,060
expect you expect all these smaller

1033
00:45:21,760 --> 00:45:19,580
galaxies are our rubens galaxies the

1034
00:45:24,430 --> 00:45:21,770
green circle in the center and then you

1035
00:45:27,130 --> 00:45:24,440
throw all these smaller galaxies at them

1036
00:45:28,810 --> 00:45:27,140
and they get completely shredded to

1037
00:45:31,060 --> 00:45:28,820
pieces as you can see they're all in

1038
00:45:33,370 --> 00:45:31,070

these streams and in these all the stars

1039
00:45:36,540 --> 00:45:33,380
gets flung all over the place and this

1040
00:45:39,970 --> 00:45:36,550
is all by tidal forces so you expect

1041
00:45:41,620 --> 00:45:39,980
this basically if you look deep enough

1042
00:45:44,440 --> 00:45:41,630
but even with the Hubble Space Telescope

1043
00:45:46,480 --> 00:45:44,450
at the distance where Ruben's galaxies

1044
00:45:48,520 --> 00:45:46,490
at we wouldn't be able to see the

1045
00:45:51,580 --> 00:45:48,530
streams we wouldn't be able to see the

1046
00:45:55,150 --> 00:45:51,590
the fuzzy plumes because they're just so

1047
00:45:56,770 --> 00:45:55,160
spread out however so here's what these

1048
00:45:58,900 --> 00:45:56,780
fuzzy plumes this is sort of what you

1049
00:46:02,200 --> 00:45:58,910
expect you expect something like this so

1050
00:46:05,380 --> 00:46:02,210
you expect shells you expect plumes you

1051
00:46:09,190 --> 00:46:05,390
expect streams of stars but they're all

1052
00:46:11,050 --> 00:46:09,200
so dim that we can't see them but how so

1053
00:46:14,470 --> 00:46:11,060
how can we find see if they have this

1054
00:46:16,390 --> 00:46:14,480
well every galaxy has clusters around it

1055
00:46:18,820 --> 00:46:16,400
every galaxy has globular clusters and

1056
00:46:22,230 --> 00:46:18,830
so what you can do is look for the

1057
00:46:24,790 --> 00:46:22,240
surviving globular clusters of these

1058
00:46:27,640 --> 00:46:24,800
galaxies that the big galaxy has eaten

1059
00:46:29,920 --> 00:46:27,650
and so this is the sombrero galaxy again

1060
00:46:32,140 --> 00:46:29,930
and we people have studied this in

1061
00:46:36,100 --> 00:46:32,150
detail and look for all the globular

1062
00:46:40,090 --> 00:46:36,110
clusters around this big again similar

1063
00:46:42,910 --> 00:46:40,100

mass not quite similar mass but big

1064
00:46:44,740 --> 00:46:42,920
ellipticals s.0 galaxies

1065
00:46:47,349 --> 00:46:44,750
and you can find a lot of globular

1066
00:46:50,470 --> 00:46:47,359
clusters it it has eaten a lot of its

1067
00:46:51,940 --> 00:46:50,480
companions clearly so this is what a

1068
00:46:53,260 --> 00:46:51,950
globular cluster it looks like in our

1069
00:46:56,640 --> 00:46:53,270
own Milky Way

1070
00:46:58,780 --> 00:46:56,650
it is a heap of stars in a spherical

1071
00:47:01,000 --> 00:46:58,790
grouping so they're always nice and

1072
00:47:02,980 --> 00:47:01,010
round they all formed at the same time

1073
00:47:07,930 --> 00:47:02,990
and they all stick together and so then

1074
00:47:10,809 --> 00:47:07,940
you look for these small blobs of stars

1075
00:47:13,569 --> 00:47:10,819
and they look like not quite a star at

1076
00:47:16,000 --> 00:47:13,579
the distance of movements galaxies the

1077
00:47:17,650 --> 00:47:16,010
nice thing is we have color information

1078
00:47:20,470 --> 00:47:17,660
so we know that there supposed to be a

1079
00:47:22,390 --> 00:47:20,480
certain color we have blue green and red

1080
00:47:26,770 --> 00:47:22,400
so we can see if they're in the right

1081
00:47:29,170 --> 00:47:26,780
part of color space for example we do we

1082
00:47:32,410 --> 00:47:29,180
compare green versus red and blue versus

1083
00:47:34,390 --> 00:47:32,420
green that's the the x-axis is V minus I

1084
00:47:38,079 --> 00:47:34,400
that's the filter names but that means

1085
00:47:41,200 --> 00:47:38,089
green - red and B - V is blue - green

1086
00:47:43,630 --> 00:47:41,210
and so we say all right the points that

1087
00:47:45,910 --> 00:47:43,640
I'm seeing where exactly do they live we

1088
00:47:49,420 --> 00:47:45,920

know that the G sees the globular

1089
00:47:51,700 --> 00:47:49,430
clusters are living in ellipsoid in the

1090
00:47:53,620 --> 00:47:51,710
center and there's two kinds this bluish

1091
00:47:55,089 --> 00:47:53,630
ones there are a little younger and

1092
00:47:58,270 --> 00:47:55,099
there's reddish ones they're even older

1093
00:48:00,700 --> 00:47:58,280
and so we go tally how many of those we

1094
00:48:03,730 --> 00:48:00,710
see that's the trick we're gonna go see

1095
00:48:07,089 --> 00:48:03,740
how many glimmer clusters Ruben's galaxy

1096
00:48:09,730 --> 00:48:07,099
had and do we see it's leftovers

1097
00:48:12,099 --> 00:48:09,740
essentially we're look we're looking in

1098
00:48:14,170 --> 00:48:12,109
Rubens galaxy's fridge and seeing if

1099
00:48:16,660 --> 00:48:14,180
it's got any leftovers from all the big

1100
00:48:19,329 --> 00:48:16,670
meals that it's had and also what we're

1101
00:48:21,010 --> 00:48:19,339
gonna do is see how bright them they are

1102
00:48:23,440 --> 00:48:21,020
and see how many are globular clusters

1103
00:48:25,299 --> 00:48:23,450
they are and if that which galaxies

1104
00:48:29,470 --> 00:48:25,309
other galaxies that we know it resembles

1105
00:48:31,539 --> 00:48:29,480
most so this is green - red the color

1106
00:48:33,940 --> 00:48:31,549
and then we also see how bright these

1107
00:48:35,380 --> 00:48:33,950
clusters are because if they have if

1108
00:48:37,450 --> 00:48:35,390
there's lots of really bright clusters

1109
00:48:39,730 --> 00:48:37,460
well that tells us that there are more

1110
00:48:41,289 --> 00:48:39,740
recent arrivals or if there are lots of

1111
00:48:43,930 --> 00:48:41,299
faint ones than they're from they're

1112
00:48:49,660 --> 00:48:43,940
much longer and much older ago so we got

1113
00:48:52,000 --> 00:48:49,670

blue and red global clusters there okay

1114
00:48:56,710 --> 00:48:52,010
so this is from my colleague Jeremy

1115
00:48:59,650 --> 00:48:56,720
Balin he models how many we see so there

1116
00:49:03,849 --> 00:48:59,660
phew they start at 20th magnitude if you

1117
00:49:06,700 --> 00:49:03,859
are an observer that is hard to do with

1118
00:49:09,310 --> 00:49:06,710
anything other than a really big

1119
00:49:11,410 --> 00:49:09,320
telescope or anything in space and

1120
00:49:13,900 --> 00:49:11,420
that's where our global cost account

1121
00:49:15,339 --> 00:49:13,910
starts and it ends at 26 magnitude so

1122
00:49:17,050 --> 00:49:15,349
we're actually going pretty deep we're

1123
00:49:21,220 --> 00:49:17,060
going to find we find a pretty good

1124
00:49:24,070 --> 00:49:21,230
tally of them and we then compare that

1125
00:49:26,109 --> 00:49:24,080
so this is a histogram of absolute

1126
00:49:27,760 --> 00:49:26,119
magnitude so how bright they are if they

1127
00:49:30,640 --> 00:49:27,770
if you would put them at a certain

1128
00:49:36,490 --> 00:49:30,650
distance so we can compare them with the

1129
00:49:39,460 --> 00:49:36,500
other numbers of globular clusters in

1130
00:49:43,740 --> 00:49:39,470
other galaxies so we've looked over the

1131
00:49:46,750 --> 00:49:43,750
years and Hubble has done this since

1132
00:49:48,940 --> 00:49:46,760
2000 I think it has taken tallies of

1133
00:49:51,339 --> 00:49:48,950
nearby galaxies and tallied up their

1134
00:49:55,000 --> 00:49:51,349
globular cluster counts how many do they

1135
00:49:57,490 --> 00:49:55,010
have how many how bright are they my

1136
00:50:00,490 --> 00:49:57,500
colleague Republic Chandra is a world is

1137
00:50:03,579 --> 00:50:00,500
the world expert on this and I also know

1138
00:50:06,130 --> 00:50:03,589

her from space telescope days and so she

1139
00:50:10,599 --> 00:50:06,140
and I will be comparing these these

1140
00:50:13,740 --> 00:50:10,609
counts so actually look at that you look

1141
00:50:15,880 --> 00:50:13,750
at where ma t81 one of the beautiful

1142
00:50:19,810 --> 00:50:15,890
disk galaxies in their local

1143
00:50:22,329 --> 00:50:19,820
neighborhood they're all much much

1144
00:50:26,170 --> 00:50:22,339
fainter than the ones in the Rubens

1145
00:50:28,210 --> 00:50:26,180
galaxy the ones in EM 51 are pretty

1146
00:50:34,089 --> 00:50:28,220
close the one in m83 are pretty close

1147
00:50:38,770 --> 00:50:34,099
but those two m101 and m81 are the

1148
00:50:41,050 --> 00:50:38,780
bigger galaxies and the m51 and m83 are

1149
00:50:43,660 --> 00:50:41,060
all the smaller disk galaxies they're

1150
00:50:47,230 --> 00:50:43,670
much lower amounts and yet they resemble

1151
00:50:49,660 --> 00:50:47,240
the closest to Ruben's galaxies so the

1152
00:50:51,700 --> 00:50:49,670
strangest thing is that as I do this

1153
00:50:55,599 --> 00:50:51,710
comparison and I'm looking at like the

1154
00:50:57,940 --> 00:50:55,609
size chart here there's no progression

1155
00:51:01,710 --> 00:50:57,950
where you go from the smallest m81

1156
00:51:05,320 --> 00:51:01,720
numbers to and 101 and then compared to

1157
00:51:07,630 --> 00:51:05,330
Ruben's galaxies because it doesn't look

1158
00:51:09,490 --> 00:51:07,640
like the the bigger galaxies he doesn't

1159
00:51:10,240 --> 00:51:09,500
have the globular clusters like the big

1160
00:51:12,100 --> 00:51:10,250
spirals to

1161
00:51:15,160 --> 00:51:12,110
and it doesn't really have that as the

1162
00:51:15,640 --> 00:51:15,170
smallest one either it's somewhere in

1163
00:51:22,030 --> 00:51:15,650

between

1164
00:51:24,550 --> 00:51:22,040
it looks like m51 just walked out just

1165
00:51:28,180 --> 00:51:24,560
really really big just not violent it

1166
00:51:29,890 --> 00:51:28,190
has just slowly grown over time that's

1167
00:51:32,350 --> 00:51:29,900
the conclusion that we're getting it is

1168
00:51:37,720 --> 00:51:32,360
really like a normal disc galaxy but

1169
00:51:39,430 --> 00:51:37,730
smaller and kind of impressive that it

1170
00:51:43,180 --> 00:51:39,440
managed to grow that size without

1171
00:51:46,300 --> 00:51:43,190
encountering anybody this is the most

1172
00:51:50,650 --> 00:51:46,310
complicated part I'll show you I promise

1173
00:51:53,170 --> 00:51:50,660
this shows on the on the x-axis the

1174
00:51:55,060 --> 00:51:53,180
brightness of the galaxy and to the left

1175
00:51:57,670 --> 00:51:55,070
of the brightest galaxies and to the

1176
00:51:59,380 --> 00:51:57,680
right are the dimmest galaxies and it's

1177
00:52:01,930 --> 00:51:59,390
because it's a magnitude then more

1178
00:52:03,730 --> 00:52:01,940
negative than number the brighter it is

1179
00:52:05,080 --> 00:52:03,740
but if you don't like that you can look

1180
00:52:07,630 --> 00:52:05,090
at the top and there in scientific

1181
00:52:10,030 --> 00:52:07,640
notation is how bright it is in solar

1182
00:52:13,660 --> 00:52:10,040
luminosities and so in solar

1183
00:52:16,630 --> 00:52:13,670
luminosities UGC 285 Reubens galaxy is

1184
00:52:21,040 --> 00:52:16,640
about 10 to the 10

1185
00:52:23,890 --> 00:52:21,050
but in mass it's a bit bigger and so if

1186
00:52:26,950 --> 00:52:23,900
you look from the y axis we get this

1187
00:52:31,450 --> 00:52:26,960
strange T value and T is basically how

1188
00:52:35,080 --> 00:52:31,460

many clusters do you have per million

1189
00:52:37,360 --> 00:52:35,090
solar masses if I add another million

1190
00:52:40,690 --> 00:52:37,370
solar masses to this galaxy you get

1191
00:52:44,350 --> 00:52:40,700
there's X number there's you know ten to

1192
00:52:46,780 --> 00:52:44,360
the ten or a hundred globular clusters

1193
00:52:48,700 --> 00:52:46,790
that clusters that go with it and so

1194
00:52:50,950 --> 00:52:48,710
what people have noticed in looking at

1195
00:52:53,110 --> 00:52:50,960
all these different studies using often

1196
00:52:58,930 --> 00:52:53,120
the Hubble Space Telescope that in the

1197
00:53:01,660 --> 00:52:58,940
so the blue points and black squares the

1198
00:53:05,020 --> 00:53:01,670
squares and this circles essentially are

1199
00:53:10,450 --> 00:53:05,030
the dwarf galaxies and dwarf galaxies

1200
00:53:15,250 --> 00:53:10,460
for any for all per million solar masses

1201
00:53:18,640 --> 00:53:15,260
of stars they have about between ten and

1202
00:53:20,740 --> 00:53:18,650
a hundred globular clusters so they have

1203
00:53:23,240 --> 00:53:20,750
a lot of they have a lot of globular

1204
00:53:25,160 --> 00:53:23,250
clusters for their size and their

1205
00:53:26,690 --> 00:53:25,170
and then if you start smashing them

1206
00:53:28,670 --> 00:53:26,700
together as you're trying to make a

1207
00:53:31,580 --> 00:53:28,680
bigger galaxy by smashing lots of dwarf

1208
00:53:33,470 --> 00:53:31,590
galaxies together you should get more

1209
00:53:35,780 --> 00:53:33,480
globular clusters even if you destroy a

1210
00:53:37,490 --> 00:53:35,790
few they're pretty resilient they said

1211
00:53:40,220 --> 00:53:37,500
stick around and so that's what you end

1212
00:53:42,770 --> 00:53:40,230
up with the on the left-hand side here

1213
00:53:44,270 --> 00:53:42,780

this all the triangles are elliptical so

1214
00:53:46,370 --> 00:53:44,280
on this side is where they elliptical to

1215
00:53:48,470 --> 00:53:46,380
live and they are made from smashing

1216
00:53:50,930 --> 00:53:48,480
lots of dwarf galaxies together so per

1217
00:53:52,850 --> 00:53:50,940
million solar masses they have the same

1218
00:53:55,310 --> 00:53:52,860
number of global across ters you know

1219
00:53:59,210 --> 00:53:55,320
give or take one or two I say you know

1220
00:54:02,090 --> 00:53:59,220
sloppily get eaten but that's okay but

1221
00:54:04,190 --> 00:54:02,100
here's UGC to 885 it's sitting all the

1222
00:54:06,470 --> 00:54:04,200
way at the bottom of this plot it has

1223
00:54:10,240 --> 00:54:06,480
the fewest numbers of globular clusters

1224
00:54:14,810 --> 00:54:10,250
of any galaxy we know it just doesn't

1225
00:54:18,080 --> 00:54:14,820
seem to have as many per million solar

1226
00:54:20,420 --> 00:54:18,090
masses so it hasn't it hasn't been made

1227
00:54:22,070 --> 00:54:20,430
by smashing the blue and red points

1228
00:54:24,260 --> 00:54:22,080
together in order to make the the

1229
00:54:26,060 --> 00:54:24,270
ellipticals it hasn't been made that way

1230
00:54:29,330 --> 00:54:26,070
it's actually sitting well below that

1231
00:54:32,210 --> 00:54:29,340
now that is a little interesting because

1232
00:54:33,860 --> 00:54:32,220
we are our whole paradigm is that in

1233
00:54:36,980 --> 00:54:33,870
order to make big things you smash

1234
00:54:38,900 --> 00:54:36,990
smaller things together and so what we

1235
00:54:40,790 --> 00:54:38,910
think is happening is that we're looking

1236
00:54:45,260 --> 00:54:40,800
at a give this galaxies like this one

1237
00:54:47,660 --> 00:54:45,270
and we think streams of gas are arriving

1238
00:54:50,150 --> 00:54:47,670

out of the intergalactic medium these

1239
00:54:53,840 --> 00:54:50,160
are called cold streams and there are

1240
00:54:55,880 --> 00:54:53,850
now a major hunt going on in the radio

1241
00:54:58,790 --> 00:54:55,890
astronomy to see if we can find these

1242
00:55:01,910 --> 00:54:58,800
streams but instead of having them those

1243
00:55:05,450 --> 00:55:01,920
little galaxies in them in the case of

1244
00:55:07,880 --> 00:55:05,460
Rubens galaxy it was just gas

1245
00:55:09,470 --> 00:55:07,890
there's just gas flowing into this disk

1246
00:55:12,350 --> 00:55:09,480
disk and it's been doing that for

1247
00:55:15,650 --> 00:55:12,360
billions of years as it just slowly grew

1248
00:55:20,000 --> 00:55:15,660
grew in disk size and slowly grew by

1249
00:55:22,880 --> 00:55:20,010
slowly converting that gas into stars so

1250
00:55:26,030 --> 00:55:22,890
a gentle giant it has not been enough

1251
00:55:28,910 --> 00:55:26,040
fiery eating giant meals it has been

1252
00:55:31,820 --> 00:55:28,920
snacking since the dawn of time turning

1253
00:55:34,880 --> 00:55:31,830
all this into its giant and beautiful

1254
00:55:36,710 --> 00:55:34,890
discs so I think we think that this is

1255
00:55:39,800 --> 00:55:36,720
the best solution for how

1256
00:55:40,940 --> 00:55:39,810
can make giant disk galaxies you don't

1257
00:55:43,390 --> 00:55:40,950
have to

1258
00:55:47,420 --> 00:55:43,400
Hulk smash here it's in fact quite a

1259
00:55:50,300 --> 00:55:47,430
non-violent and then I get some sanity

1260
00:55:52,160 --> 00:55:50,310
checks I looked at the stellar mass so

1261
00:55:54,830 --> 00:55:52,170
you can see it's just over ten to the

1262
00:55:58,940 --> 00:55:54,840
twelve and the excess is solar mass on

1263
00:55:59,900 --> 00:55:58,950

the y axis is basically size so the

1264
00:56:03,349 --> 00:55:59,910
bigger the better

1265
00:56:06,770 --> 00:56:03,359
the you know the bigger the the more

1266
00:56:08,390 --> 00:56:06,780
massive the more extended that seems to

1267
00:56:09,800 --> 00:56:08,400
hold pretty well these are all the

1268
00:56:15,380 --> 00:56:09,810
relations that different people have

1269
00:56:18,650 --> 00:56:15,390
found and are my little three corner

1270
00:56:21,950 --> 00:56:18,660
shape is Rubens galaxy again and it's

1271
00:56:24,260 --> 00:56:21,960
right on where the averages are except

1272
00:56:26,510 --> 00:56:24,270
with the average for their for the for

1273
00:56:30,470 --> 00:56:26,520
those mask galaxies has been determined

1274
00:56:34,370 --> 00:56:30,480
from elliptical galaxies but it is the

1275
00:56:36,020 --> 00:56:34,380
right size for its mass so nothing

1276
00:56:38,030 --> 00:56:36,030
strange going on there it hasn't been

1277
00:56:40,910 --> 00:56:38,040
stretched out or anything like that it

1278
00:56:43,579 --> 00:56:40,920
is the size that you expect it to be is

1279
00:56:46,160 --> 00:56:43,589
it may be rare well it is definitely the

1280
00:56:49,099 --> 00:56:46,170
rare in our local universe because as

1281
00:56:51,140 --> 00:56:49,109
you can see here the x-axis is more

1282
00:56:53,540 --> 00:56:51,150
distant so as we go further and further

1283
00:56:56,930 --> 00:56:53,550
out again the grayscale is the two mass

1284
00:56:58,910 --> 00:56:56,940
local galaxies survey and the brighter

1285
00:57:00,770 --> 00:56:58,920
galaxies are at the top it kind of

1286
00:57:05,630 --> 00:57:00,780
Peters out as you get to the brighter

1287
00:57:08,420 --> 00:57:05,640
galaxies and it is definitely one of a

1288
00:57:12,530 --> 00:57:08,430

kind in our survey surveys like this so

1289
00:57:14,560 --> 00:57:12,540
it seems to be sitting in its own corner

1290
00:57:17,150 --> 00:57:14,570
of the universe doing its own thing

1291
00:57:20,930 --> 00:57:17,160
being quite unique which is quite nice

1292
00:57:24,349 --> 00:57:20,940
to see how about its environment is it

1293
00:57:26,900 --> 00:57:24,359
particularly lonely so we look at the y

1294
00:57:29,570 --> 00:57:26,910
axis is a measure of how lonely galaxies

1295
00:57:31,040 --> 00:57:29,580
are we say the fourth nearest neighbor I

1296
00:57:33,230 --> 00:57:31,050
have to explain this to a student the

1297
00:57:35,780 --> 00:57:33,240
other day if you want to know how credit

1298
00:57:37,730 --> 00:57:35,790
your environment is you go figure out

1299
00:57:39,410 --> 00:57:37,740
not where you're near the nearest other

1300
00:57:40,520 --> 00:57:39,420
person is the nearest other person in my

1301
00:57:44,240 --> 00:57:40,530
case is downstairs

1302
00:57:46,040 --> 00:57:44,250
the next person over is also downstairs

1303
00:57:48,160 --> 00:57:46,050
the next person after that is also

1304
00:57:49,980 --> 00:57:48,170
downstairs they're all on their screens

1305
00:57:53,550 --> 00:57:49,990
but

1306
00:57:55,710 --> 00:57:53,560
the fourth nearest neighbor is my is my

1307
00:57:57,599 --> 00:57:55,720
next-door neighbor and so the fourth

1308
00:57:59,579 --> 00:57:57,609
person near you if you're sitting in a

1309
00:58:01,740 --> 00:57:59,589
crowded auditorium the fourth you can

1310
00:58:04,530 --> 00:58:01,750
probably touch the fourth nearest person

1311
00:58:07,320 --> 00:58:04,540
to you and so you know it's crowded if

1312
00:58:09,870 --> 00:58:07,330
you can in a subway for example if you

1313
00:58:12,480 --> 00:58:09,880

can touch the fourth person ears to you

1314
00:58:14,310 --> 00:58:12,490
but if you're living in the suburbs the

1315
00:58:16,470 --> 00:58:14,320
fourth nearest person to you it's

1316
00:58:18,780 --> 00:58:16,480
definitely one house over and if you're

1317
00:58:20,490 --> 00:58:18,790
living in the countryside it might take

1318
00:58:23,490 --> 00:58:20,500
a short drive for you to get through the

1319
00:58:26,310 --> 00:58:23,500
fourth person years to you so the force

1320
00:58:29,040 --> 00:58:26,320
near fourth nearest neighbor is a good

1321
00:58:31,650 --> 00:58:29,050
way to see if you're living in a crowded

1322
00:58:35,849 --> 00:58:31,660
environment or not and the distance to

1323
00:58:39,150 --> 00:58:35,859
the your fourth neighbor is for this

1324
00:58:41,280 --> 00:58:39,160
galaxy I don't know it's it seems to be

1325
00:58:43,170 --> 00:58:41,290
not in a space where most galaxies seem

1326
00:58:45,630 --> 00:58:43,180
to live they're all smaller but they're

1327
00:58:47,280 --> 00:58:45,640
also kind of in a whole range of credit

1328
00:58:49,800 --> 00:58:47,290
fields it seems to be that it is not

1329
00:58:51,900 --> 00:58:49,810
particularly unique I thought that I

1330
00:58:53,400 --> 00:58:51,910
could find a way saying like well it

1331
00:58:56,010 --> 00:58:53,410
doesn't have any friends it's sitting

1332
00:58:59,880 --> 00:58:56,020
off in the corner but it seems to be

1333
00:59:01,890 --> 00:58:59,890
fairly common density so how do you grow

1334
00:59:04,410 --> 00:59:01,900
this giant it is so much more massive

1335
00:59:06,359 --> 00:59:04,420
it's so bigger much bigger than any

1336
00:59:09,960 --> 00:59:06,369
typical spiral galaxy and I am talking

1337
00:59:12,210 --> 00:59:09,970
ten times more massive the hundred times

1338
00:59:15,000 --> 00:59:12,220

more massive than any spiral you you

1339
00:59:18,300 --> 00:59:15,010
care to name and it's also ten times

1340
00:59:20,760 --> 00:59:18,310
bigger than anything else in the spiral

1341
00:59:23,190 --> 00:59:20,770
galaxy rearrange so the question is how

1342
00:59:25,290 --> 00:59:23,200
you grow that and without mergers

1343
00:59:27,960 --> 00:59:25,300
mergers should leave a mark either in

1344
00:59:31,349 --> 00:59:27,970
the population of covered clusters or in

1345
00:59:33,510 --> 00:59:31,359
the disk itself we don't see either and

1346
00:59:35,430 --> 00:59:33,520
so the fact that we see so few global

1347
00:59:37,650 --> 00:59:35,440
across series is implying that it has

1348
00:59:39,900 --> 00:59:37,660
actually grown very gradually over time

1349
00:59:44,670 --> 00:59:39,910
we don't see the remnants of any big

1350
00:59:46,290 --> 00:59:44,680
meals so that is that is interesting so

1351
00:59:47,940 --> 00:59:46,300
apparently you don't need to smash

1352
00:59:50,730 --> 00:59:47,950
things together in order to make a big

1353
00:59:52,920 --> 00:59:50,740
galaxy and there's another way and of

1354
00:59:55,560 --> 00:59:52,930
course I have a next question because as

1355
00:59:57,150 --> 00:59:55,570
with as always with science there's a

1356
00:59:59,160 --> 00:59:57,160
next question and as I look at this

1357
01:00:01,079 --> 00:59:59,170
galaxy and I go wow this is really big

1358
01:00:02,970 --> 01:00:01,089
galaxy what's what's the other thing

1359
01:00:03,920 --> 01:00:02,980
about the galaxies the other thing about

1360
01:00:06,230 --> 01:00:03,930
Big Alex

1361
01:00:09,859 --> 01:00:06,240
they have a really big supermassive

1362
01:00:13,700 --> 01:00:09,869
black hole in the center does this guy

1363
01:00:16,309 --> 01:00:13,710

do do as well all the big the picture of

1364
01:00:20,390 --> 01:00:16,319
the hull of those black hole picture

1365
01:00:23,150 --> 01:00:20,400
that you saw a year ago that was an

1366
01:00:24,380 --> 01:00:23,160
elliptical galaxy and we know that for

1367
01:00:26,510 --> 01:00:24,390
instance our own Milky Way has a

1368
01:00:28,910 --> 01:00:26,520
supermassive black hole but I'm really

1369
01:00:32,480 --> 01:00:28,920
curious if this guy has a supermassive

1370
01:00:34,789 --> 01:00:32,490
black hole does it has it grown with the

1371
01:00:38,390 --> 01:00:34,799
Galaxy itself is it a supermassive black

1372
01:00:42,470 --> 01:00:38,400
hole that's typical for a 10 to the 12

1373
01:00:45,109 --> 01:00:42,480
Solem a stellar thing or is it more is

1374
01:00:48,019 --> 01:00:45,119
it just like in 51 is it just like I'm

1375
01:00:50,960 --> 01:00:48,029
83 like is it really just a smaller disc

1376
01:00:52,160 --> 01:00:50,970
galaxies black hole how does that work

1377
01:00:56,960 --> 01:00:52,170
and that's the thing that I'll be

1378
01:00:59,120 --> 01:00:56,970
working with with Saavik Ford aah

1379
01:01:01,460 --> 01:00:59,130
the Museum of Natural History on so I'll

1380
01:01:03,500 --> 01:01:01,470
be really interesting so we always have

1381
01:01:07,849 --> 01:01:03,510
new things to explore with this and

1382
01:01:09,349 --> 01:01:07,859
we'll use other telescopes as well as as

1383
01:01:13,730 --> 01:01:09,359
well as the Hubble picture to go study

1384
01:01:15,920 --> 01:01:13,740
now the center of this galaxy all right

1385
01:01:18,680 --> 01:01:15,930
thank you so much for listening to me

1386
01:01:22,039 --> 01:01:18,690
this is the inevitable selfie in front

1387
01:01:24,260 --> 01:01:22,049
of the galaxy if you if you get a poster

1388
01:01:26,539 --> 01:01:24,270

that's bigger than you you have to take

1389
01:01:30,109 --> 01:01:26,549
a picture of that that is just the stuff

1390
01:01:33,019 --> 01:01:30,119
that's the rules and so I really thank

1391
01:01:35,269 --> 01:01:33,029
you all very much for listening and I'll

1392
01:01:39,470 --> 01:01:35,279
take questions if you have them all

1393
01:01:43,220 --> 01:01:39,480
right that was wonderful bene we're

1394
01:01:48,440 --> 01:01:43,230
really enjoyed what a really deep tour

1395
01:01:50,299 --> 01:01:48,450
of a very unusual galaxy although I have

1396
01:01:52,130 --> 01:01:50,309
to tell you that when we first came up

1397
01:01:54,200 --> 01:01:52,140
in the news meeting that we were going

1398
01:01:56,180 --> 01:01:54,210
to present this we looked at that big

1399
01:01:58,430 --> 01:01:56,190
bright star with the spikes all over in

1400
01:02:06,529 --> 01:01:58,440
front of it yeah and we referred to it

1401
01:02:08,930 --> 01:02:06,539
as a star crossed galaxy I do understand

1402
01:02:10,700 --> 01:02:08,940
that this is not the first galaxy you

1403
01:02:13,490 --> 01:02:10,710
would point your bright shiny new

1404
01:02:15,440 --> 01:02:13,500
telescope at because of that story you'd

1405
01:02:17,330 --> 01:02:15,450
be worried that you just damaged the

1406
01:02:19,820 --> 01:02:17,340
camera but

1407
01:02:22,310 --> 01:02:19,830
we did a careful check throughout to

1408
01:02:25,790 --> 01:02:22,320
make sure that that didn't happen but it

1409
01:02:27,650 --> 01:02:25,800
is very hard to look at the galaxy with

1410
01:02:31,480 --> 01:02:27,660
such a bright we're kind of squinting at

1411
01:02:34,730 --> 01:02:31,490
our screen half the time but it's pretty

1412
01:02:36,850 --> 01:02:34,740
wonderful so I got a question from as

1413
01:02:40,670 --> 01:02:36,860

somebody who worked on galaxy formation

1414
01:02:41,930 --> 01:02:40,680
and development over time it sounds like

1415
01:02:43,820 --> 01:02:41,940
what you're saying is this is a

1416
01:02:45,770 --> 01:02:43,830
quiescent galaxy alright this has sort

1417
01:02:48,170 --> 01:02:45,780
of formed quiescent lis which sort of

1418
01:02:50,120 --> 01:02:48,180
means that you know it forms generally

1419
01:02:51,650 --> 01:02:50,130
out in a void --is-- area because you're

1420
01:02:55,790 --> 01:02:51,660
not going to have the things smashing in

1421
01:02:57,740 --> 01:02:55,800
from all directions but you Gen show the

1422
01:02:59,720 --> 01:02:57,750
force nearest-neighbor statistic and

1423
01:03:02,330 --> 01:02:59,730
it's not that atypical for a fourth

1424
01:03:04,330 --> 01:03:02,340
nearest neighbor statistic so it doesn't

1425
01:03:09,500 --> 01:03:04,340
sound like it's in this floyd region so

1426
01:03:15,410 --> 01:03:09,510
what's going on here dude okay so if you

1427
01:03:17,270 --> 01:03:15,420
only have one galaxy then there might

1428
01:03:19,460 --> 01:03:17,280
just you have to take into account that

1429
01:03:21,560 --> 01:03:19,470
you might just be looking at a very

1430
01:03:23,930 --> 01:03:21,570
lucky galaxy and I think this is what

1431
01:03:27,020 --> 01:03:23,940
happened I think it just narrowly

1432
01:03:29,360 --> 01:03:27,030
escaped smashing into anything else okay

1433
01:03:35,630 --> 01:03:29,370
it's not it's it's kind of it's the its

1434
01:03:38,630 --> 01:03:35,640
I have a Giuliano Canton has a saying

1435
01:03:40,760 --> 01:03:38,640
that's like every galaxy strange you as

1436
01:03:43,720 --> 01:03:40,770
soon as you get to know them this is

1437
01:03:47,450 --> 01:03:43,730
true for people astronomers and galaxies

1438
01:03:50,630 --> 01:03:47,460

this galaxy might just be lucky it

1439
01:03:52,100 --> 01:03:50,640
hasn't it's not quiescent as in a dozen

1440
01:03:54,230 --> 01:03:52,110
florrum stars all the blue stuff that

1441
01:03:59,420 --> 01:03:54,240
you see is new stars it's making new

1442
01:04:01,760 --> 01:03:59,430
stars alright it's just hasn't smashed

1443
01:04:04,300 --> 01:04:01,770
into anything but it even hasn't smashed

1444
01:04:08,720 --> 01:04:04,310
into anything small as far as I can tell

1445
01:04:10,460 --> 01:04:08,730
it hasn't gone and eaten something like

1446
01:04:12,170 --> 01:04:10,470
the Magellanic Clouds for example which

1447
01:04:14,420 --> 01:04:12,180
is what our Milky Way has done the Milky

1448
01:04:16,610 --> 01:04:14,430
Way has two major events in our it's

1449
01:04:19,160 --> 01:04:16,620
history already and it's a lot smaller

1450
01:04:22,430 --> 01:04:19,170
in the Miss galaxy it has the

1451
01:04:25,730 --> 01:04:22,440
Sagittarius stream which is a Magellanic

1452
01:04:28,010 --> 01:04:25,740
large running on a cloud size collision

1453
01:04:30,890 --> 01:04:28,020
and it has a Magellanic Clouds falling

1454
01:04:32,569 --> 01:04:30,900
in right now so it's got two of these

1455
01:04:35,960 --> 01:04:32,579
events happening and it as far as I can

1456
01:04:39,650 --> 01:04:35,970
tell this conscious is dodged all of it

1457
01:04:43,700 --> 01:04:39,660
okay well we have over 150 people

1458
01:04:45,859 --> 01:04:43,710
watching live so we have a bunch of

1459
01:04:47,120 --> 01:04:45,869
questions online and I haven't been able

1460
01:04:49,609 --> 01:04:47,130
to follow them while I'm listening to

1461
01:04:51,680 --> 01:04:49,619
you but grant justice has taken them so

1462
01:04:52,779 --> 01:04:51,690
grant give us some questions from our

1463
01:04:55,849 --> 01:04:52,789

audience

1464
01:04:57,620 --> 01:04:55,859
absolutely thank you everyone for tuning

1465
01:05:00,829 --> 01:04:57,630
in and I'll start off with some of the

1466
01:05:03,230 --> 01:05:00,839
easier ones and also the ones that we

1467
01:05:06,710 --> 01:05:03,240
get each time will Hubble continue its

1468
01:05:07,880 --> 01:05:06,720
mission after the launch of JWST and now

1469
01:05:11,299 --> 01:05:07,890
rst

1470
01:05:14,630 --> 01:05:11,309
Roman scope and what happens to Hubble

1471
01:05:17,750 --> 01:05:14,640
when its life is over okay so I'll take

1472
01:05:19,099 --> 01:05:17,760
that one because we Hansel and we answer

1473
01:05:22,519 --> 01:05:19,109
that every now and then at Space

1474
01:05:24,740 --> 01:05:22,529
Telescope so Hubble will continue as

1475
01:05:27,079 --> 01:05:24,750
long as it is producing cutting-edge

1476
01:05:30,140 --> 01:05:27,089
science okay Hubble has been up for 30

1477
01:05:31,970 --> 01:05:30,150
years yes but it is still producing

1478
01:05:35,150 --> 01:05:31,980
science that no other telescope can

1479
01:05:36,950 --> 01:05:35,160
produce and as long as that is true it's

1480
01:05:39,710 --> 01:05:36,960
really producer of producing quality

1481
01:05:42,950 --> 01:05:39,720
science I expect Hubble will probably be

1482
01:05:45,490 --> 01:05:42,960
funded to continue the James Webb Space

1483
01:05:49,370 --> 01:05:45,500
Telescope will be an infrared telescope

1484
01:05:52,130 --> 01:05:49,380
and the Rubin Space Telescope is also an

1485
01:05:53,809 --> 01:05:52,140
infrared survey telescope so neither one

1486
01:05:55,849 --> 01:05:53,819
of them will replace Hubble they will

1487
01:06:00,559 --> 01:05:55,859
complement Hubble in the science that

1488
01:06:02,510 --> 01:06:00,569

they do when Hubble does have say

1489
01:06:06,079 --> 01:06:02,520
battery failures or gyroscope failures

1490
01:06:08,750 --> 01:06:06,089
or electronic failures and is no longer

1491
01:06:10,309 --> 01:06:08,760
producing the cutting-edge science it

1492
01:06:14,539 --> 01:06:10,319
needs to produce for it to be continued

1493
01:06:16,370 --> 01:06:14,549
the current plan is to let it orbit it's

1494
01:06:18,609 --> 01:06:16,380
not it doesn't have any problems with

1495
01:06:21,650 --> 01:06:18,619
orbiting into well into the 2030s

1496
01:06:23,569 --> 01:06:21,660
timeframe there is a soft capture

1497
01:06:26,450 --> 01:06:23,579
mechanism on the bottom of Hubble so if

1498
01:06:28,400 --> 01:06:26,460
necessary we can fly a mission up grab

1499
01:06:30,980 --> 01:06:28,410
soft capture measurement mechanism and

1500
01:06:34,250 --> 01:06:30,990
do orbit huh but how that Hubble

1501
01:06:38,539 --> 01:06:34,260
carefully into the ocean okay

1502
01:06:40,849 --> 01:06:38,549
Hubble is too heavy to bring down in a

1503
01:06:42,769 --> 01:06:40,859
control like putting it into a future

1504
01:06:44,509 --> 01:06:42,779
space shock or something like that

1505
01:06:47,259 --> 01:06:44,519
and we can't let it just fall

1506
01:06:49,929 --> 01:06:47,269
willy-nilly so it would have to be

1507
01:06:52,219 --> 01:06:49,939
attempted to have a controlled descent

1508
01:06:54,679 --> 01:06:52,229
there of course others who want to just

1509
01:06:56,419 --> 01:06:54,689
move it up to a higher parking orbit and

1510
01:06:57,679 --> 01:06:56,429
let it sit there for decades until we

1511
01:06:59,269 --> 01:06:57,689
can figure out a great way to bring it

1512
01:07:01,669 --> 01:06:59,279
back down I mean everyone would love to

1513
01:07:04,669 --> 01:07:01,679

put it in the Smithsonian right it's

1514
01:07:08,449 --> 01:07:04,679
just kind of much too dangerous with the

1515
01:07:10,399 --> 01:07:08,459
current technology okay next gotcha okay

1516
01:07:12,829 --> 01:07:10,409
so let me take a look here and find our

1517
01:07:16,279 --> 01:07:12,839
next question all right

1518
01:07:20,229 --> 01:07:16,289
so how many billions of years does it

1519
01:07:23,779 --> 01:07:20,239
take to build a galaxy that big

1520
01:07:28,539 --> 01:07:23,789
something like the large spiral galaxy

1521
01:07:31,069 --> 01:07:28,549
that you have in the image behind us so

1522
01:07:34,249 --> 01:07:31,079
you take as long as you can so I think

1523
01:07:36,469 --> 01:07:34,259
that's you start right after the Big

1524
01:07:38,870 --> 01:07:36,479
Bang that's the thing that I quite love

1525
01:07:40,909 --> 01:07:38,880
about galaxy evolution something like a

1526
01:07:43,069 --> 01:07:40,919
few million years after the Big Bang

1527
01:07:46,059 --> 01:07:43,079
happens you see the first galaxies peak

1528
01:07:50,479 --> 01:07:46,069
up except that these are as big as

1529
01:07:52,699 --> 01:07:50,489
really some of the clumps of blue that

1530
01:07:54,499 --> 01:07:52,709
you see in this guy in this galaxy right

1531
01:07:56,929 --> 01:07:54,509
there oh they're tiny they're the little

1532
01:08:01,279 --> 01:07:56,939
seedlings that you grow a galaxy this

1533
01:08:03,309 --> 01:08:01,289
big from I think you need most of the

1534
01:08:05,839 --> 01:08:03,319
lifetime of the universe to build this

1535
01:08:10,669 --> 01:08:05,849
you got all that time please take it

1536
01:08:13,159 --> 01:08:10,679
right so 13 billion years it's got an

1537
01:08:15,199 --> 01:08:13,169
elven time for about 13 billion years I

1538
01:08:17,299 --> 01:08:15,209

think it's been actually but it's a slow

1539
01:08:20,689 --> 01:08:17,309
bake since everybody's baking right now

1540
01:08:23,029 --> 01:08:20,699
it's a slow bake because I think it has

1541
01:08:25,640 --> 01:08:23,039
slowly done this star formation about

1542
01:08:28,729 --> 01:08:25,650
you know half of solar mass so it's it

1543
01:08:34,249 --> 01:08:28,739
basically produces a Suns worth of new

1544
01:08:37,220 --> 01:08:34,259
stars every two years that is not the

1545
01:08:40,760 --> 01:08:37,230
world record in making new stars that's

1546
01:08:43,069 --> 01:08:40,770
many times that but it's been doing it

1547
01:08:45,620 --> 01:08:43,079
for a very long time and then you can

1548
01:08:49,039 --> 01:08:45,630
get there it probably was a little more

1549
01:08:51,169 --> 01:08:49,049
active in the early days but just by

1550
01:08:53,930 --> 01:08:51,179
having this big disk and just slowly

1551
01:08:56,390 --> 01:08:53,940
forming stars throughout you will build

1552
01:08:56,780 --> 01:08:56,400
a galaxy that big but yeah you need

1553
01:08:59,180 --> 01:08:56,790
probably

1554
01:09:03,860 --> 01:08:59,190
I need the whole age of the universe for

1555
01:09:06,380 --> 01:09:03,870
that all right and the next one we we

1556
01:09:09,110 --> 01:09:06,390
had a fun time in the comments talking

1557
01:09:13,880 --> 01:09:09,120
about space dust so I'll continue that

1558
01:09:16,340 --> 01:09:13,890
love on here could dark matter just be

1559
01:09:19,360 --> 01:09:16,350
some really really cold dust and gas

1560
01:09:21,980 --> 01:09:19,370
that spread out far away from the stars

1561
01:09:23,720 --> 01:09:21,990
yeah you'd hope that's the case at least

1562
01:09:26,000 --> 01:09:23,730
that certainly was the question but they

1563
01:09:28,789 --> 01:09:26,010

they asked me in 2000 when I started my

1564
01:09:30,650 --> 01:09:28,799
grats I started grad school so how much

1565
01:09:33,079 --> 01:09:30,660
dust is there in these disks and is it

1566
01:09:35,840 --> 01:09:33,089
enough to either hide enough stars and

1567
01:09:40,010 --> 01:09:35,850
then also have enough mass sitting in

1568
01:09:42,680 --> 01:09:40,020
its in itself to be to be the dark

1569
01:09:45,320 --> 01:09:42,690
matter there's two things wrong with it

1570
01:09:49,820 --> 01:09:45,330
we can kind of know how much dust there

1571
01:09:51,460 --> 01:09:49,830
is now we've really studied many spiral

1572
01:09:55,820 --> 01:09:51,470
galaxies and so we know what the average

1573
01:09:58,400 --> 01:09:55,830
dust masses are simply we did the

1574
01:10:01,670 --> 01:09:58,410
accounting we looked at how much light

1575
01:10:06,440 --> 01:10:01,680
was missing and this dust is very much

1576
01:10:08,960 --> 01:10:06,450
like smog unlike yeah if you look at the

1577
01:10:11,210 --> 01:10:08,970
sunset and it's like if you're in LA and

1578
01:10:16,280 --> 01:10:11,220
it's been a smoggy day you've got a red

1579
01:10:18,380 --> 01:10:16,290
sunset right and and so you know how

1580
01:10:20,210 --> 01:10:18,390
much how much color change you've got

1581
01:10:23,870 --> 01:10:20,220
from the stars you know how much you're

1582
01:10:28,070 --> 01:10:23,880
missing but also that dust radiates it

1583
01:10:31,280 --> 01:10:28,080
back out as infrared light and so you

1584
01:10:33,500 --> 01:10:31,290
need to make it very very cold and you

1585
01:10:35,330 --> 01:10:33,510
need to make it a very special kind of

1586
01:10:38,540 --> 01:10:35,340
dust I think the technical term is

1587
01:10:41,390 --> 01:10:38,550
cannonballs you need to make them very

1588
01:10:43,580 --> 01:10:41,400

dense very black and they're completely

1589
01:10:46,940 --> 01:10:43,590
away from all the stars so they don't do

1590
01:10:48,200 --> 01:10:46,950
much than have gravity and then

1591
01:10:51,440 --> 01:10:48,210
occasionally block a little bit of

1592
01:10:53,600 --> 01:10:51,450
starlight I don't know about you but

1593
01:10:57,650 --> 01:10:53,610
that sounds like dark matter to me and

1594
01:10:59,180 --> 01:10:57,660
so but that's the problem for that is

1595
01:11:02,390 --> 01:10:59,190
that basically you've got this magic

1596
01:11:05,000 --> 01:11:02,400
stuff that doesn't do anything else just

1597
01:11:07,040 --> 01:11:05,010
just gravity and the problem is that we

1598
01:11:09,140 --> 01:11:07,050
also know where the mass is because we

1599
01:11:10,490 --> 01:11:09,150
looked at the rotation curve and you can

1600
01:11:12,650 --> 01:11:10,500
see what the dust is in

1601
01:11:15,110 --> 01:11:12,660
Galaxy it's in the brighter parts of

1602
01:11:16,790 --> 01:11:15,120
this spiral and as you go further and

1603
01:11:19,010 --> 01:11:16,800
further out I will be the first to tell

1604
01:11:20,450 --> 01:11:19,020
you that yes those spiral arms also have

1605
01:11:24,380 --> 01:11:20,460
a little bit of dust in them

1606
01:11:26,620 --> 01:11:24,390
but that's not nearly enough to to

1607
01:11:29,570 --> 01:11:26,630
account for how fast it's rotating

1608
01:11:32,290 --> 01:11:29,580
because I kind of leads me into another

1609
01:11:34,760 --> 01:11:32,300
facet of this right

1610
01:11:36,410 --> 01:11:34,770
Ruben's explanation for how galaxies

1611
01:11:37,880 --> 01:11:36,420
have flat rotation is that there is

1612
01:11:42,080 --> 01:11:37,890
missing mass which is what you were just

1613
01:11:44,390 --> 01:11:42,090

touching on there which she called dark

1614
01:11:46,280 --> 01:11:44,400
matter but is there another way to

1615
01:11:48,500 --> 01:11:46,290
account for the observed strength of the

1616
01:11:50,570 --> 01:11:48,510
gravity other than mass is it possible

1617
01:11:54,080 --> 01:11:50,580
its energy is it possible it's something

1618
01:11:55,940 --> 01:11:54,090
else so or we know it's Matt it has to

1619
01:11:58,250 --> 01:11:55,950
be well it has the characteristics of

1620
01:12:00,830 --> 01:11:58,260
mass meaning that it's gravity it's got

1621
01:12:04,310 --> 01:12:00,840
a pull right it's got to pull this stuff

1622
01:12:06,350 --> 01:12:04,320
in and to keep it in its orbit energy

1623
01:12:08,840 --> 01:12:06,360
doesn't have a pull to it sorry we need

1624
01:12:14,990 --> 01:12:08,850
something that exerts good a good amount

1625
01:12:16,940 --> 01:12:15,000
of gravity so that's one bit you need

1626
01:12:18,560 --> 01:12:16,950
stuff to do

1627
01:12:20,030 --> 01:12:18,570
Benny can I just jump in here second

1628
01:12:22,450 --> 01:12:20,040
yeah just to make sure our questioner

1629
01:12:25,910 --> 01:12:22,460
understands that gravity is a force

1630
01:12:28,580 --> 01:12:25,920
derived from mass you're not getting

1631
01:12:30,320 --> 01:12:28,590
gravity from I mean it you get the

1632
01:12:32,330 --> 01:12:30,330
electromagnetic force from charged

1633
01:12:34,580 --> 01:12:32,340
particles everything gravity is defined

1634
01:12:38,330 --> 01:12:34,590
as force so if you're seeing evidence of

1635
01:12:40,310 --> 01:12:38,340
gravity you're seeing evidence of mass I

1636
01:12:41,750 --> 01:12:40,320
think they're trying to say is there

1637
01:12:45,710 --> 01:12:41,760
something something else that could

1638
01:12:47,240 --> 01:12:45,720

cause these flat rotation curves I do

1639
01:12:49,850 --> 01:12:47,250
can't formulate it in terms of gravity

1640
01:12:51,740 --> 01:12:49,860
without being massive right right it has

1641
01:12:53,420 --> 01:12:51,750
to be if you say it's gravity there's

1642
01:12:56,360 --> 01:12:53,430
two more things you either have missing

1643
01:12:59,420 --> 01:12:56,370
mass or and that's always a good thing

1644
01:13:01,970 --> 01:12:59,430
to check you don't understand gravity as

1645
01:13:03,560 --> 01:13:01,980
well as you thought you did and so as

1646
01:13:07,460 --> 01:13:03,570
soon as those flat rotation curves came

1647
01:13:09,170 --> 01:13:07,470
out one of the explanation was that well

1648
01:13:12,710 --> 01:13:09,180
we know how gravity works on the solar

1649
01:13:15,290 --> 01:13:12,720
system incredibly well and to the thanks

1650
01:13:19,490 --> 01:13:15,300
to Newton and later Einstein we know how

1651
01:13:21,380 --> 01:13:19,500
it works next to big heavy rantings but

1652
01:13:21,890 --> 01:13:21,390
maybe we don't know what it worked how

1653
01:13:24,779 --> 01:13:21,900
it works

1654
01:13:27,809 --> 01:13:24,789
on really large scales so

1655
01:13:30,179 --> 01:13:27,819
maybe all the galactic scale we're sort

1656
01:13:33,929 --> 01:13:30,189
of missing something and so people have

1657
01:13:36,089 --> 01:13:33,939
been putting this theory forward as like

1658
01:13:38,939 --> 01:13:36,099
well you should always check whether or

1659
01:13:41,779 --> 01:13:38,949
not we understand gravity this well on

1660
01:13:44,759 --> 01:13:41,789
these scales however we have some

1661
01:13:46,619 --> 01:13:44,769
confirmation that galaxies do have a lot

1662
01:13:50,849 --> 01:13:46,629
of stuff in them from something called

1663
01:13:53,179 --> 01:13:50,859

gravitational lensing and this this

1664
01:13:57,239 --> 01:13:53,189
alternative theory called modified

1665
01:13:59,429 --> 01:13:57,249
Newtonian dynamics long does have a

1666
01:14:01,949 --> 01:13:59,439
little bit of trouble making those big

1667
01:14:04,319 --> 01:14:01,959
structures of galaxies and so you need a

1668
01:14:08,489 --> 01:14:04,329
lot of gravity in order to pull

1669
01:14:10,829 --> 01:14:08,499
everything together and so mom hasn't

1670
01:14:12,299 --> 01:14:10,839
been ruled out right so that's that's

1671
01:14:13,739 --> 01:14:12,309
something that I want to be very clear

1672
01:14:16,469 --> 01:14:13,749
about and I think it's incredibly

1673
01:14:18,239 --> 01:14:16,479
healthy to just check your work whether

1674
01:14:21,629 --> 01:14:18,249
or not you understand the gravity or not

1675
01:14:24,479 --> 01:14:21,639
so yeah curious to see how that plays

1676
01:14:27,839 --> 01:14:24,489
out and Ben had add in that those

1677
01:14:29,309 --> 01:14:27,849
computer simulations you showed a lot of

1678
01:14:31,259 --> 01:14:29,319
those computer simulations are very

1679
01:14:33,299 --> 01:14:31,269
successful at producing the observed

1680
01:14:35,759 --> 01:14:33,309
characteristics of gravity and those

1681
01:14:39,359 --> 01:14:35,769
simulations in have inherent in them the

1682
01:14:41,699 --> 01:14:39,369
assumption that dark matter is mass and

1683
01:14:43,799 --> 01:14:41,709
such so we have a very strong

1684
01:14:46,229 --> 01:14:43,809
consistency argument for the dark matter

1685
01:14:49,169 --> 01:14:46,239
up there all right grant got another

1686
01:14:51,569 --> 01:14:49,179
question I do I just want to take one

1687
01:14:53,549 --> 01:14:51,579
minute to say that that would mean that

1688
01:14:58,079 --> 01:14:53,559

they are made out of star stuff wouldn't

1689
01:15:00,959 --> 01:14:58,089
it been a I couldn't resist I'm sorry

1690
01:15:04,889 --> 01:15:00,969
alright I have two quick ones and I

1691
01:15:07,919 --> 01:15:04,899
think we will call it a stream our most

1692
01:15:11,099 --> 01:15:07,929
galaxies dwarf and what is the average

1693
01:15:14,489 --> 01:15:11,109
size of galaxies based on star masses to

1694
01:15:17,759 --> 01:15:14,499
your best knowledge to the off the top

1695
01:15:22,229 --> 01:15:17,769
of my head yes so observable galaxies of

1696
01:15:23,789 --> 01:15:22,239
course right so we have a in I keep

1697
01:15:25,589 --> 01:15:23,799
telling my students this if you're an

1698
01:15:27,569 --> 01:15:25,599
astronomer you're going to see what

1699
01:15:30,779 --> 01:15:27,579
you're gonna see and you're gonna miss

1700
01:15:34,259 --> 01:15:30,789
what you're gonna miss and so small

1701
01:15:36,449 --> 01:15:34,269
galaxies are easy to miss but there are

1702
01:15:38,459 --> 01:15:36,459
a lot of them and so you can only see

1703
01:15:40,890 --> 01:15:38,469
them in a very small volume

1704
01:15:42,689 --> 01:15:40,900
could only see them very nearby but they

1705
01:15:45,540 --> 01:15:42,699
seem to be very very common but some big

1706
01:15:48,060 --> 01:15:45,550
guys like this this one you can see them

1707
01:15:51,330 --> 01:15:48,070
too much further away so if you just

1708
01:15:53,430 --> 01:15:51,340
take your you know you just count

1709
01:15:56,609 --> 01:15:53,440
whatever you've got on the sky and you

1710
01:15:58,649 --> 01:15:56,619
take that at face value you've over

1711
01:16:00,750 --> 01:15:58,659
counted big things like this completely

1712
01:16:04,529 --> 01:16:00,760
and so you said go like home

1713
01:16:06,959 --> 01:16:04,539

monsters are everywhere but that's not

1714
01:16:11,310 --> 01:16:06,969
the case you've just missed all the

1715
01:16:16,919 --> 01:16:11,320
little things and and so small galaxies

1716
01:16:20,279 --> 01:16:16,929
if about billion yeah a billion to about

1717
01:16:21,839 --> 01:16:20,289
ten billion solar masses that's the most

1718
01:16:23,819 --> 01:16:21,849
common galaxies those are the most

1719
01:16:25,770 --> 01:16:23,829
common galaxies in their universe they

1720
01:16:27,239 --> 01:16:25,780
are everywhere but they are the first

1721
01:16:28,620 --> 01:16:27,249
things that drop out of your survey

1722
01:16:30,239 --> 01:16:28,630
they're the first things if you start

1723
01:16:32,040 --> 01:16:30,249
staring like you pick up you're like oh

1724
01:16:34,370 --> 01:16:32,050
there's all the little dwarf galaxies

1725
01:16:38,069 --> 01:16:34,380
there they are so they're quite common

1726
01:16:42,290 --> 01:16:38,079
excuse people a sense of scale what

1727
01:16:44,910 --> 01:16:42,300
would that be in relation to the skies

1728
01:16:46,379 --> 01:16:44,920
so we're gonna add warf galaxies the

1729
01:16:48,629 --> 01:16:46,389
most common what would be a benchmark

1730
01:16:50,910 --> 01:16:48,639
for the audience well if you look at

1731
01:16:53,759 --> 01:16:50,920
this picture so got the picture up you

1732
01:16:55,529 --> 01:16:53,769
should look at one of these blue clumps

1733
01:16:57,540 --> 01:16:55,539
on the outskirts you can see one right

1734
01:16:59,239 --> 01:16:57,550
you see that diffraction spike you see

1735
01:17:03,509 --> 01:16:59,249
something right underneath there that's

1736
01:17:06,330 --> 01:17:03,519
a dwarf galaxy this thing is like that

1737
01:17:07,830 --> 01:17:06,340
would be the size of a dwarf galaxy but

1738
01:17:09,660 --> 01:17:07,840

that's not what a dwarf galaxy looks

1739
01:17:12,229 --> 01:17:09,670
like that's clearly part of the spiral

1740
01:17:14,640 --> 01:17:12,239
structure of this whole thing but yeah

1741
01:17:18,989 --> 01:17:14,650
it gives an idea of the sense of scale

1742
01:17:21,419 --> 01:17:18,999
they are much smaller it's worse yeah

1743
01:17:22,950 --> 01:17:21,429
and you know using the numbers that you

1744
01:17:26,040 --> 01:17:22,960
provided if this is a trillion solar

1745
01:17:27,660 --> 01:17:26,050
masses and a typical galaxy is a billion

1746
01:17:30,509 --> 01:17:27,670
solar mass that's one one thousandth the

1747
01:17:31,950 --> 01:17:30,519
size of this galaxy you know so and

1748
01:17:33,270 --> 01:17:31,960
that's just in the stellar mass that

1749
01:17:35,669 --> 01:17:33,280
doesn't include the dark matter on it

1750
01:17:38,489 --> 01:17:35,679
and it there so that gives you some

1751
01:17:39,750 --> 01:17:38,499
numbers also in the local group of

1752
01:17:43,350 --> 01:17:39,760
galaxies we have about three dozen

1753
01:17:46,020 --> 01:17:43,360
galaxies only three of those are big

1754
01:17:49,709 --> 01:17:46,030
galaxies the Andromeda the Milky Way and

1755
01:17:52,649 --> 01:17:49,719
m33 the rest are these small galaxies so

1756
01:17:56,779 --> 01:17:52,659
even locally the the dwarfs have

1757
01:17:59,879 --> 01:17:56,789
inherited the universe mile and slide

1758
01:18:01,609 --> 01:17:59,889
all right and the last question one of

1759
01:18:04,379 --> 01:18:01,619
the things that you noted was that

1760
01:18:06,989 --> 01:18:04,389
globular clusters have a tendency to

1761
01:18:10,890 --> 01:18:06,999
stay together in this almost spherical

1762
01:18:13,560 --> 01:18:10,900
pattern do they break apart when they

1763
01:18:15,450 --> 01:18:13,570

are devoured by another body or when

1764
01:18:18,540 --> 01:18:15,460
they interact with other galaxies or do

1765
01:18:20,370 --> 01:18:18,550
they tend to keep their cohesion they

1766
01:18:22,680 --> 01:18:20,380
tend to keep they tend to stick around

1767
01:18:24,959 --> 01:18:22,690
and the reason for that is not because

1768
01:18:27,479 --> 01:18:24,969
of dark matter they are just a really

1769
01:18:31,770 --> 01:18:27,489
dense grouping of stars so they kind of

1770
01:18:34,859 --> 01:18:31,780
stick together based on that so while

1771
01:18:37,290 --> 01:18:34,869
the the more extended galaxy is tidally

1772
01:18:39,629 --> 01:18:37,300
stripped and into these streams the

1773
01:18:41,250 --> 01:18:39,639
globular clusters themselves stay stick

1774
01:18:44,910 --> 01:18:41,260
around let's start orbiting the bigger

1775
01:18:48,660 --> 01:18:44,920
galaxies so you tend to find the globe

1776
01:18:50,489 --> 01:18:48,670
of the clusters long after the the

1777
01:18:53,729 --> 01:18:50,499
parent galaxy has been shredded by the

1778
01:18:57,359 --> 01:18:53,739
body encounter and not only that we've

1779
01:18:58,890 --> 01:18:57,369
actually seen some strings of globular

1780
01:19:00,810 --> 01:18:58,900
clusters that clearly have a different

1781
01:19:03,959 --> 01:19:00,820
color than the rest of them and so they

1782
01:19:05,129 --> 01:19:03,969
must have come from another galaxy and

1783
01:19:07,859 --> 01:19:05,139
they serve a fault they're still

1784
01:19:10,739 --> 01:19:07,869
following the old galaxies orbit but

1785
01:19:12,959 --> 01:19:10,749
they they definitely seemed to survive

1786
01:19:17,850 --> 01:19:12,969
pretty well they survived our own Milky

1787
01:19:20,310 --> 01:19:17,860
Way for a few billion years so yeah all

1788
01:19:22,709 --> 01:19:20,320

right well thank you Benny thank you

1789
01:19:24,870 --> 01:19:22,719
grant for providing the questions and

1790
01:19:28,109 --> 01:19:24,880
thank you to our audience for showing up

1791
01:19:29,819 --> 01:19:28,119
this was our very first online only

1792
01:19:32,100 --> 01:19:29,829
public lecture series we were doing them

1793
01:19:34,680 --> 01:19:32,110
again every month we're gonna try and

1794
01:19:39,330 --> 01:19:34,690
keep to the first Tuesday of the month

1795
01:19:41,189 --> 01:19:39,340
us date but we'll have to figure out

1796
01:19:43,859 --> 01:19:41,199
whether or not it works out doing that

1797
01:19:46,379 --> 01:19:43,869
like this in the afternoon or if it

1798
01:19:49,529 --> 01:19:46,389
might work better if we do it

1799
01:19:53,819 --> 01:19:49,539
back at the APM in the evening well

1800
01:19:56,489 --> 01:19:53,829
probably survey the folks on our email

1801
01:19:59,399 --> 01:19:56,499
list to find out about that next month

1802
01:20:01,799 --> 01:19:59,409
again interstellar comets by am i

1803
01:20:03,419 --> 01:20:01,809
immoral martin going to be a cool talk

1804
01:20:05,399 --> 01:20:03,429
let us give one more