

1  
00:00:00,030 --> 00:00:04,080  
good evening ladies and gentlemen and

2  
00:00:02,279 --> 00:00:06,568  
welcome to the Space Telescope Science

3  
00:00:04,080 --> 00:00:08,309  
Institute I'm your host dr. Frank

4  
00:00:06,569 --> 00:00:12,150  
summers and it is my pleasure to welcome

5  
00:00:08,308 --> 00:00:14,548  
you for our public lecture series when

6  
00:00:12,150 --> 00:00:16,469  
you came in I hope that you are

7  
00:00:14,548 --> 00:00:19,379  
accustomed now to getting pretty

8  
00:00:16,469 --> 00:00:21,379  
pictures either on that table or I got

9  
00:00:19,379 --> 00:00:24,028  
smart I put them on this side as well so

10  
00:00:21,379 --> 00:00:26,820  
tonight's pretty picture that we have is

11  
00:00:24,028 --> 00:00:29,460  
the core of the globular cluster omega

12  
00:00:26,820 --> 00:00:30,689  
centauri if that doesn't make any sense

13  
00:00:29,460 --> 00:00:32,460  
to you turnover

14  
00:00:30,689 --> 00:00:34,649  
there are a few hundred words to explain

15  
00:00:32,460 --> 00:00:37,320  
it on the back and if you want to know

16  
00:00:34,649 --> 00:00:40,379  
even more tom says he's going to be

17  
00:00:37,320 --> 00:00:42,359  
featuring this in part of his talk

18  
00:00:40,378 --> 00:00:46,289  
tonight you didn't get it on your way in

19  
00:00:42,359 --> 00:00:48,750  
please grab one on the way out our talk

20  
00:00:46,289 --> 00:00:50,850  
tonight is on the trail of the missing

21  
00:00:48,750 --> 00:00:54,988  
galaxies the oldest stars in the

22  
00:00:50,850 --> 00:00:57,600  
neighborhood by Tom Brown coming up next

23  
00:00:54,988 --> 00:01:00,448  
month we have a multi-wavelength view of

24  
00:00:57,600 --> 00:01:03,660  
stellar life in death in the galaxy

25  
00:01:00,448 --> 00:01:05,569  
Messier 83 by Bill Blair who's from

26  
00:01:03,659 --> 00:01:08,429  
across the street at Johns Hopkins

27  
00:01:05,569 --> 00:01:11,819  
November first we have the infinite the

28  
00:01:08,430 --> 00:01:14,100  
infamous TBA which means I'm trying to

29

00:01:11,819 --> 00:01:15,688  
get somebody to talk I was hoping

30  
00:01:14,099 --> 00:01:17,849  
somebody will come in and do a talk like

31  
00:01:15,688 --> 00:01:21,298  
make the universe great again right

32  
00:01:17,849 --> 00:01:23,250  
because of course this is one week

33  
00:01:21,299 --> 00:01:25,890  
before Election Day it's not election

34  
00:01:23,250 --> 00:01:27,599  
night usually in election years my

35  
00:01:25,890 --> 00:01:29,879  
November talk has to be pushed back a

36  
00:01:27,599 --> 00:01:33,750  
week here it's just fine because

37  
00:01:29,879 --> 00:01:37,109  
election is actually on November 8th on

38  
00:01:33,750 --> 00:01:39,060  
December 6 the talk is to be a to be

39  
00:01:37,109 --> 00:01:41,459  
decided upon but the speaker is

40  
00:01:39,060 --> 00:01:42,750  
Christine Chen who will be giving she's

41  
00:01:41,459 --> 00:01:45,478  
given a talk here before she does

42  
00:01:42,750 --> 00:01:48,259  
wonderful talks she just hasn't told me

43  
00:01:45,478 --> 00:01:52,019

what she's going to talk about this time

44

00:01:48,259 --> 00:01:53,549

hahaha or one of our one of our one of

45

00:01:52,019 --> 00:01:55,408

the campaign surrogates can go and give

46

00:01:53,549 --> 00:01:57,868

the November first talk I'm sure this is

47

00:01:55,409 --> 00:01:59,640

a very coveted audience yeah Maryland it

48

00:01:57,868 --> 00:02:07,079

Maryland is a state that could go either

49

00:01:59,640 --> 00:02:08,909

way right all right construction update

50

00:02:07,078 --> 00:02:12,568

and there really is an update this month

51

00:02:08,909 --> 00:02:13,740

okay it has been closed this is phase 1

52

00:02:12,568 --> 00:02:17,489

has been closed since

53

00:02:13,740 --> 00:02:20,700

of 2016 however next week

54

00:02:17,490 --> 00:02:22,560

phase two and phase three at the north

55

00:02:20,699 --> 00:02:25,829

and south ends the project will begin on

56

00:02:22,560 --> 00:02:27,810

Monday September 12th okay so this is

57

00:02:25,830 --> 00:02:29,370

the last public lecture series of this

58  
00:02:27,810 --> 00:02:31,530  
year that you could approach from the

59  
00:02:29,370 --> 00:02:33,900  
north you'll now have to approach from

60  
00:02:31,530 --> 00:02:37,229  
the south let me show you the map okay

61  
00:02:33,900 --> 00:02:39,539  
so you see this blue area here this is

62  
00:02:37,229 --> 00:02:41,189  
what's currently under construction that

63  
00:02:39,539 --> 00:02:45,900  
will stop being under construction

64  
00:02:41,189 --> 00:02:49,289  
as of next Monday okay then the part in

65  
00:02:45,900 --> 00:02:51,360  
red up here from our building here up to

66  
00:02:49,289 --> 00:02:54,419  
the north up up to University Parkway

67  
00:02:51,360 --> 00:02:56,640  
and down here in yellow along Wyman Park

68  
00:02:54,419 --> 00:03:00,869  
Drive those will be closed from

69  
00:02:56,639 --> 00:03:03,000  
September to December okay so next month

70  
00:03:00,870 --> 00:03:03,569  
in October when you come to the lecture

71  
00:03:03,000 --> 00:03:07,740  
series

72  
00:03:03,569 --> 00:03:10,019  
you must come via the South Gate into

73  
00:03:07,740 --> 00:03:12,810  
johns hopkins come up Weinman park drive

74  
00:03:10,020 --> 00:03:15,000  
to get to us here you cannot approach by

75  
00:03:12,810 --> 00:03:16,949  
a University Parkway this will all be

76  
00:03:15,000 --> 00:03:20,430  
closed through tool for the rest of this

77  
00:03:16,949 --> 00:03:25,469  
year okay if you need to know more about

78  
00:03:20,430 --> 00:03:27,150  
it here is the website I don't know have

79  
00:03:25,469 --> 00:03:29,069  
a way to memorize that just look for the

80  
00:03:27,150 --> 00:03:32,760  
San Martin project on the Johns Hopkins

81  
00:03:29,069 --> 00:03:34,859  
University website okay so next month

82  
00:03:32,759 --> 00:03:38,239  
north of st 2sc i will be closed

83  
00:03:34,860 --> 00:03:40,860  
approach STScI from the south all right

84  
00:03:38,240 --> 00:03:44,520  
hopefully I will see you all here next

85  
00:03:40,860 --> 00:03:47,550  
next month and you won't get lost our

86

00:03:44,520 --> 00:03:51,150  
website if you need to check on things

87  
00:03:47,550 --> 00:03:53,670  
we have you can do our Hubbell site go

88  
00:03:51,150 --> 00:03:55,319  
tox link or just use your favorite

89  
00:03:53,669 --> 00:03:57,929  
search engine look for Hubble public

90  
00:03:55,319 --> 00:04:01,109  
talks you'll find this you have a list

91  
00:03:57,930 --> 00:04:03,780  
of the upcoming lectures you can watch

92  
00:04:01,110 --> 00:04:05,460  
the links to the live online webcasting

93  
00:04:03,780 --> 00:04:07,860  
from both on YouTube and SD s CI

94  
00:04:05,460 --> 00:04:11,400  
webcasting you can watch our past

95  
00:04:07,860 --> 00:04:13,110  
lectures all the way back to 2005 these

96  
00:04:11,400 --> 00:04:14,909  
wonderful folks have been webcasting it

97  
00:04:13,110 --> 00:04:17,129  
so there's lots of stuff and you can

98  
00:04:14,909 --> 00:04:19,379  
sign up for our public lecture series

99  
00:04:17,129 --> 00:04:21,659  
announcements a couple times a month we

100  
00:04:19,379 --> 00:04:23,730

send out reminders of what's up and we

101

00:04:21,660 --> 00:04:25,860

tell you where the webcasts are posted

102

00:04:23,730 --> 00:04:27,150

if you want to see that a lecture that

103

00:04:25,860 --> 00:04:29,669

you missed

104

00:04:27,149 --> 00:04:32,069

um these are the announcements you can

105

00:04:29,668 --> 00:04:34,019

sign up at mail list at STScI to ddu

106

00:04:32,069 --> 00:04:36,389

it's easier to go to our web page

107

00:04:34,019 --> 00:04:38,339

actually we've gotten a ton of signups

108

00:04:36,389 --> 00:04:41,310

from our web page so that's probably the

109

00:04:38,339 --> 00:04:43,349

best thing to do if you need to if you

110

00:04:41,310 --> 00:04:44,728

would like to have a question i tom says

111

00:04:43,350 --> 00:04:46,949

something absolutely brilliant you want

112

00:04:44,728 --> 00:04:50,219

to ask him another question send it to

113

00:04:46,949 --> 00:04:52,259

public lecture at STScI to edu give us

114

00:04:50,220 --> 00:04:53,669

your comment and yet another way you

115  
00:04:52,259 --> 00:04:57,240  
could even sign up for the announcements

116  
00:04:53,668 --> 00:05:00,000  
alright on social media Hubble has

117  
00:04:57,240 --> 00:05:02,668  
Facebook to Twitter accounts it's on

118  
00:05:00,000 --> 00:05:04,168  
Google+ it's on Pinterest and maybe on a

119  
00:05:02,668 --> 00:05:07,500  
couple other places that I don't know

120  
00:05:04,168 --> 00:05:10,469  
about I myself am on Facebook Google+

121  
00:05:07,500 --> 00:05:13,019  
and Twitter when I have time I don't do

122  
00:05:10,470 --> 00:05:16,289  
a heck of a lot of social media but I

123  
00:05:13,019 --> 00:05:18,870  
try to do a couple times a week uh there

124  
00:05:16,288 --> 00:05:21,418  
will not be an observatory tonight it

125  
00:05:18,870 --> 00:05:22,978  
probably is clear enough but the person

126  
00:05:21,418 --> 00:05:25,918  
running the observatory technician is

127  
00:05:22,978 --> 00:05:28,019  
out of town at the time okay so you will

128  
00:05:25,918 --> 00:05:30,269  
not have a Observatory but for those of

129  
00:05:28,019 --> 00:05:32,370  
you who are new usually after the

130  
00:05:30,269 --> 00:05:34,409  
lecture someone from the Maryland Space

131  
00:05:32,370 --> 00:05:35,579  
Grant observatory comes and will take

132  
00:05:34,410 --> 00:05:38,939  
you across the street to do some

133  
00:05:35,579 --> 00:05:42,649  
observing they do have a website MD

134  
00:05:38,939 --> 00:05:45,839  
space grant o RG and I believe they do

135  
00:05:42,649 --> 00:05:47,969  
open nights at the telescope every

136  
00:05:45,839 --> 00:05:49,560  
mostly every Friday okay so check their

137  
00:05:47,970 --> 00:05:51,090  
website to find out when their next

138  
00:05:49,560 --> 00:05:52,759  
observing session is because

139  
00:05:51,089 --> 00:05:56,098  
unfortunately we won't have it tonight

140  
00:05:52,759 --> 00:05:59,120  
okay now my favorite part of the night

141  
00:05:56,098 --> 00:06:03,689  
news from the universe for September

142  
00:05:59,120 --> 00:06:07,800  
2016 now everybody knows that August is

143

00:06:03,689 --> 00:06:11,069  
a slow news month right not this month

144  
00:06:07,800 --> 00:06:12,870  
not for astronomy we had so much that I

145  
00:06:11,069 --> 00:06:14,668  
actually had to cut down so there's a

146  
00:06:12,870 --> 00:06:16,978  
bunch of cool news that I'm not going to

147  
00:06:14,668 --> 00:06:18,389  
get to tonight okay so let me just go

148  
00:06:16,978 --> 00:06:21,870  
through what I do have relatively

149  
00:06:18,389 --> 00:06:25,889  
quickly my top story or I guess I should

150  
00:06:21,870 --> 00:06:29,550  
say my top nan story is from curious to

151  
00:06:25,889 --> 00:06:32,038  
spurious I am talking about a something

152  
00:06:29,550 --> 00:06:34,259  
I noticed on Saturday August 27th an

153  
00:06:32,038 --> 00:06:38,579  
interesting set it SETI candidate in

154  
00:06:34,259 --> 00:06:40,769  
Hercules this was on a I noticed this on

155  
00:06:38,579 --> 00:06:42,959  
social media and that was

156  
00:06:40,769 --> 00:06:46,049  
to comment that there was a signal in

157  
00:06:42,959 --> 00:06:49,799

the direction of the star HD 164 five

158

00:06:46,050 --> 00:06:53,129

nine five and that star is known to have

159

00:06:49,800 --> 00:06:55,439

an extrasolar planet around it okay and

160

00:06:53,129 --> 00:06:58,229

it came from the Ratan 600 radio

161

00:06:55,439 --> 00:07:03,870

telescope in some unpronounceable place

162

00:06:58,228 --> 00:07:07,288

in Russia okay um and so here is the

163

00:07:03,870 --> 00:07:09,478

signal that was published that you can

164

00:07:07,288 --> 00:07:13,288

see that the pink line is the actual

165

00:07:09,478 --> 00:07:17,098

signal and the green line is a fit for a

166

00:07:13,288 --> 00:07:21,478

point source located in the position of

167

00:07:17,098 --> 00:07:23,908

HD one six four five nine five so the

168

00:07:21,478 --> 00:07:26,818

conclusion of this article was not that

169

00:07:23,908 --> 00:07:30,478

oh my god we found aliens but it was

170

00:07:26,819 --> 00:07:34,098

rather softly stated the signal is

171

00:07:30,478 --> 00:07:38,459

interesting and merits further scrutiny

172  
00:07:34,098 --> 00:07:42,449  
however once the internet gets hold of

173  
00:07:38,459 --> 00:07:43,519  
it what do we get we get this SETI is

174  
00:07:42,449 --> 00:07:45,360  
investigating a possible

175  
00:07:43,519 --> 00:07:48,478  
extraterrestrial signal from deep space

176  
00:07:45,360 --> 00:07:52,259  
a strong signal that may originate from

177  
00:07:48,478 --> 00:07:57,120  
a sun-like star aliens sunlight being

178  
00:07:52,259 --> 00:07:59,180  
verified by SETI now okay so and it got

179  
00:07:57,120 --> 00:08:01,860  
off into all sorts of interesting

180  
00:07:59,180 --> 00:08:03,598  
conversations about extraterrestrial

181  
00:08:01,860 --> 00:08:05,550  
civilizations that have built a Dyson

182  
00:08:03,598 --> 00:08:08,038  
Sphere around their star and are

183  
00:08:05,550 --> 00:08:10,168  
capturing all the light from That star

184  
00:08:08,038 --> 00:08:12,089  
and for some reason then beaming all

185  
00:08:10,168 --> 00:08:13,978  
that energy right back out into space

186  
00:08:12,089 --> 00:08:17,098  
I'm not sure exactly why you would do

187  
00:08:13,978 --> 00:08:19,800  
that um I got home Monday night and my

188  
00:08:17,098 --> 00:08:22,978  
wife started telling me about an

189  
00:08:19,800 --> 00:08:25,408  
astronomy discovery my friends on

190  
00:08:22,978 --> 00:08:27,000  
Facebook my high school friends who I'm

191  
00:08:25,408 --> 00:08:28,319  
friends with on Facebook they always

192  
00:08:27,000 --> 00:08:29,339  
start to tag me whenever they see

193  
00:08:28,319 --> 00:08:32,700  
something interesting say Frank

194  
00:08:29,339 --> 00:08:35,038  
explained and explained so I had to kick

195  
00:08:32,700 --> 00:08:36,750  
in and I put up something a little less

196  
00:08:35,038 --> 00:08:38,490  
glamorous that said something like a

197  
00:08:36,750 --> 00:08:41,700  
single worth investigating but it's

198  
00:08:38,490 --> 00:08:43,168  
probably not aliens I wrote about ten or

199  
00:08:41,700 --> 00:08:45,089  
twelve paragraphs about it on my

200

00:08:43,168 --> 00:08:46,350  
Facebook page so that I get explained to

201  
00:08:45,089 --> 00:08:48,320  
people well you know here's what's

202  
00:08:46,350 --> 00:08:51,990  
really going on

203  
00:08:48,320 --> 00:08:53,250  
meanwhile the folks who are actually

204  
00:08:51,990 --> 00:08:54,419  
going to follow up this investigation

205  
00:08:53,250 --> 00:08:57,958  
we're due

206  
00:08:54,419 --> 00:09:00,870  
to follow up this is the SETI folks here

207  
00:08:57,958 --> 00:09:02,549  
in the United States and this is their

208  
00:09:00,870 --> 00:09:05,399  
webpage that they put up to talk about

209  
00:09:02,549 --> 00:09:06,719  
this solar system 94 light-years away as

210  
00:09:05,399 --> 00:09:09,450  
a possible candidate

211  
00:09:06,720 --> 00:09:12,300  
well they immediately started turning

212  
00:09:09,450 --> 00:09:14,459  
their telescopes on to this star looking

213  
00:09:12,299 --> 00:09:17,039  
for something and they had ten times

214  
00:09:14,458 --> 00:09:19,109

better sensitivity and they didn't find

215

00:09:17,039 --> 00:09:23,789

anything so they were pretty doubtful

216

00:09:19,110 --> 00:09:25,470

and then two days later on August 31st a

217

00:09:23,789 --> 00:09:28,230

press release came out from the Russian

218

00:09:25,470 --> 00:09:29,970

news agency Tass that said an additional

219

00:09:28,230 --> 00:09:32,278

check showed that it was emanating from

220

00:09:29,970 --> 00:09:36,560

a Soviet military satellite which had

221

00:09:32,278 --> 00:09:40,169

not be entered into any of the catalogs

222

00:09:36,559 --> 00:09:41,879

now we look at this we say Oh everyone's

223

00:09:40,169 --> 00:09:42,389

yo-yo everyone's making a big fuss over

224

00:09:41,879 --> 00:09:46,399

nothing

225

00:09:42,389 --> 00:09:48,269

um but this is how science is done okay

226

00:09:46,399 --> 00:09:50,129

astronomers who find something

227

00:09:48,269 --> 00:09:52,589

interesting and don't have enough

228

00:09:50,129 --> 00:09:55,049

sensitivity to really check it out tell

229  
00:09:52,589 --> 00:09:56,519  
others about it and then those go in and

230  
00:09:55,049 --> 00:09:58,319  
check it and see mmm and they

231  
00:09:56,519 --> 00:09:59,879  
cross-check it it has to be observed by

232  
00:09:58,320 --> 00:10:01,528  
multiple people using multiple

233  
00:09:59,879 --> 00:10:03,929  
instruments in order for people to

234  
00:10:01,528 --> 00:10:05,970  
really take it seriously so the science

235  
00:10:03,929 --> 00:10:07,889  
was done right because they said look

236  
00:10:05,970 --> 00:10:08,940  
we're not claiming extraterrestrials

237  
00:10:07,889 --> 00:10:09,480  
here we're just saying this is

238  
00:10:08,940 --> 00:10:11,790  
interesting

239  
00:10:09,480 --> 00:10:14,399  
somebody please follow up and the follow

240  
00:10:11,789 --> 00:10:17,189  
ups showed you oh sorry it isn't

241  
00:10:14,399 --> 00:10:21,179  
actually interesting okay however in the

242  
00:10:17,190 --> 00:10:24,260  
Internet age we have a moral to to go by

243  
00:10:21,179 --> 00:10:26,849  
here and the moral of the story is

244  
00:10:24,259 --> 00:10:29,909  
scientists must strive not to cry wolf

245  
00:10:26,850 --> 00:10:35,790  
because that's the job of the internet

246  
00:10:29,909 --> 00:10:38,370  
okay all right our second story we're

247  
00:10:35,789 --> 00:10:40,889  
doing to do some interplanetary mission

248  
00:10:38,370 --> 00:10:44,399  
updates the first update comes from the

249  
00:10:40,889 --> 00:10:46,500  
Juno mission to Jupiter and if you're

250  
00:10:44,399 --> 00:10:48,509  
here in July I told you about the Juno

251  
00:10:46,500 --> 00:10:50,909  
mission inserting itself into orbit

252  
00:10:48,509 --> 00:10:52,740  
around Jupiter the beginning of the Juno

253  
00:10:50,909 --> 00:10:54,568  
mission and the fact that it's going to

254  
00:10:52,740 --> 00:10:56,250  
go into this very tight orbit and go

255  
00:10:54,568 --> 00:10:58,278  
very far away and it's going to sample

256  
00:10:56,250 --> 00:11:01,948  
the full range of the magnetic field

257

00:10:58,278 --> 00:11:04,850  
well it's on a very long orbit initially

258  
00:11:01,948 --> 00:11:08,370  
and it just got back for its first pass

259  
00:11:04,850 --> 00:11:10,860  
so in July 2016 is the insertion

260  
00:11:08,370 --> 00:11:12,720  
it's going to do two orbits with 53 and

261  
00:11:10,860 --> 00:11:15,210  
a half day period then it's going to

262  
00:11:12,720 --> 00:11:18,360  
follow that by 35 orbits with a 14-day

263  
00:11:15,210 --> 00:11:21,269  
period so on August 27th it made its

264  
00:11:18,360 --> 00:11:24,240  
first fly by of Jupiter and this image

265  
00:11:21,269 --> 00:11:27,240  
right here is as it's approaching for

266  
00:11:24,240 --> 00:11:28,740  
its first flyby okay and what we're

267  
00:11:27,240 --> 00:11:31,740  
going to get at least in the visible

268  
00:11:28,740 --> 00:11:35,070  
light images come from a camera called

269  
00:11:31,740 --> 00:11:37,589  
Juno cam and Juno cam is not a science

270  
00:11:35,070 --> 00:11:39,930  
camera all right I want to dent lesson

271  
00:11:37,589 --> 00:11:41,760

your expectations here because it is an

272

00:11:39,929 --> 00:11:43,889

outreach camera it's just a 2 megapixel

273

00:11:41,759 --> 00:11:45,838

it's like a webcam sitting on the

274

00:11:43,889 --> 00:11:48,120

science a satellite ok it's going to get

275

00:11:45,839 --> 00:11:50,700

some cool pictures but it's not a

276

00:11:48,120 --> 00:11:53,100

science a real science deep science

277

00:11:50,700 --> 00:11:54,870

based eyes camera most of the science

278

00:11:53,100 --> 00:11:56,399

going to be done from Juno is about on

279

00:11:54,870 --> 00:11:57,990

the atmosphere and the magnetosphere

280

00:11:56,399 --> 00:11:59,939

it's going to have some ultraviolet

281

00:11:57,990 --> 00:12:01,200

imaging and some infrared imaging and

282

00:11:59,940 --> 00:12:03,420

it's going to look at the Aurora and

283

00:12:01,200 --> 00:12:06,270

such but the visible light images from

284

00:12:03,419 --> 00:12:08,370

Juno they aren't the highlight they are

285

00:12:06,269 --> 00:12:11,149

at the science goal of the mission ok

286

00:12:08,370 --> 00:12:14,519  
but it did get some cool pictures

287

00:12:11,149 --> 00:12:17,189  
because we have not studied the poles of

288

00:12:14,519 --> 00:12:19,939  
Jupiter very very much the last time we

289

00:12:17,190 --> 00:12:25,110  
saw the North Pole of Jupiter was in

290

00:12:19,940 --> 00:12:27,600  
1974 well now we have these images okay

291

00:12:25,110 --> 00:12:29,490  
so this is Jupiter's North Pole alright

292

00:12:27,600 --> 00:12:31,050  
let me just go back to this one here you

293

00:12:29,490 --> 00:12:32,490  
can see that most of Jupiter is this

294

00:12:31,049 --> 00:12:34,500  
banded structure ok

295

00:12:32,490 --> 00:12:36,629  
that's the stuff we're used to if we go

296

00:12:34,500 --> 00:12:38,339  
look at the North Pole however you can

297

00:12:36,629 --> 00:12:39,870  
start to see especially in this enhanced

298

00:12:38,339 --> 00:12:42,270  
image that you've got all sorts of

299

00:12:39,870 --> 00:12:45,149  
storminess going on in here you do not

300  
00:12:42,269 --> 00:12:47,399  
have that banded structure alright and

301  
00:12:45,149 --> 00:12:49,259  
what's really cool not just to see that

302  
00:12:47,399 --> 00:12:52,850  
the North Pole but they got this

303  
00:12:49,259 --> 00:12:55,319  
gorgeous picture of Jupiter's South Pole

304  
00:12:52,850 --> 00:12:57,930  
all right now can you see the amazing

305  
00:12:55,320 --> 00:12:59,640  
number of storms and there's still a

306  
00:12:57,929 --> 00:13:01,379  
little bit of banded nough stu the

307  
00:12:59,639 --> 00:13:02,909  
structure but there's a lot more

308  
00:13:01,379 --> 00:13:05,850  
turbulence going on

309  
00:13:02,909 --> 00:13:08,519  
there's slower speeds down here okay in

310  
00:13:05,850 --> 00:13:11,580  
a motion of it and so you can see that

311  
00:13:08,519 --> 00:13:14,579  
you've got an entire a different pattern

312  
00:13:11,580 --> 00:13:16,110  
on Jupiter at the poles than you do in

313  
00:13:14,580 --> 00:13:18,120  
that space star standard banded

314

00:13:16,110 --> 00:13:20,220  
structure that runs around most of the

315  
00:13:18,120 --> 00:13:21,429  
planet so this is really cool because

316  
00:13:20,220 --> 00:13:23,830  
we've really not

317  
00:13:21,429 --> 00:13:25,989  
in the polls of Jupiter and we will get

318  
00:13:23,830 --> 00:13:28,930  
more of these as the mission continues

319  
00:13:25,990 --> 00:13:30,940  
okay but the next pass won't be until

320  
00:13:28,929 --> 00:13:33,669  
October at that time they're going to do

321  
00:13:30,940 --> 00:13:36,580  
a burn to go into the 14-day orbit so

322  
00:13:33,669 --> 00:13:39,549  
Juno has gone into it's serious science

323  
00:13:36,580 --> 00:13:41,470  
mode all right it's getting great great

324  
00:13:39,549 --> 00:13:43,659  
observations and we look forward to more

325  
00:13:41,470 --> 00:13:45,850  
cool pictures but really a lot more

326  
00:13:43,659 --> 00:13:49,600  
serious science about the atmosphere to

327  
00:13:45,850 --> 00:13:52,899  
come our second mission update is about

328  
00:13:49,600 --> 00:13:56,259

Rosetta the Rosetta mission and the

329

00:13:52,899 --> 00:13:58,539

lander feel a now if you remember how

330

00:13:56,259 --> 00:14:01,379

many of you were you he we're coming to

331

00:13:58,539 --> 00:14:05,579

the public lecture series back in 2014

332

00:14:01,379 --> 00:14:10,208

okay do you remember November 2014

333

00:14:05,580 --> 00:14:11,560

because that's when we had a particular

334

00:14:10,208 --> 00:14:13,750

event now let me just go through his

335

00:14:11,559 --> 00:14:16,599

throw over this okay so the Rosetta

336

00:14:13,750 --> 00:14:22,059

mission its final goal was to comment

337

00:14:16,600 --> 00:14:24,399

67p churyumov-gerasimenko okay or just

338

00:14:22,059 --> 00:14:29,169

to make it easier we like to call it

339

00:14:24,399 --> 00:14:32,230

Comet rubber ducky simply because of its

340

00:14:29,169 --> 00:14:35,649

shape now so 67p was the target of it

341

00:14:32,230 --> 00:14:40,839

okay and the Rosetta main orbiter went

342

00:14:35,649 --> 00:14:46,049

into orbit around 67p the feel a lander

343  
00:14:40,839 --> 00:14:48,160  
was released in November 2014 to land on

344  
00:14:46,049 --> 00:14:51,490  
actually uh what would be the head of

345  
00:14:48,159 --> 00:14:54,639  
the duck okay and it dropped on down for

346  
00:14:51,490 --> 00:14:56,500  
seven hours and when it hit two harpoons

347  
00:14:54,639 --> 00:14:59,980  
were supposed to dig into the ice and

348  
00:14:56,500 --> 00:15:02,860  
hold it on well the harpoons didn't go

349  
00:14:59,980 --> 00:15:05,259  
so instead fillet bounced it bounced a

350  
00:15:02,860 --> 00:15:07,180  
kilometer upward okay

351  
00:15:05,259 --> 00:15:08,889  
relatively low gravity you know it could

352  
00:15:07,179 --> 00:15:12,489  
jump really high and actually did a

353  
00:15:08,889 --> 00:15:15,549  
second bounce and settled into a an

354  
00:15:12,490 --> 00:15:18,250  
unknown region on the surface of the

355  
00:15:15,549 --> 00:15:20,099  
comet it was obviously not pointed

356  
00:15:18,250 --> 00:15:22,809  
upward because it couldn't communicate

357  
00:15:20,100 --> 00:15:25,600  
it got they got a few pictures from it

358  
00:15:22,809 --> 00:15:27,849  
but they couldn't keep it alive and the

359  
00:15:25,600 --> 00:15:29,970  
feel a lander was declared a loss in

360  
00:15:27,850 --> 00:15:32,590  
March of 2016

361  
00:15:29,970 --> 00:15:34,660  
however they

362  
00:15:32,590 --> 00:15:36,879  
knew where it was and the rosetta

363  
00:15:34,659 --> 00:15:38,709  
mission main orbiter kept orbiting

364  
00:15:36,879 --> 00:15:40,809  
around it and actually moved into closer

365  
00:15:38,710 --> 00:15:43,830  
and closer orbits as the mission

366  
00:15:40,809 --> 00:15:49,119  
continued and they searched for it and

367  
00:15:43,830 --> 00:15:52,570  
just a few days ago they found it now

368  
00:15:49,120 --> 00:15:54,279  
can you spot the feel a lander those of

369  
00:15:52,570 --> 00:16:00,280  
you who know where it is yes it's

370  
00:15:54,279 --> 00:16:02,169  
actually over there all right let me

371

00:16:00,279 --> 00:16:04,019  
give you the blow-up okay this is an

372  
00:16:02,169 --> 00:16:07,659  
amazing image by the way it's 5

373  
00:16:04,019 --> 00:16:09,879  
centimeters per pixel okay 5 centimeters

374  
00:16:07,659 --> 00:16:10,539  
per pixel amazing stuff of the surface

375  
00:16:09,879 --> 00:16:12,730  
of a comet

376  
00:16:10,539 --> 00:16:15,579  
here is the feel a lander they found it

377  
00:16:12,730 --> 00:16:17,350  
ok and you can see it's tipped over on

378  
00:16:15,580 --> 00:16:19,600  
its side so of course it's not going to

379  
00:16:17,350 --> 00:16:22,180  
have good communication with the with

380  
00:16:19,600 --> 00:16:24,430  
the orbiter all right and here is a

381  
00:16:22,179 --> 00:16:27,639  
diagram annotated diagram to help you

382  
00:16:24,429 --> 00:16:31,809  
understand that the there the legs of

383  
00:16:27,639 --> 00:16:34,409  
the lander on huh where's the ice the

384  
00:16:31,809 --> 00:16:37,539  
whole the whole comet is is ice and rock

385  
00:16:34,409 --> 00:16:39,129

yes but if you know the the surface of a

386

00:16:37,539 --> 00:16:42,429

comet is generally a sort of a tar-like

387

00:16:39,129 --> 00:16:45,399

substance ok because the volatiles have

388

00:16:42,429 --> 00:16:47,469

have gone away all right this one this

389

00:16:45,399 --> 00:16:50,139

comment only gets into about 1.2

390

00:16:47,470 --> 00:16:52,420

astronomical units as closest approach

391

00:16:50,139 --> 00:16:56,169

to the Sun but still the volatiles will

392

00:16:52,419 --> 00:16:57,969

will go away you get inside 3a you then

393

00:16:56,169 --> 00:17:01,569

the volatiles on the surface will

394

00:16:57,970 --> 00:17:03,340

definitely definitely go away ok so it

395

00:17:01,570 --> 00:17:06,519

actually one of the reasons why the

396

00:17:03,340 --> 00:17:08,230

field a lander bounced was at the

397

00:17:06,519 --> 00:17:11,709

surface was was harder than they

398

00:17:08,230 --> 00:17:13,120

expected it to be okay based on pron

399

00:17:11,709 --> 00:17:16,209

previous things the deep impact they

400  
00:17:13,119 --> 00:17:17,559  
expected a softer surface alright so

401  
00:17:16,209 --> 00:17:19,870  
this is the feel a lander here

402  
00:17:17,559 --> 00:17:27,119  
unfortunately it's unrecoverable all

403  
00:17:19,869 --> 00:17:30,969  
right ah call Bruce Willis there you go

404  
00:17:27,119 --> 00:17:32,679  
alright so here's what I just I just

405  
00:17:30,970 --> 00:17:35,400  
want to recap for you the rosetta

406  
00:17:32,680 --> 00:17:39,460  
mission okay it was launched in March of

407  
00:17:35,400 --> 00:17:42,280  
2004 it had flybys of Earth three times

408  
00:17:39,460 --> 00:17:45,819  
it flew by Mars once it flew by two

409  
00:17:42,279 --> 00:17:48,240  
different asteroids it

410  
00:17:45,819 --> 00:17:51,159  
five dat 67p in August the feel a

411  
00:17:48,240 --> 00:17:54,849  
landing was in November 2014

412  
00:17:51,160 --> 00:17:56,410  
Rosetta stayed with 67p as it went came

413  
00:17:54,849 --> 00:17:59,859  
up approached the Sun went through

414  
00:17:56,410 --> 00:18:02,980  
perihelion last August and two years

415  
00:17:59,859 --> 00:18:05,109  
later now all right it's still with it

416  
00:18:02,980 --> 00:18:08,019  
and it's moved down to that very close

417  
00:18:05,109 --> 00:18:08,979  
orbit and the mission is finally going

418  
00:18:08,019 --> 00:18:12,819  
to end this month

419  
00:18:08,980 --> 00:18:15,130  
on September 30th they're going to take

420  
00:18:12,819 --> 00:18:18,069  
the main orbiter and have that also land

421  
00:18:15,130 --> 00:18:21,790  
on the comet now I say land in a general

422  
00:18:18,069 --> 00:18:25,419  
sense because as one one blog put it

423  
00:18:21,789 --> 00:18:27,430  
it'll be more like a soft crash because

424  
00:18:25,420 --> 00:18:29,890  
it doesn't have the kind of landing gear

425  
00:18:27,430 --> 00:18:33,039  
that filet was built with so it will

426  
00:18:29,890 --> 00:18:35,830  
effectively crash into 67p at the time

427  
00:18:33,039 --> 00:18:37,930  
and will continue to orbit with 67p for

428

00:18:35,829 --> 00:18:40,480  
the rest of history alright so we can

429  
00:18:37,930 --> 00:18:41,920  
look for some really cool images from

430  
00:18:40,480 --> 00:18:44,230  
the Rosetta mission the end of this

431  
00:18:41,920 --> 00:18:46,060  
month on September 30th because as this

432  
00:18:44,230 --> 00:18:48,460  
main orbiter gets in close to the comet

433  
00:18:46,059 --> 00:18:50,409  
it's got a lot more science instruments

434  
00:18:48,460 --> 00:18:52,720  
that it can take all sorts of cool

435  
00:18:50,410 --> 00:18:55,450  
readings and get a lot of interesting

436  
00:18:52,720 --> 00:18:59,259  
science as it comes in for landing the

437  
00:18:55,450 --> 00:19:01,539  
end of this month okay alright I had to

438  
00:18:59,259 --> 00:19:03,069  
throw in one Hubble story I'm sorry Tom

439  
00:19:01,539 --> 00:19:05,259  
I'm taking so long but I had to throw it

440  
00:19:03,069 --> 00:19:07,359  
once one Hubble story because the rest

441  
00:19:05,259 --> 00:19:09,549  
of the stuff was from from elsewhere and

442  
00:19:07,359 --> 00:19:13,089

our final story tonight is galaxies late

443

00:19:09,549 --> 00:19:15,940

bloomers okay so Hubble release these

444

00:19:13,089 --> 00:19:20,740

two cool images of this this month of

445

00:19:15,940 --> 00:19:23,980

Pisces a and Pisces B two dwarf galaxies

446

00:19:20,740 --> 00:19:25,900

alright and what's one of the really

447

00:19:23,980 --> 00:19:28,630

cool things was how these galaxies were

448

00:19:25,900 --> 00:19:30,040

discovered so when I say galaxies you

449

00:19:28,630 --> 00:19:32,050

probably think of something like the

450

00:19:30,039 --> 00:19:36,569

Whirlpool Galaxy sort of the standard

451

00:19:32,049 --> 00:19:39,579

big giant spiral galaxies okay but the

452

00:19:36,569 --> 00:19:41,619

Whirlpool Galaxy is actually bigger than

453

00:19:39,579 --> 00:19:44,289

you think because this is the visible

454

00:19:41,619 --> 00:19:46,029

light view if we go into the radio and

455

00:19:44,289 --> 00:19:49,960

search for the hydrogen gas the

456

00:19:46,029 --> 00:19:53,470

Whirlpool Galaxy looks like that there

457  
00:19:49,960 --> 00:19:55,990  
is a lot more hydrogen gas up there that

458  
00:19:53,470 --> 00:19:58,930  
we can see in radio than can be seen in

459  
00:19:55,990 --> 00:20:02,019  
the visible eye of stars so these

460  
00:19:58,930 --> 00:20:04,960  
or galaxies here were actually found in

461  
00:20:02,019 --> 00:20:07,809  
by radio searches looking for blobs of

462  
00:20:04,960 --> 00:20:09,789  
hydrogen it was actually a survey of the

463  
00:20:07,809 --> 00:20:13,419  
Milky Way galaxy looking for hydrogen

464  
00:20:09,789 --> 00:20:15,490  
clouds and they found 30 to 50

465  
00:20:13,420 --> 00:20:18,100  
candidates that might actually be

466  
00:20:15,490 --> 00:20:20,109  
external galaxies they went through and

467  
00:20:18,099 --> 00:20:22,629  
they narrowed them down to the top 10 or

468  
00:20:20,109 --> 00:20:24,549  
12 and they chose two of them that had

469  
00:20:22,630 --> 00:20:26,410  
the highest probability of actually

470  
00:20:24,549 --> 00:20:28,480  
being galaxies they didn't know they

471  
00:20:26,410 --> 00:20:30,130  
couldn't see the stars in these galaxies

472  
00:20:28,480 --> 00:20:32,349  
they could just see there was a blob of

473  
00:20:30,130 --> 00:20:35,200  
hydrogen there and when they looked with

474  
00:20:32,349 --> 00:20:37,959  
Hubble they found the two dwarf galaxies

475  
00:20:35,200 --> 00:20:40,269  
and with Hubble being able to resolve

476  
00:20:37,960 --> 00:20:43,059  
the stars and be able to do the stellar

477  
00:20:40,269 --> 00:20:45,609  
populations of it they were actually

478  
00:20:43,059 --> 00:20:49,149  
able to tell that these these dwarf

479  
00:20:45,609 --> 00:20:51,549  
galaxies are late bloomers they had a

480  
00:20:49,150 --> 00:20:53,860  
burst of star formation only a hundred

481  
00:20:51,549 --> 00:20:56,829  
million years ago all right now I know

482  
00:20:53,859 --> 00:20:59,289  
100 million years is really long to you

483  
00:20:56,829 --> 00:21:02,949  
and me but in terms of the cosmos that's

484  
00:20:59,289 --> 00:21:06,430  
13.8 billion years old 100 million years

485

00:21:02,950 --> 00:21:09,549  
ago is way late in universe to have such

486  
00:21:06,430 --> 00:21:11,890  
a burst of star formation okay so these

487  
00:21:09,549 --> 00:21:13,569  
are galaxies that have been hanging out

488  
00:21:11,890 --> 00:21:16,270  
in what we call in what we call a void

489  
00:21:13,569 --> 00:21:18,730  
region of the universe they're very very

490  
00:21:16,269 --> 00:21:21,099  
slow developers they're late developers

491  
00:21:18,730 --> 00:21:23,140  
and only in the last hundred million

492  
00:21:21,099 --> 00:21:25,589  
years have they had a burst a

493  
00:21:23,140 --> 00:21:29,440  
significant amount of star formation

494  
00:21:25,589 --> 00:21:31,929  
okay so by using the radio to then

495  
00:21:29,440 --> 00:21:36,070  
follow up with optical we can actually

496  
00:21:31,930 --> 00:21:40,180  
find these rare small galaxies out in

497  
00:21:36,069 --> 00:21:41,950  
universe okay they're in the direction

498  
00:21:40,180 --> 00:21:43,690  
of Pisces they're not in the local group

499  
00:21:41,950 --> 00:21:45,730

okay there's they're far enough away

500

00:21:43,690 --> 00:21:48,850

that that they're there they're outside

501

00:21:45,730 --> 00:21:51,819

the local group okay all right we got to

502

00:21:48,849 --> 00:21:55,899

get to our featured speaker all right

503

00:21:51,819 --> 00:21:58,839

let me switch over and our speaker

504

00:21:55,900 --> 00:22:01,060

tonight is Tom Brown and I want to thank

505

00:21:58,839 --> 00:22:02,859

him for postponing his talk from May so

506

00:22:01,059 --> 00:22:05,500

I could bring in sandy Faber back then

507

00:22:02,859 --> 00:22:07,719

and I know you guys enjoyed her talk

508

00:22:05,500 --> 00:22:10,150

you're definitely gonna enjoy Tom Tom

509

00:22:07,720 --> 00:22:12,170

got his degree across the street at

510

00:22:10,150 --> 00:22:14,600

Johns Hopkins University

511

00:22:12,170 --> 00:22:16,820

he did hippo stock down in Goddard Space

512

00:22:14,599 --> 00:22:19,609

Flight Center and then he came to work

513

00:22:16,819 --> 00:22:22,669

here at Space Telescope a very Maryland

514  
00:22:19,609 --> 00:22:25,579  
career here at Space Telescope he's done

515  
00:22:22,670 --> 00:22:27,140  
some amazing things he's worked on the

516  
00:22:25,579 --> 00:22:29,990  
Hubble Space Telescope he's worked on

517  
00:22:27,140 --> 00:22:33,080  
the James Webb Space Telescope and he is

518  
00:22:29,990 --> 00:22:36,740  
now the head of the Hubble mission here

519  
00:22:33,079 --> 00:22:39,048  
and he is a famous in astronomy circles

520  
00:22:36,740 --> 00:22:43,519  
for having taken the deepest visible

521  
00:22:39,048 --> 00:22:44,990  
light image ever of a star field in the

522  
00:22:43,519 --> 00:22:47,869  
andromeda galaxy

523  
00:22:44,990 --> 00:22:51,319  
we call it the stellar deep field and it

524  
00:22:47,869 --> 00:22:56,149  
was recently honored by being on the

525  
00:22:51,319 --> 00:22:59,058  
cover of david bowie's last album so a

526  
00:22:56,150 --> 00:23:07,400  
true true famous guy ladies and

527  
00:22:59,058 --> 00:23:08,779  
gentlemen Tom Brown all right thank you

528  
00:23:07,400 --> 00:23:09,650  
Frank thanks for that introduction can

529  
00:23:08,779 --> 00:23:11,418  
everyone hear me all right with the

530  
00:23:09,650 --> 00:23:12,830  
microphone all right and another thing

531  
00:23:11,419 --> 00:23:14,929  
you got to remind me now and then is I'm

532  
00:23:12,829 --> 00:23:16,308  
both a little hyperactive and I'm from

533  
00:23:14,929 --> 00:23:17,570  
New York so you got to slow me down now

534  
00:23:16,308 --> 00:23:20,149  
and then if I start going too quickly

535  
00:23:17,569 --> 00:23:22,189  
okay so again as Frank said I'll be

536  
00:23:20,150 --> 00:23:23,419  
talking today about the missing galaxies

537  
00:23:22,190 --> 00:23:25,130  
and the nearby universe this is

538  
00:23:23,419 --> 00:23:26,660  
something known as the missing satellite

539  
00:23:25,130 --> 00:23:28,400  
problem that astronomers have been

540  
00:23:26,660 --> 00:23:29,870  
studying for decades and one way to

541  
00:23:28,400 --> 00:23:32,870  
attack this problem is by looking at the

542

00:23:29,869 --> 00:23:34,879  
oldest stars in the nearby universe so

543  
00:23:32,869 --> 00:23:36,469  
this is work I'm doing with the Hubble

544  
00:23:34,880 --> 00:23:37,910  
Space Telescope it's a program I put

545  
00:23:36,470 --> 00:23:40,548  
together a few years ago it was about

546  
00:23:37,910 --> 00:23:42,470  
113 orbits on Hubble and the team of

547  
00:23:40,548 --> 00:23:44,119  
folks I show here from around the world

548  
00:23:42,470 --> 00:23:45,679  
worked on it with me I've listed their

549  
00:23:44,119 --> 00:23:47,058  
names I won't go through them all but

550  
00:23:45,679 --> 00:23:48,710  
some of them are observers on Hubble

551  
00:23:47,058 --> 00:23:50,210  
like myself there's some folks here who

552  
00:23:48,710 --> 00:23:52,250  
had time on the Keck telescope in Hawaii

553  
00:23:50,210 --> 00:23:53,929  
and then there are also some theorists

554  
00:23:52,250 --> 00:23:56,089  
on this program who study both the

555  
00:23:53,929 --> 00:23:57,440  
evolution of galaxies and time the

556  
00:23:56,089 --> 00:23:59,149

evolution of the universe and the

557

00:23:57,440 --> 00:24:00,440

evolution of stars so it's a good mix of

558

00:23:59,150 --> 00:24:04,940

people who use telescopes on the ground

559

00:24:00,440 --> 00:24:06,679

in space and then also theorists so this

560

00:24:04,940 --> 00:24:08,870

is a simulation from been more

561

00:24:06,679 --> 00:24:10,850

universities Uruk of how the structure

562

00:24:08,869 --> 00:24:12,558

of the universe evolved with time on the

563

00:24:10,849 --> 00:24:14,178

right hand side here so this little

564

00:24:12,558 --> 00:24:15,259

number cutting down here is red ship to

565

00:24:14,179 --> 00:24:16,820

those who are familiar with it so this

566

00:24:15,259 --> 00:24:18,140

is red shift going into the present and

567

00:24:16,819 --> 00:24:20,389

the beginning of the simulation I'll

568

00:24:18,140 --> 00:24:21,590

back up here when it stops so you can

569

00:24:20,390 --> 00:24:24,110

see it again the begin the simulation

570

00:24:21,589 --> 00:24:25,669

starts right after the Big Bang and then

571  
00:24:24,109 --> 00:24:27,649  
the matter in the universe call

572  
00:24:25,670 --> 00:24:30,050  
les is in this filamentary structure you

573  
00:24:27,650 --> 00:24:32,240  
see here this is how theorists predict

574  
00:24:30,049 --> 00:24:34,039  
the universe evolved under the paradigm

575  
00:24:32,240 --> 00:24:35,210  
of cold dark matter and the assumption

576  
00:24:34,039 --> 00:24:37,279  
here is that there is dark matter

577  
00:24:35,210 --> 00:24:37,759  
permeating the universe it's cold and

578  
00:24:37,279 --> 00:24:39,200  
dark

579  
00:24:37,759 --> 00:24:42,379  
that's like cold cold dark matter theory

580  
00:24:39,200 --> 00:24:44,390  
and you can't see it but you do see are

581  
00:24:42,380 --> 00:24:45,710  
the galaxies that form in the filaments

582  
00:24:44,390 --> 00:24:48,680  
along the structure of cold dark matter

583  
00:24:45,710 --> 00:24:51,230  
so dark matter is the scaffolding upon

584  
00:24:48,680 --> 00:24:52,490  
which galaxies are built so the dark

585  
00:24:51,230 --> 00:24:53,720  
matter permeates the universe and then

586  
00:24:52,490 --> 00:24:55,549  
these filaments are where you have large

587  
00:24:53,720 --> 00:24:57,710  
galaxies so these bright red points here

588  
00:24:55,549 --> 00:24:59,119  
are galaxies like the Milky Way giant

589  
00:24:57,710 --> 00:25:00,799  
spiral galaxies are giant elliptical

590  
00:24:59,119 --> 00:25:04,699  
galaxies and the little tiny dots are

591  
00:25:00,799 --> 00:25:07,430  
satellite galaxies the cold egg matter

592  
00:25:04,700 --> 00:25:08,809  
theory confirm conforms with a lot of

593  
00:25:07,430 --> 00:25:11,480  
the observable phenomena in the universe

594  
00:25:08,809 --> 00:25:13,519  
but one thing it strikes out on is it

595  
00:25:11,480 --> 00:25:15,200  
over predicts the number of tiny little

596  
00:25:13,519 --> 00:25:17,049  
galaxies so that's Ana long-standing

597  
00:25:15,200 --> 00:25:19,970  
problem with the cold dark matter theory

598  
00:25:17,049 --> 00:25:21,919  
so here's a zoom in of an environment

599

00:25:19,970 --> 00:25:23,660  
like our own Milky Way this is from my

600  
00:25:21,920 --> 00:25:25,640  
collaborator Jason Tomlinson who also

601  
00:25:23,660 --> 00:25:28,009  
works here at the Institute he's a

602  
00:25:25,640 --> 00:25:29,690  
theorist and observer and the simulation

603  
00:25:28,009 --> 00:25:31,759  
I'm showing here is about a million

604  
00:25:29,690 --> 00:25:33,440  
light years on aside and so this is the

605  
00:25:31,759 --> 00:25:35,420  
environment around a galaxy like our own

606  
00:25:33,440 --> 00:25:37,490  
Milky Way and this shows in his

607  
00:25:35,420 --> 00:25:39,320  
simulation here in Jason simulation the

608  
00:25:37,490 --> 00:25:41,089  
expectations for the distribution of

609  
00:25:39,319 --> 00:25:42,439  
dark matter in the nearby universe the

610  
00:25:41,089 --> 00:25:43,579  
very nearby universe within a million

611  
00:25:42,440 --> 00:25:45,830  
light years I might not sound that

612  
00:25:43,579 --> 00:25:47,389  
nearby but this is roughly the the

613  
00:25:45,829 --> 00:25:48,559

sphere of influence of the Milky Way

614

00:25:47,390 --> 00:25:50,300

so the Milky Way would be sitting here

615

00:25:48,559 --> 00:25:52,490

at the center and we know there's a

616

00:25:50,299 --> 00:25:53,720

galaxy there it's the Milky Way and then

617

00:25:52,490 --> 00:25:55,819

there's all these little clumps of dark

618

00:25:53,720 --> 00:25:57,829

matter orbiting the gravitational well

619

00:25:55,819 --> 00:26:00,230

of the Milky Way and there are hundreds

620

00:25:57,829 --> 00:26:01,609

of them in this simulation and when you

621

00:26:00,230 --> 00:26:02,750

look at the number of galaxies actually

622

00:26:01,609 --> 00:26:05,389

orbiting the Milky Way there's only a

623

00:26:02,750 --> 00:26:07,210

few dozen so it's off by a large amount

624

00:26:05,390 --> 00:26:09,740

it's grossly off the number of observed

625

00:26:07,210 --> 00:26:10,819

satellite galaxies compared to the

626

00:26:09,740 --> 00:26:13,039

predictions of the cold dark matter

627

00:26:10,819 --> 00:26:14,720

theory so this is the missing satellite

628  
00:26:13,039 --> 00:26:16,009  
problem that call dark matter says

629  
00:26:14,720 --> 00:26:17,990  
there's lots of little clumps of dark

630  
00:26:16,009 --> 00:26:19,910  
matter out here and yet we only see a

631  
00:26:17,990 --> 00:26:21,740  
few dozen galaxies and these clumps to

632  
00:26:19,910 --> 00:26:23,509  
dark matter are the seeds of galaxy

633  
00:26:21,740 --> 00:26:25,130  
formation so this was a big shock when

634  
00:26:23,509 --> 00:26:27,740  
people started doing censuses of

635  
00:26:25,130 --> 00:26:29,000  
galaxies comparing them to theory and so

636  
00:26:27,740 --> 00:26:33,200  
things are off by more than an order of

637  
00:26:29,000 --> 00:26:34,549  
magnitude so that's it a summary theory

638  
00:26:33,200 --> 00:26:36,289  
predicts more dark matter clumps

639  
00:26:34,549 --> 00:26:38,029  
orbiting the Milky Way than the number

640  
00:26:36,289 --> 00:26:40,879  
of dwarf satellites we actually

641  
00:26:38,029 --> 00:26:43,399  
that's the missing satellite problem so

642  
00:26:40,880 --> 00:26:44,990  
a solution to this was proposed a while

643  
00:26:43,400 --> 00:26:47,509  
back and has to do with the realization

644  
00:26:44,990 --> 00:26:49,009  
of the universe so this is a cartoon I'm

645  
00:26:47,509 --> 00:26:50,990  
showing here with the big bang on the

646  
00:26:49,009 --> 00:26:52,400  
left and the modern era on the right and

647  
00:26:50,990 --> 00:26:54,140  
time is just progressing from left to

648  
00:26:52,400 --> 00:26:56,120  
right here in this cartoon this is the

649  
00:26:54,140 --> 00:26:58,730  
evolution of the universe so the Big

650  
00:26:56,119 --> 00:27:01,189  
Bang is right here right after the Big

651  
00:26:58,730 --> 00:27:03,259  
Bang there's a short pier here called

652  
00:27:01,190 --> 00:27:05,120  
the Dark Ages where the universe cooled

653  
00:27:03,259 --> 00:27:06,710  
enough to become neutral so you have

654  
00:27:05,119 --> 00:27:07,939  
hydrogen is neutral

655  
00:27:06,710 --> 00:27:10,490  
you just have electron orbiting the

656

00:27:07,940 --> 00:27:13,490  
proton things have cooled down those

657  
00:27:10,490 --> 00:27:15,289  
stars have not yet come on then the

658  
00:27:13,490 --> 00:27:17,170  
first stars and galaxies are born right

659  
00:27:15,289 --> 00:27:19,099  
here shortly after the Big Bang and

660  
00:27:17,170 --> 00:27:20,600  
ironically what happens is when the

661  
00:27:19,099 --> 00:27:22,159  
first stars and galaxies come on they

662  
00:27:20,599 --> 00:27:24,379  
illuminate everything that actually

663  
00:27:22,160 --> 00:27:25,730  
snuffs out a lot of star formation all

664  
00:27:24,380 --> 00:27:27,080  
around the universe because that light

665  
00:27:25,730 --> 00:27:28,519  
comes on it's a very strong source of

666  
00:27:27,079 --> 00:27:30,139  
ultraviolet light and it blows out the

667  
00:27:28,519 --> 00:27:31,549  
gas out of a lot of little dark matter

668  
00:27:30,140 --> 00:27:33,560  
clumps and turns off the star formation

669  
00:27:31,549 --> 00:27:34,849  
that's the theory here so you have the

670  
00:27:33,559 --> 00:27:36,349

first stars and galaxies come on they

671

00:27:34,849 --> 00:27:37,849

come on so rapidly they actually shut

672

00:27:36,349 --> 00:27:40,339

off the star formation in a lot of parts

673

00:27:37,849 --> 00:27:42,109

of the universe so this is the era of

674

00:27:40,339 --> 00:27:43,909

reionisation when the universe gets

675

00:27:42,109 --> 00:27:47,269

ionized from those first stars and

676

00:27:43,910 --> 00:27:49,310

galaxies forming then after that era is

677

00:27:47,269 --> 00:27:51,170

done galaxies continued evolve new stars

678

00:27:49,309 --> 00:27:52,339

are born from a rich enriched gas you've

679

00:27:51,170 --> 00:27:54,110

heard this before we're all made from

680

00:27:52,339 --> 00:27:55,429

star stuff so stars explode their

681

00:27:54,109 --> 00:27:56,959

material goes out into the interstellar

682

00:27:55,430 --> 00:27:59,900

medium new stars are born from that

683

00:27:56,960 --> 00:28:01,880

enriched gas and time goes on and here's

684

00:27:59,900 --> 00:28:04,430

when the Sun would be born at this point

685  
00:28:01,880 --> 00:28:05,450  
in history and here we are today so the

686  
00:28:04,430 --> 00:28:07,220  
Sun was born about four-and-a-half

687  
00:28:05,450 --> 00:28:08,390  
billion years ago here we are sitting

688  
00:28:07,220 --> 00:28:11,839  
here in the modern universe and we look

689  
00:28:08,390 --> 00:28:13,340  
back in time so now we return to Jason

690  
00:28:11,839 --> 00:28:15,079  
simulation so this is the Dark Matter

691  
00:28:13,339 --> 00:28:19,069  
distribution around a galaxy like our

692  
00:28:15,079 --> 00:28:21,019  
Milky Way and the theory goes he's

693  
00:28:19,069 --> 00:28:23,029  
highlighted here in green those are the

694  
00:28:21,019 --> 00:28:24,500  
satellite galaxies that formed lots of

695  
00:28:23,029 --> 00:28:26,420  
stars and that's why we know about them

696  
00:28:24,500 --> 00:28:28,549  
so for decades we've known about these

697  
00:28:26,420 --> 00:28:30,350  
satellite dwarf galaxies these clumps of

698  
00:28:28,549 --> 00:28:32,990  
dark matter were large enough to

699  
00:28:30,349 --> 00:28:34,939  
accumulate a bunch of gas have stars

700  
00:28:32,990 --> 00:28:36,980  
form and then they continued forming

701  
00:28:34,940 --> 00:28:39,500  
stars until the present era so these

702  
00:28:36,980 --> 00:28:41,000  
little clumps here all continued forming

703  
00:28:39,500 --> 00:28:42,440  
stars to the present day and this is

704  
00:28:41,000 --> 00:28:43,819  
what we knew about galaxies up until the

705  
00:28:42,440 --> 00:28:44,930  
stuff I'll show you tonight this is the

706  
00:28:43,819 --> 00:28:46,939  
assumption that's been made about all

707  
00:28:44,930 --> 00:28:49,039  
galaxies that galaxies are groups of

708  
00:28:46,940 --> 00:28:51,289  
stars built upon dark matter that have a

709  
00:28:49,039 --> 00:28:51,529  
wide range of Ages as stars born in the

710  
00:28:51,289 --> 00:28:53,089  
early

711  
00:28:51,529 --> 00:28:54,649  
University of Stars continuing to form

712  
00:28:53,089 --> 00:28:56,329  
up until today I mean Frank just showed

713

00:28:54,650 --> 00:28:58,580  
this press release with these galaxies

714  
00:28:56,329 --> 00:29:01,099  
form stars very recently so until

715  
00:28:58,579 --> 00:29:02,859  
recently every single galaxy had not

716  
00:29:01,099 --> 00:29:06,469  
only old stars but younger stars as well

717  
00:29:02,859 --> 00:29:08,929  
what's that okay that's I thought maybe

718  
00:29:06,470 --> 00:29:10,850  
it was me sorry I thought I'd turn off

719  
00:29:08,930 --> 00:29:12,170  
my phone as a string okay so so anyway

720  
00:29:10,849 --> 00:29:14,629  
this is the theory this is the

721  
00:29:12,170 --> 00:29:16,370  
theoretical prediction for the kinds of

722  
00:29:14,630 --> 00:29:17,860  
galaxies we've known about forever for

723  
00:29:16,369 --> 00:29:19,849  
decades orbiting the Milky Way the

724  
00:29:17,859 --> 00:29:21,379  
problem is here you see that a lot of

725  
00:29:19,849 --> 00:29:22,849  
these little clumps of dark matter don't

726  
00:29:21,380 --> 00:29:24,560  
aren't highlighted they just stay dark

727  
00:29:22,849 --> 00:29:26,000

this is what the theory predicts that

728

00:29:24,559 --> 00:29:27,319

most of this guy most of these Dark

729

00:29:26,000 --> 00:29:28,160

Matter clumps and never form stars and

730

00:29:27,319 --> 00:29:29,929

that's why you don't know they're there

731

00:29:28,160 --> 00:29:31,640

but they are there it's just clumps of

732

00:29:29,930 --> 00:29:34,340

dark matter orbiting the Milky Way if

733

00:29:31,640 --> 00:29:36,440

this is true here are these red ones

734

00:29:34,339 --> 00:29:38,089

I've highlighted there should be fossil

735

00:29:36,440 --> 00:29:40,220

galaxies out there that we didn't know

736

00:29:38,089 --> 00:29:41,569

about that are just ancient and are made

737

00:29:40,220 --> 00:29:43,730

from pristine gas the early universe

738

00:29:41,569 --> 00:29:45,230

form stars and then we're shut off by

739

00:29:43,730 --> 00:29:47,299

the realisation universe so these ones

740

00:29:45,230 --> 00:29:48,589

are on the cusp you have the galaxies

741

00:29:47,299 --> 00:29:50,119

that kept forming stars because they

742  
00:29:48,589 --> 00:29:52,220  
were big then you have these smaller

743  
00:29:50,119 --> 00:29:53,359  
guys that started to form stars in the

744  
00:29:52,220 --> 00:29:54,950  
early universe and then with the lights

745  
00:29:53,359 --> 00:29:56,750  
came on and they snuffed them out and

746  
00:29:54,950 --> 00:29:58,100  
they never formed stars again so these

747  
00:29:56,750 --> 00:30:00,319  
are ones a kind of like a transition

748  
00:29:58,099 --> 00:30:01,730  
between the galaxies that kept forming

749  
00:30:00,319 --> 00:30:04,789  
stars and the ones that never form stars

750  
00:30:01,730 --> 00:30:06,230  
at all and then here I'm highlighting

751  
00:30:04,789 --> 00:30:07,700  
both so in green now these are the

752  
00:30:06,230 --> 00:30:09,079  
galaxies that continue to form stars

753  
00:30:07,700 --> 00:30:10,670  
these are the classical satellites we've

754  
00:30:09,079 --> 00:30:12,980  
known about for decades in red and pink

755  
00:30:10,670 --> 00:30:14,810  
here these are the galaxies that got

756  
00:30:12,980 --> 00:30:16,819  
snuffed out right after the Big Bang and

757  
00:30:14,809 --> 00:30:18,799  
then most of these little clumps never

758  
00:30:16,819 --> 00:30:21,169  
form stars at all and that's the

759  
00:30:18,799 --> 00:30:22,460  
possible theoretical solution to the

760  
00:30:21,170 --> 00:30:23,690  
missing satellite problem is that these

761  
00:30:22,460 --> 00:30:24,860  
dark matter clumps are just sitting out

762  
00:30:23,690 --> 00:30:26,990  
there orbiting around they didn't form

763  
00:30:24,859 --> 00:30:30,649  
enough stars for us to see them so this

764  
00:30:26,990 --> 00:30:32,539  
is true if this is true we need to find

765  
00:30:30,650 --> 00:30:34,250  
these fossil galaxies these ones in red

766  
00:30:32,539 --> 00:30:35,930  
we've known about these ones in green

767  
00:30:34,250 --> 00:30:37,069  
for a long time and Frank showed some of

768  
00:30:35,930 --> 00:30:39,500  
those tonight I'll show you some

769  
00:30:37,069 --> 00:30:40,849  
pictures of other ones the key here

770

00:30:39,500 --> 00:30:42,769  
since we can't see the dark matter

771  
00:30:40,849 --> 00:30:44,089  
clumps without stars to prove this

772  
00:30:42,769 --> 00:30:45,500  
theory you got to look at these pink

773  
00:30:44,089 --> 00:30:47,269  
ones and find evidence for fossil

774  
00:30:45,500 --> 00:30:48,759  
galaxies so that was the goal of a

775  
00:30:47,269 --> 00:30:53,180  
Hubble program we decided to undertake

776  
00:30:48,759 --> 00:30:54,799  
so if this theory is true we should have

777  
00:30:53,180 --> 00:30:55,850  
ancient dwarf galaxies besides the

778  
00:30:54,799 --> 00:30:57,500  
bright galaxies we've known about for

779  
00:30:55,849 --> 00:30:58,909  
decades this is Fornax one of the

780  
00:30:57,500 --> 00:31:01,940  
brightest satellite galaxies of the

781  
00:30:58,910 --> 00:31:04,850  
Milky Way it's a group of stars millions

782  
00:31:01,940 --> 00:31:07,640  
of stars with a very wide range of rage

783  
00:31:04,849 --> 00:31:09,319  
of ranges a range of Ages and a wide

784  
00:31:07,640 --> 00:31:10,580

range of chemistry so I talk about

785

00:31:09,319 --> 00:31:12,049

chemistry I'm always talking irrelevant

786

00:31:10,579 --> 00:31:14,210

to the Sun so there's some stars that

787

00:31:12,049 --> 00:31:16,789

have just as many chemical but chemists

788

00:31:14,210 --> 00:31:18,559

chemical abundances as the Sun and we

789

00:31:16,789 --> 00:31:20,000

have some stars that are much much more

790

00:31:18,559 --> 00:31:21,919

metal-poor than the Sun there's like one

791

00:31:20,000 --> 00:31:23,509

percent of the metals the Sun has so

792

00:31:21,920 --> 00:31:25,279

wide range in chemistry wide range in

793

00:31:23,509 --> 00:31:27,259

ages from right after the Big Bang 13

794

00:31:25,279 --> 00:31:28,819

billion years old to up to just a few

795

00:31:27,259 --> 00:31:33,410

hundred million years old so this is

796

00:31:28,819 --> 00:31:34,669

Fornax has a wide range of Ages so a big

797

00:31:33,410 --> 00:31:36,080

step forward in the missing satellite

798

00:31:34,670 --> 00:31:38,300

problem is the Sloan Digital Sky Survey

799

00:31:36,079 --> 00:31:39,980

this was a survey of a wide range of the

800

00:31:38,299 --> 00:31:42,019

sky done with a small telescope on the

801

00:31:39,980 --> 00:31:43,789

ground New Mexico it's done from the

802

00:31:42,019 --> 00:31:45,529

ground this patch of sky is the

803

00:31:43,789 --> 00:31:47,359

summation of all the data from the

804

00:31:45,529 --> 00:31:50,119

Digital Sky Survey from a paper from

805

00:31:47,359 --> 00:31:51,500

Bella Cerf at all in 2007 this is tens

806

00:31:50,119 --> 00:31:53,000

of degrees across in the sky and they

807

00:31:51,500 --> 00:31:55,220

basically he basically summed up all the

808

00:31:53,000 --> 00:31:57,289

data from this scan of the sky and this

809

00:31:55,220 --> 00:31:58,309

scan revealed a lot of structure in the

810

00:31:57,289 --> 00:31:59,389

nearby universe we didn't know about

811

00:31:58,309 --> 00:32:00,950

before and you're like is already

812

00:31:59,390 --> 00:32:03,320

probably picking up on some of it but

813  
00:32:00,950 --> 00:32:05,180  
I'll highlight it here so in white I've

814  
00:32:03,319 --> 00:32:07,099  
highlighted three streams of tidal

815  
00:32:05,180 --> 00:32:09,500  
debris so this is the Sagittarii stream

816  
00:32:07,099 --> 00:32:10,759  
along here this is the orphan stream

817  
00:32:09,500 --> 00:32:13,579  
over here and this is the Montessori

818  
00:32:10,759 --> 00:32:15,289  
ring these are debris streams from

819  
00:32:13,579 --> 00:32:16,669  
satellite galaxies that fell into the

820  
00:32:15,289 --> 00:32:18,349  
gravitational well the Milky Way and

821  
00:32:16,670 --> 00:32:20,360  
then got disrupted by the tidal forces

822  
00:32:18,349 --> 00:32:22,490  
so the GAT the galaxies not really there

823  
00:32:20,359 --> 00:32:24,409  
anymore it's getting eaten alive by the

824  
00:32:22,490 --> 00:32:26,180  
Milky Way's gravitational well and it's

825  
00:32:24,410 --> 00:32:29,029  
just strewn across the sky this stream

826  
00:32:26,180 --> 00:32:30,590  
of stars here then they also found a lot

827

00:32:29,029 --> 00:32:32,029  
of other little satellite galaxies which

828  
00:32:30,589 --> 00:32:33,559  
I've highlighted here in pink so these

829  
00:32:32,029 --> 00:32:34,670  
are new galaxies that were too faint to

830  
00:32:33,559 --> 00:32:36,889  
be noticed before but they're little

831  
00:32:34,670 --> 00:32:38,720  
over densities of stars so this went

832  
00:32:36,890 --> 00:32:40,220  
part of the way towards solving the

833  
00:32:38,720 --> 00:32:42,200  
missing satellite problems we had a few

834  
00:32:40,220 --> 00:32:43,700  
dozen galaxies and this found that well

835  
00:32:42,200 --> 00:32:44,990  
okay some of them are being disrupted

836  
00:32:43,700 --> 00:32:46,700  
which is making them hard to see these

837  
00:32:44,990 --> 00:32:48,650  
big streams and then other little ones

838  
00:32:46,700 --> 00:32:50,930  
were too faint to see these little faint

839  
00:32:48,650 --> 00:32:52,519  
ones are excellent candidates for these

840  
00:32:50,930 --> 00:32:53,840  
fossil galaxies that the theorists

841  
00:32:52,519 --> 00:32:55,579

predicted they said okay well we didn't

842

00:32:53,839 --> 00:32:57,589

know about this ones before maybe these

843

00:32:55,579 --> 00:32:59,839

are these ancient fossil galaxies and

844

00:32:57,589 --> 00:33:02,029

there should be a big support for this

845

00:32:59,839 --> 00:33:03,399

theory so these ones we decided at

846

00:33:02,029 --> 00:33:05,539

Target with Hubble

847

00:33:03,400 --> 00:33:07,430

before I go on to that this is the dark

848

00:33:05,539 --> 00:33:09,529

energy survey this came out with results

849

00:33:07,430 --> 00:33:11,630

last year it found nine new satellite

850

00:33:09,529 --> 00:33:12,980

galaxies this is a projection on the sky

851

00:33:11,630 --> 00:33:15,260

of where they found them highlighted in

852

00:33:12,980 --> 00:33:16,549

blue here here's where they are in a

853

00:33:15,259 --> 00:33:17,700

different projection from two different

854

00:33:16,549 --> 00:33:19,169

papers that came out last year

855

00:33:17,700 --> 00:33:20,789

there are a lot of surveys right now

856  
00:33:19,170 --> 00:33:22,350  
from the ground this is a really active

857  
00:33:20,789 --> 00:33:23,670  
subfield of astronomer people are

858  
00:33:22,349 --> 00:33:25,259  
banging away it's mapping the whole sky

859  
00:33:23,670 --> 00:33:26,279  
trying to find the missing satellites

860  
00:33:25,259 --> 00:33:27,809  
but they're not coming up to the

861  
00:33:26,279 --> 00:33:29,160  
hundreds of satellites that theory

862  
00:33:27,809 --> 00:33:30,509  
predicts they're getting out there

863  
00:33:29,160 --> 00:33:32,550  
increasing the number from you know a

864  
00:33:30,509 --> 00:33:33,720  
few dozen to several more dozen but

865  
00:33:32,549 --> 00:33:35,309  
they're not coming up to the hundreds

866  
00:33:33,720 --> 00:33:37,110  
and that's because most of those

867  
00:33:35,309 --> 00:33:39,210  
galaxies are probably dark they have no

868  
00:33:37,109 --> 00:33:41,869  
stars that just comes to Dark Matter but

869  
00:33:39,210 --> 00:33:43,799  
we are finding more and more satellites

870  
00:33:41,869 --> 00:33:45,539  
so just to put things in perspective

871  
00:33:43,799 --> 00:33:47,490  
just to give you a sense of scale here

872  
00:33:45,539 --> 00:33:48,869  
here's a giant spiral galaxy of about a

873  
00:33:47,490 --> 00:33:51,000  
hundred billion stars in the upper left

874  
00:33:48,869 --> 00:33:53,729  
this is like the Milky Way or in

875  
00:33:51,000 --> 00:33:54,960  
Andromeda and down here is New York City

876  
00:33:53,730 --> 00:33:56,339  
I'm from New York's is the comparison

877  
00:33:54,960 --> 00:33:59,329  
going to use so this is 10 million

878  
00:33:56,339 --> 00:34:01,679  
people okay in the city of New York

879  
00:33:59,329 --> 00:34:03,389  
typical galaxies that orbit the Milky

880  
00:34:01,680 --> 00:34:05,100  
Way that we've known about for decades I

881  
00:34:03,390 --> 00:34:07,110  
like this here like for next 10 million

882  
00:34:05,099 --> 00:34:08,489  
stars scale down New York City you're

883  
00:34:07,109 --> 00:34:10,559  
talking about one theater showing The

884

00:34:08,489 --> 00:34:11,609  
Lion King in New York City so this is

885  
00:34:10,559 --> 00:34:14,690  
the relative scale here we're talking

886  
00:34:11,610 --> 00:34:17,309  
about these ultra faint dwarf galaxies

887  
00:34:14,690 --> 00:34:18,990  
go down even further so they only have

888  
00:34:17,309 --> 00:34:20,610  
10,000 stars in them they're barely a

889  
00:34:18,989 --> 00:34:22,469  
galaxy at all and now you're talking

890  
00:34:20,610 --> 00:34:23,970  
about one guy in New York the host of

891  
00:34:22,469 --> 00:34:25,079  
the Jimmy Fallon show that sounds the

892  
00:34:23,969 --> 00:34:27,899  
relative scales here we're talking about

893  
00:34:25,079 --> 00:34:29,699  
so the Giants file like Andromeda or the

894  
00:34:27,900 --> 00:34:31,590  
Milky Way a classical dwarf like Fornax

895  
00:34:29,699 --> 00:34:35,428  
and these new ultra faint dwarf galaxies

896  
00:34:31,590 --> 00:34:37,200  
that were only recently discovered so

897  
00:34:35,429 --> 00:34:38,579  
when you show people the especially

898  
00:34:37,199 --> 00:34:39,839

astronomers when I give this talk to

899

00:34:38,579 --> 00:34:41,219

professional astronomers in particular I

900

00:34:39,840 --> 00:34:42,539

sometimes get into arguments afterwards

901

00:34:41,219 --> 00:34:44,279

they say well why is that even a galaxy

902

00:34:42,539 --> 00:34:45,449

if it only has 10 mm stars in it because

903

00:34:44,280 --> 00:34:48,000

there are star clusters that have many

904

00:34:45,449 --> 00:34:49,710

more stars and that's true so this is a

905

00:34:48,000 --> 00:34:51,059

globular star cluster like the picture

906

00:34:49,710 --> 00:34:53,159

the Frank handed out tonight like a mega

907

00:34:51,059 --> 00:34:54,719

sin this one's actually a picture from

908

00:34:53,159 --> 00:34:56,909

that Andromeda image I took awhile ago

909

00:34:54,719 --> 00:34:58,109

that's a star cluster and Andromeda it's

910

00:34:56,909 --> 00:34:59,789

a cloud of the star cluster of a hundred

911

00:34:58,110 --> 00:35:01,620

thousand stars and this is an ultra

912

00:34:59,789 --> 00:35:03,509

faint dwarf galaxy of 10,000 stars so

913  
00:35:01,619 --> 00:35:04,889  
why is this a galaxy and that's a star

914  
00:35:03,510 --> 00:35:06,870  
cluster and the reason is because it's

915  
00:35:04,889 --> 00:35:09,000  
dark matter as well as talked about

916  
00:35:06,869 --> 00:35:10,710  
earlier globular clusters as far as we

917  
00:35:09,000 --> 00:35:12,449  
can tell have little to no dark matter

918  
00:35:10,710 --> 00:35:13,740  
so if you measure the mass to light

919  
00:35:12,449 --> 00:35:16,079  
ratio which is something astronomers

920  
00:35:13,739 --> 00:35:18,719  
doing these objects in units of the Sun

921  
00:35:16,079 --> 00:35:20,400  
you can amass the light ratio of about

922  
00:35:18,719 --> 00:35:21,750  
two which is consistent with an old

923  
00:35:20,400 --> 00:35:23,340  
population of stars that means there's

924  
00:35:21,750 --> 00:35:25,050  
compared to the Sun there's a you know

925  
00:35:23,340 --> 00:35:27,329  
the ratio of mass to light in the Sun

926  
00:35:25,050 --> 00:35:28,260  
these globular clusters have about twice

927  
00:35:27,329 --> 00:35:29,730  
as much mass to

928  
00:35:28,260 --> 00:35:31,320  
ratio and that's because most of the

929  
00:35:29,730 --> 00:35:33,240  
stars are really faint and dim compared

930  
00:35:31,320 --> 00:35:34,590  
to the Sun most stars and universe are

931  
00:35:33,239 --> 00:35:37,349  
really faint endemic compared to the Sun

932  
00:35:34,590 --> 00:35:40,019  
in contrast these ultra faint Dwarf

933  
00:35:37,349 --> 00:35:41,369  
galaxies have a lot of dark matter again

934  
00:35:40,019 --> 00:35:43,259  
because dark matter is the scaffolding

935  
00:35:41,369 --> 00:35:44,579  
upon which galaxies are built so

936  
00:35:43,260 --> 00:35:46,380  
galaxies have significant dark matter

937  
00:35:44,579 --> 00:35:47,639  
the classical dwarf galaxies we've known

938  
00:35:46,380 --> 00:35:50,309  
about for decades have mass-to-light

939  
00:35:47,639 --> 00:35:51,989  
ratios exceeding 10 and the ultra faint

940  
00:35:50,309 --> 00:35:54,329  
dwarf galaxies have mass-to-light ratios

941

00:35:51,989 --> 00:35:56,039  
exceeding 100 so these new galaxies are

942  
00:35:54,329 --> 00:35:57,329  
almost entirely dark matter this is the

943  
00:35:56,039 --> 00:35:59,039  
big clump of dark matter there with a

944  
00:35:57,329 --> 00:36:00,420  
few stars sprinkled on top which is

945  
00:35:59,039 --> 00:36:02,099  
consistent with this theory that the

946  
00:36:00,420 --> 00:36:03,389  
theorists used to predict you know the

947  
00:36:02,099 --> 00:36:04,920  
solutions the missing satellite problem

948  
00:36:03,389 --> 00:36:06,599  
is that they had the Dark Matter they're

949  
00:36:04,920 --> 00:36:07,769  
a few stars formed and then things were

950  
00:36:06,599 --> 00:36:09,389  
turned off the lights were turned off

951  
00:36:07,769 --> 00:36:12,269  
when when the most of the universe came

952  
00:36:09,389 --> 00:36:13,799  
out in the star formation another big

953  
00:36:12,269 --> 00:36:15,030  
difference is that globular clusters are

954  
00:36:13,800 --> 00:36:17,340  
usually what we call simple stellar

955  
00:36:15,030 --> 00:36:18,630

populations all the stars to first order

956

00:36:17,340 --> 00:36:20,550  
are just one age and one chemical

957

00:36:18,630 --> 00:36:24,150  
composition you have a cloud out there

958

00:36:20,550 --> 00:36:25,769  
in space it collapses you form a bunch

959

00:36:24,150 --> 00:36:27,780  
of stars they all have one age one

960

00:36:25,769 --> 00:36:29,670  
chemical composition galaxies have a

961

00:36:27,780 --> 00:36:31,080  
wide range in ages and a wide range of

962

00:36:29,670 --> 00:36:32,639  
chemical composition that's true of

963

00:36:31,079 --> 00:36:35,429  
every galaxy that we've known about

964

00:36:32,639 --> 00:36:37,049  
until the ones I'll show you tonight so

965

00:36:35,429 --> 00:36:38,039  
this is a plot now of just put these

966

00:36:37,050 --> 00:36:40,050  
things into perspective this is

967

00:36:38,039 --> 00:36:42,090  
luminosity relative to the Sun so 10 to

968

00:36:40,050 --> 00:36:43,830  
the 6 is a million times luminosity of

969

00:36:42,090 --> 00:36:46,559  
the Sun this is diameter in lightyears

970  
00:36:43,829 --> 00:36:47,849  
from one to a thousand so star clusters

971  
00:36:46,559 --> 00:36:49,529  
fall over here these are globular

972  
00:36:47,849 --> 00:36:51,029  
clusters they have up to a million times

973  
00:36:49,530 --> 00:36:52,350  
the luminosity the Sun or maybe even a

974  
00:36:51,030 --> 00:36:53,730  
thousand times the luminosity of the Sun

975  
00:36:52,349 --> 00:36:55,739  
but they're pretty compact than the

976  
00:36:53,730 --> 00:36:57,389  
left-hand side of this diagram the

977  
00:36:55,739 --> 00:36:58,919  
classical dwarf galaxies are shown here

978  
00:36:57,389 --> 00:37:00,480  
in blue so they're much more extended

979  
00:36:58,920 --> 00:37:01,889  
and they're generally brighter than star

980  
00:37:00,480 --> 00:37:03,990  
clusters they're up and to the right

981  
00:37:01,889 --> 00:37:05,759  
these ultra faint dork galaxies are down

982  
00:37:03,989 --> 00:37:07,619  
here they're an extension of these dwarf

983  
00:37:05,760 --> 00:37:09,630  
galaxies to faint your luminosities and

984  
00:37:07,619 --> 00:37:11,819  
smaller sizes but they're not as compact

985  
00:37:09,630 --> 00:37:13,619  
as globular clusters so they're mostly

986  
00:37:11,820 --> 00:37:15,740  
dark matter and they're these wispy

987  
00:37:13,619 --> 00:37:18,210  
things with just a few stars on them and

988  
00:37:15,739 --> 00:37:19,619  
so we decide to look at these six very

989  
00:37:18,210 --> 00:37:21,240  
closely with Hubble because Hubble is

990  
00:37:19,619 --> 00:37:25,769  
excellent in measuring the ages of stars

991  
00:37:21,239 --> 00:37:27,209  
to test these theories so how do we know

992  
00:37:25,769 --> 00:37:28,619  
of a group of stars is old well there's

993  
00:37:27,210 --> 00:37:29,909  
two ways you can go about it one is to

994  
00:37:28,619 --> 00:37:31,199  
get spectra these stars you take the

995  
00:37:29,909 --> 00:37:33,089  
light from the stars you've spread it

996  
00:37:31,199 --> 00:37:35,099  
out into its rainbow and then you look

997  
00:37:33,090 --> 00:37:36,570  
for features in that spectrum to see

998

00:37:35,099 --> 00:37:38,519  
what kind of metal abundances there are

999  
00:37:36,570 --> 00:37:39,900  
and so if we want to see if it's old it

1000  
00:37:38,519 --> 00:37:41,570  
should have a low abundance of metals if

1001  
00:37:39,900 --> 00:37:42,950  
it was born in the early universe before

1002  
00:37:41,570 --> 00:37:44,660  
there are many generations of stars the

1003  
00:37:42,949 --> 00:37:45,799  
gas should be pretty pristine and so

1004  
00:37:44,659 --> 00:37:48,049  
there shouldn't be a very high chemical

1005  
00:37:45,800 --> 00:37:49,160  
composition in these stars we also do

1006  
00:37:48,050 --> 00:37:51,080  
photometry we measure the brightness

1007  
00:37:49,159 --> 00:37:52,759  
--is and colors of the stars and when we

1008  
00:37:51,079 --> 00:37:55,759  
do that we can see what masses are left

1009  
00:37:52,760 --> 00:37:57,260  
only low mass stars less massive than

1010  
00:37:55,760 --> 00:37:59,510  
the Sun should be present if it's old

1011  
00:37:57,260 --> 00:38:01,880  
because massive stars more massive than

1012  
00:37:59,510 --> 00:38:03,260

the Sun die very quickly so these are

1013

00:38:01,880 --> 00:38:07,160

the two tests we do to see if these

1014

00:38:03,260 --> 00:38:09,230

things are actually old galaxies so

1015

00:38:07,159 --> 00:38:11,119

here's a spectrum from ultra main Dorf

1016

00:38:09,230 --> 00:38:12,230

galaxies and it tells us a couple

1017

00:38:11,119 --> 00:38:13,699

different things so well you know it

1018

00:38:12,230 --> 00:38:15,889

gets broken into its constituent light

1019

00:38:13,699 --> 00:38:17,210

from blue green to red and these little

1020

00:38:15,889 --> 00:38:19,069

dark patches and their absorption

1021

00:38:17,210 --> 00:38:21,349

features from metals in the atmosphere

1022

00:38:19,070 --> 00:38:23,840

of the star so by usually measuring the

1023

00:38:21,349 --> 00:38:25,250

velocities we from the Doppler effect of

1024

00:38:23,840 --> 00:38:26,960

these absorption features we can measure

1025

00:38:25,250 --> 00:38:28,460

the motions of these stars and the

1026

00:38:26,960 --> 00:38:30,289

motions of the stars and the old faint

1027  
00:38:28,460 --> 00:38:32,960  
Dwarf galaxies imply there's a lot of

1028  
00:38:30,289 --> 00:38:35,239  
dark matter there so the matter in these

1029  
00:38:32,960 --> 00:38:36,710  
galaxies the luminous matter is feeling

1030  
00:38:35,239 --> 00:38:39,199  
the presence of the gravity gravity from

1031  
00:38:36,710 --> 00:38:40,670  
the dark matter the absorption features

1032  
00:38:39,199 --> 00:38:42,349  
these little patches here are also very

1033  
00:38:40,670 --> 00:38:44,450  
weak so it means these stars have a

1034  
00:38:42,349 --> 00:38:46,579  
hundred to ten thousand times fewer

1035  
00:38:44,449 --> 00:38:48,079  
metals than the Sun so these stars were

1036  
00:38:46,579 --> 00:38:49,639  
really born in the early universe when

1037  
00:38:48,079 --> 00:38:51,739  
the gas was still pretty pristine and

1038  
00:38:49,639 --> 00:38:53,449  
many this is also a little cottage

1039  
00:38:51,739 --> 00:38:54,799  
industry in astronomy a lot of people

1040  
00:38:53,449 --> 00:38:56,389  
are looking for the first stars and the

1041  
00:38:54,800 --> 00:38:57,800  
earliest stars and oldest stars and

1042  
00:38:56,389 --> 00:38:59,119  
folks who are looking for the most

1043  
00:38:57,800 --> 00:39:00,650  
metal-poor stars have found a lot of

1044  
00:38:59,119 --> 00:39:01,880  
them in these ultra faint dwarf galaxies

1045  
00:39:00,650 --> 00:39:05,570  
so this is fertile ground for these

1046  
00:39:01,880 --> 00:39:06,920  
searches so this is the same handout you

1047  
00:39:05,570 --> 00:39:08,600  
have tonight this Omega sign so it's

1048  
00:39:06,920 --> 00:39:10,490  
fortunate that Frank came to that hands

1049  
00:39:08,599 --> 00:39:11,719  
out I'm going to sort this is an image

1050  
00:39:10,489 --> 00:39:13,789  
from Hubble with the Wide Field Camera 3

1051  
00:39:11,719 --> 00:39:15,259  
is a camera I worked on before I

1052  
00:39:13,789 --> 00:39:17,090  
switched over to James Webb for a while

1053  
00:39:15,260 --> 00:39:20,150  
I'm going to sort this this is from my

1054  
00:39:17,090 --> 00:39:21,829  
collaborator colleague J Anderson we

1055

00:39:20,150 --> 00:39:23,900  
sort this in color first from left to

1056  
00:39:21,829 --> 00:39:25,849  
right so hotter stars that are blue will

1057  
00:39:23,900 --> 00:39:28,940  
be on the left cooler stars that are red

1058  
00:39:25,849 --> 00:39:30,230  
will be on the right then we're going to

1059  
00:39:28,940 --> 00:39:31,909  
sort it in luminosity with brighter

1060  
00:39:30,230 --> 00:39:35,389  
stars at the top fainter stars at the

1061  
00:39:31,909 --> 00:39:37,460  
bottom when you do that you see that

1062  
00:39:35,389 --> 00:39:39,379  
stars don't just have random colors and

1063  
00:39:37,460 --> 00:39:40,940  
random brightnesses it actually traced

1064  
00:39:39,380 --> 00:39:42,500  
out a very specific pattern my wife

1065  
00:39:40,940 --> 00:39:44,599  
calls this the duct diagram because our

1066  
00:39:42,500 --> 00:39:46,099  
minds are of a duct but anyway here's

1067  
00:39:44,599 --> 00:39:48,019  
the body here's the neck who's the beak

1068  
00:39:46,099 --> 00:39:50,119  
but main sequence stars like the Sun

1069  
00:39:48,019 --> 00:39:53,269

that are burning hydrogen fall down here

1070

00:39:50,119 --> 00:39:54,469

and then have to exhaust their hydrogen

1071

00:39:53,269 --> 00:39:55,340

they go up here and become red giant

1072

00:39:54,469 --> 00:39:57,379

stars

1073

00:39:55,340 --> 00:39:58,579

and then they finally burn helium they

1074

00:39:57,380 --> 00:40:00,079

become this thing called horizontal

1075

00:39:58,579 --> 00:40:02,269

branch stars because this distributions

1076

00:40:00,079 --> 00:40:04,460

horizontal say burn helium then they die

1077

00:40:02,269 --> 00:40:06,289

as white dwarfs so when you sort a

1078

00:40:04,460 --> 00:40:08,059

population of stars by brightness and

1079

00:40:06,289 --> 00:40:09,500

color they're not random they trace had

1080

00:40:08,059 --> 00:40:11,809

a very specific pattern that's the life

1081

00:40:09,500 --> 00:40:13,340

cycle of the star and that's how we can

1082

00:40:11,809 --> 00:40:15,799

use that information to tell how old a

1083

00:40:13,340 --> 00:40:17,269

group of stars of this so that's where

1084  
00:40:15,800 --> 00:40:18,710  
those stars now fall in that image of a

1085  
00:40:17,269 --> 00:40:24,230  
magazine which is on the handout over

1086  
00:40:18,710 --> 00:40:26,000  
here so here's measurements of a galaxy

1087  
00:40:24,230 --> 00:40:27,559  
this is brightness again on the y axis

1088  
00:40:26,000 --> 00:40:29,659  
here in these funny hoots astronomers

1089  
00:40:27,559 --> 00:40:32,779  
use so this is in a filter 8:14 so 800

1090  
00:40:29,659 --> 00:40:35,089  
nanometer filter 606 minus 814 600

1091  
00:40:32,780 --> 00:40:36,500  
nanometer minus 800 nanometer filter so

1092  
00:40:35,090 --> 00:40:38,539  
this is a color with redder stars on the

1093  
00:40:36,500 --> 00:40:40,130  
right bluer stars on the left brighter

1094  
00:40:38,539 --> 00:40:42,590  
stars at the top fainter stars at the

1095  
00:40:40,130 --> 00:40:45,530  
bottom hydrogen burning stars fall along

1096  
00:40:42,590 --> 00:40:47,450  
here here's this kink and then they

1097  
00:40:45,530 --> 00:40:49,010  
exhaust hydrogen the core and then you

1098  
00:40:47,449 --> 00:40:51,079  
become a red giant star and that's how

1099  
00:40:49,010 --> 00:40:54,080  
you measure the age of a population so

1100  
00:40:51,079 --> 00:40:55,849  
these are low mass hydrogen burning

1101  
00:40:54,079 --> 00:40:57,529  
stars more massive hydrogen burning

1102  
00:40:55,849 --> 00:41:00,139  
stars and then they peel off and become

1103  
00:40:57,530 --> 00:41:02,090  
red giants so these are stars that are

1104  
00:41:00,139 --> 00:41:03,529  
still burning hydrogen in the core these

1105  
00:41:02,090 --> 00:41:06,410  
are stars that exhausted hydrogen the

1106  
00:41:03,530 --> 00:41:08,390  
quorum become Giants so that's the clock

1107  
00:41:06,409 --> 00:41:09,949  
that little kink right there tells you

1108  
00:41:08,389 --> 00:41:10,909  
that's the best clock in astronomy right

1109  
00:41:09,949 --> 00:41:12,259  
now there's a lot of different ways to

1110  
00:41:10,909 --> 00:41:13,789  
measure the ages of stars but that's the

1111  
00:41:12,260 --> 00:41:17,420  
gold standard since Allan Sandage

1112

00:41:13,789 --> 00:41:19,159  
started doing this in the 50s so this is

1113  
00:41:17,420 --> 00:41:20,930  
for you get for a population that's 13

1114  
00:41:19,159 --> 00:41:22,129  
billion years old an ancient population

1115  
00:41:20,929 --> 00:41:23,559  
and that's what it would look like for a

1116  
00:41:22,130 --> 00:41:25,610  
population that's 6 billion years old

1117  
00:41:23,559 --> 00:41:26,480  
and that's what it is for 13 billion

1118  
00:41:25,610 --> 00:41:28,039  
years old it's a very dramatic

1119  
00:41:26,480 --> 00:41:29,599  
difference and the reason why is because

1120  
00:41:28,039 --> 00:41:31,789  
the massive stars die more quickly than

1121  
00:41:29,599 --> 00:41:32,989  
the less massive stars ironically if

1122  
00:41:31,789 --> 00:41:34,369  
you're a massive star you have a lot of

1123  
00:41:32,989 --> 00:41:35,599  
fuel but you're very bright you burn it

1124  
00:41:34,369 --> 00:41:37,639  
very quickly so you'll leave the main

1125  
00:41:35,599 --> 00:41:41,569  
sequence to become a giant more rapidly

1126  
00:41:37,639 --> 00:41:44,029

than these stars down here so here's the

1127

00:41:41,570 --> 00:41:46,789

Carina two classical dwarf galaxies is

1128

00:41:44,030 --> 00:41:48,680

out in the local group again a pretty

1129

00:41:46,789 --> 00:41:51,170

massive dwarf galaxy we've known about

1130

00:41:48,679 --> 00:41:52,759

for decades and here's its color

1131

00:41:51,170 --> 00:41:54,470

magnitude diagram so this is brightness

1132

00:41:52,760 --> 00:41:56,950

on the y axis color on the x axis and

1133

00:41:54,469 --> 00:41:59,359

you get these three distinct little

1134

00:41:56,949 --> 00:42:01,219

shapes here each of those is from a

1135

00:41:59,360 --> 00:42:04,010

burst of star formation if I put models

1136

00:42:01,219 --> 00:42:05,419

on top of that this is where stars about

1137

00:42:04,010 --> 00:42:07,550

half a billion years old would lie and

1138

00:42:05,420 --> 00:42:08,900

this brighter curve here stars five

1139

00:42:07,550 --> 00:42:10,400

billion years old with

1140

00:42:08,900 --> 00:42:12,230

along this intermediate curve here and

1141  
00:42:10,400 --> 00:42:14,030  
really old stars 11 billion years old

1142  
00:42:12,230 --> 00:42:15,559  
would lie here so this is a kind of

1143  
00:42:14,030 --> 00:42:17,600  
curious galaxy you don't usually see

1144  
00:42:15,559 --> 00:42:18,920  
these episodes of star formation but in

1145  
00:42:17,599 --> 00:42:20,150  
this one you did and it makes it kind of

1146  
00:42:18,920 --> 00:42:22,369  
interesting to show the clock in three

1147  
00:42:20,150 --> 00:42:24,289  
different paces one two three and this

1148  
00:42:22,369 --> 00:42:25,609  
is similar to the stories we've seen for

1149  
00:42:24,289 --> 00:42:27,079  
a lot of dwarf galaxies there's a wide

1150  
00:42:25,610 --> 00:42:28,130  
range of Ages you know you don't see

1151  
00:42:27,079 --> 00:42:29,569  
just old stars you know interesting

1152  
00:42:28,130 --> 00:42:32,990  
young stars usually see a wide range of

1153  
00:42:29,570 --> 00:42:34,280  
Ages so here's the ones we decided to

1154  
00:42:32,989 --> 00:42:36,500  
look at again tonight the ultra main

1155  
00:42:34,280 --> 00:42:39,650  
doors and again I looked at these with

1156  
00:42:36,500 --> 00:42:41,090  
Hubble they're kind of a sample of that

1157  
00:42:39,650 --> 00:42:43,400  
six galaxies out of the recently

1158  
00:42:41,090 --> 00:42:44,660  
discovered ones from Sloan and this is

1159  
00:42:43,400 --> 00:42:46,130  
what it looks like when Hubble looks at

1160  
00:42:44,659 --> 00:42:47,929  
one of these so in the background here

1161  
00:42:46,130 --> 00:42:49,789  
I'm showing a Digital Sky Survey image

1162  
00:42:47,929 --> 00:42:51,049  
and then Hubble has a pretty small field

1163  
00:42:49,789 --> 00:42:53,150  
of view compared to some of these ground

1164  
00:42:51,050 --> 00:42:54,740  
telescopes so the footprint from Hubble

1165  
00:42:53,150 --> 00:42:56,930  
from its advanced camera for surveys is

1166  
00:42:54,739 --> 00:42:59,659  
one of these blue tiles here we kind of

1167  
00:42:56,929 --> 00:43:01,849  
went and tile that part of the galaxy we

1168  
00:42:59,659 --> 00:43:03,859  
turned on Wide Field Camera 3 in pink

1169

00:43:01,849 --> 00:43:05,059  
here in parallel it kind of missed the

1170  
00:43:03,860 --> 00:43:06,170  
galaxies here so it was just getting a

1171  
00:43:05,059 --> 00:43:08,960  
sample of some of the stars in the

1172  
00:43:06,170 --> 00:43:12,409  
background this is about 200 arc seconds

1173  
00:43:08,960 --> 00:43:14,570  
on the side this is Leo 4 so this

1174  
00:43:12,409 --> 00:43:15,980  
galaxies further out from the Milky Way

1175  
00:43:14,570 --> 00:43:17,390  
so it's a little more compact on the sky

1176  
00:43:15,980 --> 00:43:18,800  
so if you look carefully you can see

1177  
00:43:17,389 --> 00:43:20,629  
there's an over density of stars right

1178  
00:43:18,800 --> 00:43:22,490  
here compared to the background and so

1179  
00:43:20,630 --> 00:43:24,289  
we stuck a CS the advanced camera for

1180  
00:43:22,489 --> 00:43:25,549  
surveys right here we stuck will feel

1181  
00:43:24,289 --> 00:43:27,739  
camera 3 out here it got pretty much

1182  
00:43:25,550 --> 00:43:31,010  
nothing but this one measured the

1183  
00:43:27,739 --> 00:43:34,459

galaxies and so that's the image we got

1184

00:43:31,010 --> 00:43:37,880

of Leo 4 in that patch that's this patch

1185

00:43:34,460 --> 00:43:39,740

of sky right here this is the Hubble

1186

00:43:37,880 --> 00:43:41,090

image it's about 16 orbits we hand out

1187

00:43:39,739 --> 00:43:42,319

time on Hubble and units of orbits

1188

00:43:41,090 --> 00:43:43,880

Hubble goes around the earth every 96

1189

00:43:42,320 --> 00:43:45,950

minutes that's the currency and Hubble

1190

00:43:43,880 --> 00:43:48,470

so you know people asked for 5 orbits 10

1191

00:43:45,949 --> 00:43:50,149

orbits 100 orbits this was 16 orbits on

1192

00:43:48,469 --> 00:43:52,279

this one galaxy we looked at six

1193

00:43:50,150 --> 00:43:53,869

galaxies in total it's a fairly deep

1194

00:43:52,280 --> 00:43:55,220

image like a lot of images with Hubble

1195

00:43:53,869 --> 00:43:56,029

when you're trying to go deep you get

1196

00:43:55,219 --> 00:43:57,079

the rest of the universe in the

1197

00:43:56,030 --> 00:43:59,000

background so there's all these really

1198  
00:43:57,079 --> 00:44:00,199  
pretty galaxies in the background and a

1199  
00:43:59,000 --> 00:44:01,429  
lot of people like those because the

1200  
00:44:00,199 --> 00:44:03,079  
stars are just points that are kind of

1201  
00:44:01,429 --> 00:44:04,009  
boring but for me it's wasted real

1202  
00:44:03,079 --> 00:44:05,000  
estate because every one of these

1203  
00:44:04,010 --> 00:44:06,410  
patches is where I can't make

1204  
00:44:05,000 --> 00:44:07,789  
measurements of the star so people like

1205  
00:44:06,409 --> 00:44:10,460  
these galaxies they're just kind of

1206  
00:44:07,789 --> 00:44:12,199  
irritating to me but I'll zoom in on a

1207  
00:44:10,460 --> 00:44:14,480  
patch here so here's this yellow box

1208  
00:44:12,199 --> 00:44:15,859  
that I'm going to zoom in so again you

1209  
00:44:14,480 --> 00:44:17,599  
have these nice beautiful galaxies in

1210  
00:44:15,860 --> 00:44:19,670  
the background which I just mask out and

1211  
00:44:17,599 --> 00:44:22,279  
far away and then you have these points

1212  
00:44:19,670 --> 00:44:24,289  
which are stars in Leo for

1213  
00:44:22,280 --> 00:44:26,060  
I like two of them these are the most

1214  
00:44:24,289 --> 00:44:28,579  
massive hydrogen burning stars in Leo

1215  
00:44:26,059 --> 00:44:29,989  
four so these tell you the clock so when

1216  
00:44:28,579 --> 00:44:31,789  
you get measurements of the brightness

1217  
00:44:29,989 --> 00:44:33,529  
and colors of these stars that tells you

1218  
00:44:31,789 --> 00:44:35,329  
how well the galaxy is so these are the

1219  
00:44:33,530 --> 00:44:39,320  
brightest hydrogen burning stars in Leo

1220  
00:44:35,329 --> 00:44:40,909  
four so here's the image again and what

1221  
00:44:39,320 --> 00:44:43,309  
I'm going to do now is highlight the

1222  
00:44:40,909 --> 00:44:45,319  
stars in this image and show you how

1223  
00:44:43,309 --> 00:44:46,670  
they tell us the clock for the galaxies

1224  
00:44:45,320 --> 00:44:48,590  
so this is the these are the stars in

1225  
00:44:46,670 --> 00:44:50,750  
Leo 4 if I sort them in color and

1226

00:44:48,590 --> 00:44:52,490  
luminosity that's where they fall at an

1227  
00:44:50,750 --> 00:44:54,889  
age of around 13 billion years and now I

1228  
00:44:52,489 --> 00:44:56,779  
can use theory of stellar evolution to

1229  
00:44:54,889 --> 00:44:58,219  
roll back the clock here so now I'm

1230  
00:44:56,780 --> 00:44:59,720  
taking the data and just morphing it

1231  
00:44:58,219 --> 00:45:01,399  
backwards in time towards the Big Bang

1232  
00:44:59,719 --> 00:45:03,049  
so now this is what the data would look

1233  
00:45:01,400 --> 00:45:05,200  
like if we made that measurement a

1234  
00:45:03,050 --> 00:45:07,580  
billion years after the galaxy was born

1235  
00:45:05,199 --> 00:45:09,500  
so this brightness over here color over

1236  
00:45:07,579 --> 00:45:11,779  
here and now the clocks rolling forwards

1237  
00:45:09,500 --> 00:45:13,130  
to the present era so five billion years

1238  
00:45:11,780 --> 00:45:14,720  
six million years and here's the clock

1239  
00:45:13,130 --> 00:45:17,570  
is right here this kink this tells you

1240  
00:45:14,719 --> 00:45:18,919

how old the population of stars is until

1241

00:45:17,570 --> 00:45:21,320

you get to the galaxy being about 13

1242

00:45:18,920 --> 00:45:22,700

billion years old today and those are

1243

00:45:21,320 --> 00:45:28,640

the points and this is where they fall

1244

00:45:22,699 --> 00:45:30,559

in that image so these the data we got

1245

00:45:28,639 --> 00:45:31,789

so we got six of these duck diagrams

1246

00:45:30,559 --> 00:45:33,289

like I said these contracted diaries

1247

00:45:31,789 --> 00:45:35,150

with my wife calls on duck diagrams and

1248

00:45:33,289 --> 00:45:36,920

the first one we got was here and now

1249

00:45:35,150 --> 00:45:38,420

here's full disclosure I'm an observer I

1250

00:45:36,920 --> 00:45:40,340

have a team of folks on here some work

1251

00:45:38,420 --> 00:45:42,170

on Hubble like me some work on Keck I

1252

00:45:40,340 --> 00:45:44,030

have some theorists on the team and I'm

1253

00:45:42,170 --> 00:45:45,860

used to theorist not to be disparaging a

1254

00:45:44,030 --> 00:45:47,420

theorist coming up with a theory and

1255  
00:45:45,860 --> 00:45:49,910  
then you go test and you go well let me

1256  
00:45:47,420 --> 00:45:51,860  
revise that theory so we got these data

1257  
00:45:49,909 --> 00:45:53,599  
right here and because I work on these

1258  
00:45:51,860 --> 00:45:54,980  
kind of diagrams a lot I immediately saw

1259  
00:45:53,599 --> 00:45:57,019  
in my office that this was a very

1260  
00:45:54,980 --> 00:45:57,860  
ancient population which is not what I

1261  
00:45:57,019 --> 00:45:59,960  
was expecting

1262  
00:45:57,860 --> 00:46:01,670  
I wrote this proposal to measure how all

1263  
00:45:59,960 --> 00:46:03,139  
these stars were and I was sure just

1264  
00:46:01,670 --> 00:46:04,579  
like every galaxy we've ever measured

1265  
00:46:03,139 --> 00:46:06,829  
before there would be young stars and

1266  
00:46:04,579 --> 00:46:09,110  
old stars but instead the stars were all

1267  
00:46:06,829 --> 00:46:10,159  
just old and I almost fell out of my

1268  
00:46:09,110 --> 00:46:11,300  
chair and you're looking at these and

1269  
00:46:10,159 --> 00:46:13,250  
going okay it's a bunch of yellow dots

1270  
00:46:11,300 --> 00:46:14,870  
but for me it was really surprising

1271  
00:46:13,250 --> 00:46:16,579  
because I did not expect the theory to

1272  
00:46:14,869 --> 00:46:18,109  
be true and so I called up Jason

1273  
00:46:16,579 --> 00:46:19,940  
Tomlinson who made that simulation in

1274  
00:46:18,110 --> 00:46:21,230  
the beginning of my talk tried him down

1275  
00:46:19,940 --> 00:46:22,639  
to my office he works one floor up for

1276  
00:46:21,230 --> 00:46:23,659  
me here in this building and he said

1277  
00:46:22,639 --> 00:46:24,889  
well yeah that's what's supposed to do

1278  
00:46:23,659 --> 00:46:26,179  
they're supposed to be old and I said

1279  
00:46:24,889 --> 00:46:27,650  
yeah but I didn't think that was really

1280  
00:46:26,179 --> 00:46:28,639  
going to happen I thought there was

1281  
00:46:27,650 --> 00:46:30,170  
going to be young stars and old stars

1282  
00:46:28,639 --> 00:46:32,239  
just like every galaxy we've ever looked

1283

00:46:30,170 --> 00:46:33,940  
at before so those were the first data

1284  
00:46:32,239 --> 00:46:35,969  
that executed the program Hercules

1285  
00:46:33,940 --> 00:46:37,889  
satellite the Milky Way and then

1286  
00:46:35,969 --> 00:46:39,480  
got the other five galaxies and they're

1287  
00:46:37,889 --> 00:46:40,529  
all in different positions in each of

1288  
00:46:39,480 --> 00:46:41,608  
these diagrams here cuz some are closed

1289  
00:46:40,530 --> 00:46:44,160  
or some are furthest that makes the

1290  
00:46:41,608 --> 00:46:45,239  
stars brighter and fainter but if you do

1291  
00:46:44,159 --> 00:46:46,889  
this kind of work you look at each of

1292  
00:46:45,239 --> 00:46:48,149  
these you say oh my god the stars are

1293  
00:46:46,889 --> 00:46:49,618  
really ancient every one of these

1294  
00:46:48,150 --> 00:46:51,000  
galaxies they also look very similar

1295  
00:46:49,619 --> 00:46:53,119  
these diagrams all look very similar to

1296  
00:46:51,000 --> 00:46:56,010  
each other so just for a comparison

1297  
00:46:53,119 --> 00:46:57,750

without using any theory I'm going to

1298

00:46:56,010 --> 00:46:59,550

take data from another well studied

1299

00:46:57,750 --> 00:47:00,719

object that we use to make comparisons

1300

00:46:59,550 --> 00:47:03,630

the data like I just showed you this is

1301

00:47:00,719 --> 00:47:05,489

m92 NGC 634 one it's one of the most

1302

00:47:03,630 --> 00:47:06,090

well studied ancient objects in the

1303

00:47:05,489 --> 00:47:08,039

universe

1304

00:47:06,090 --> 00:47:10,349

it's a metal-poor star cluster Allan

1305

00:47:08,039 --> 00:47:12,420

Sandage looked at this in the 1950s to

1306

00:47:10,349 --> 00:47:13,650

figure out how stars evolve it's an

1307

00:47:12,420 --> 00:47:15,599

ancient star cluster

1308

00:47:13,650 --> 00:47:17,099

its chemical abundances are such that

1309

00:47:15,599 --> 00:47:19,380

the metals in the atmosphere are less

1310

00:47:17,099 --> 00:47:21,630

than 1% of the abundance in the Sun it's

1311

00:47:19,380 --> 00:47:24,240

a globular cluster this is a half second

1312  
00:47:21,630 --> 00:47:25,470  
exposure on Hubble Allan Sandage would

1313  
00:47:24,239 --> 00:47:26,729  
spend nights of the telescope in the

1314  
00:47:25,469 --> 00:47:27,449  
ground looking at this with Hubble's so

1315  
00:47:26,730 --> 00:47:28,980  
powerful this is

1316  
00:47:27,449 --> 00:47:30,719  
oops this is just a half second exposure

1317  
00:47:28,980 --> 00:47:33,449  
this is the advanced camera for surveys

1318  
00:47:30,719 --> 00:47:35,459  
it's kind of like your CC the CCD chip

1319  
00:47:33,449 --> 00:47:37,649  
on here is kind of like your chip on

1320  
00:47:35,460 --> 00:47:39,300  
your digital camera now there's a crack

1321  
00:47:37,650 --> 00:47:41,338  
down the middle here splits the chip

1322  
00:47:39,300 --> 00:47:42,960  
into two halves so that's why you see

1323  
00:47:41,338 --> 00:47:44,909  
this two sections here but it's a 4k by

1324  
00:47:42,960 --> 00:47:46,949  
4k image the 16 megapixel camera

1325  
00:47:44,909 --> 00:47:49,819  
basically on Hubble and all these are

1326  
00:47:46,949 --> 00:47:52,919  
stars in this globular cluster m92

1327  
00:47:49,820 --> 00:47:55,440  
this is the climactic diagram from those

1328  
00:47:52,920 --> 00:47:56,970  
data so this is the luminosity here

1329  
00:47:55,440 --> 00:47:59,400  
bright stars at the top here's the color

1330  
00:47:56,969 --> 00:48:00,659  
red stars on the right and again stars

1331  
00:47:59,400 --> 00:48:02,160  
don't just have random colors and

1332  
00:48:00,659 --> 00:48:04,440  
brightnesses they trace out this very

1333  
00:48:02,159 --> 00:48:05,969  
specific pattern that's the lifecycle of

1334  
00:48:04,440 --> 00:48:07,320  
the star hydrogen burning stars the

1335  
00:48:05,969 --> 00:48:08,399  
exhaust hydrogen go up here become red

1336  
00:48:07,320 --> 00:48:11,070  
giants that come over here and burn

1337  
00:48:08,400 --> 00:48:13,139  
helium and this is the kink right here

1338  
00:48:11,070 --> 00:48:15,510  
it tells you the age so what I can do is

1339  
00:48:13,139 --> 00:48:17,338  
I can say all right I'll highlight the

1340

00:48:15,510 --> 00:48:19,349  
helium burning stars over here and then

1341  
00:48:17,338 --> 00:48:21,299  
I'll draw a curve through this and I'll

1342  
00:48:19,349 --> 00:48:22,980  
just compare that to the data I got on

1343  
00:48:21,300 --> 00:48:24,539  
those galaxies this is an ancient star

1344  
00:48:22,980 --> 00:48:27,869  
cluster 13 billion years old that's been

1345  
00:48:24,539 --> 00:48:29,699  
studied for 60 years so here are the

1346  
00:48:27,869 --> 00:48:32,910  
data on the new galaxies that we found

1347  
00:48:29,699 --> 00:48:33,989  
and here's where the m92 data fall when

1348  
00:48:32,909 --> 00:48:35,969  
you superimpose them at the same

1349  
00:48:33,989 --> 00:48:38,368  
distance and goes right through the data

1350  
00:48:35,969 --> 00:48:39,509  
in every case and really this was I know

1351  
00:48:38,369 --> 00:48:41,099  
how shocking is to you but I was

1352  
00:48:39,510 --> 00:48:42,480  
flabbergasted when we did this that all

1353  
00:48:41,099 --> 00:48:44,039  
these galaxies which like I said

1354  
00:48:42,480 --> 00:48:45,570

galaxies by definition usually have a

1355

00:48:44,039 --> 00:48:47,550

wide range in age every single one of

1356

00:48:45,570 --> 00:48:49,200

them looks like I'm 92 so not only do

1357

00:48:47,550 --> 00:48:50,280

they all look exactly like each

1358

00:48:49,199 --> 00:48:52,379

there - first order you know it's at

1359

00:48:50,280 --> 00:48:53,760

least by I so this was kind of

1360

00:48:52,380 --> 00:48:56,039

astonishing but it's a pretty good

1361

00:48:53,760 --> 00:48:57,330

support for this theory of what's

1362

00:48:56,039 --> 00:48:59,130

happening to missing satellites we've

1363

00:48:57,329 --> 00:49:01,710

known about these galaxies for decades

1364

00:48:59,130 --> 00:49:03,660

that form a wide range of stars or wide

1365

00:49:01,710 --> 00:49:05,610

range ages but the theory of the missing

1366

00:49:03,659 --> 00:49:07,379

satellites you know why we don't find

1367

00:49:05,610 --> 00:49:09,150

them is that most of them never form

1368

00:49:07,380 --> 00:49:10,950

stars at all and between those two

1369  
00:49:09,150 --> 00:49:12,240  
categories the ones that been forming

1370  
00:49:10,949 --> 00:49:14,069  
stars forever the ones that never form

1371  
00:49:12,239 --> 00:49:16,469  
stars at all should be this transition

1372  
00:49:14,070 --> 00:49:18,030  
group of galaxies that just formed old

1373  
00:49:16,469 --> 00:49:19,199  
stars and then we're snuffed out in the

1374  
00:49:18,030 --> 00:49:20,910  
early universe and that's what this is

1375  
00:49:19,199 --> 00:49:22,919  
telling us these galaxies form stars

1376  
00:49:20,909 --> 00:49:24,899  
right around the same time m92 was

1377  
00:49:22,920 --> 00:49:27,960  
formed and then we're snuffed out when

1378  
00:49:24,900 --> 00:49:29,430  
the lights came on these are pretty

1379  
00:49:27,960 --> 00:49:31,170  
boring data about just show them this is

1380  
00:49:29,429 --> 00:49:33,239  
the Keck data we got so this is number

1381  
00:49:31,170 --> 00:49:35,760  
of stars versus the chemical composition

1382  
00:49:33,239 --> 00:49:37,679  
so four stars here this is one percent

1383  
00:49:35,760 --> 00:49:40,020  
of the subtler composition this is 0.1%

1384  
00:49:37,679 --> 00:49:41,699  
this is 0.01 percent so these are very

1385  
00:49:40,019 --> 00:49:43,280  
low metallicity compared to the sun and

1386  
00:49:41,699 --> 00:49:45,719  
this is number of stars in the galaxy

1387  
00:49:43,280 --> 00:49:47,550  
compared to what fraction of the solar

1388  
00:49:45,719 --> 00:49:49,619  
composition there is so most of the

1389  
00:49:47,550 --> 00:49:51,210  
stars fall between 0.1 percent and 10

1390  
00:49:49,619 --> 00:49:53,159  
percent of the solar composition so the

1391  
00:49:51,210 --> 00:49:54,630  
stars are very metal-poor they're very

1392  
00:49:53,159 --> 00:49:56,369  
few metals so they're born from pristine

1393  
00:49:54,630 --> 00:49:57,599  
gas in the early universe this is again

1394  
00:49:56,369 --> 00:50:00,389  
supporting evidence that these are

1395  
00:49:57,599 --> 00:50:01,710  
pristine ancient galaxies m92 just for

1396  
00:50:00,389 --> 00:50:04,319  
comparison is right here where the green

1397

00:50:01,710 --> 00:50:05,909  
line is so m92 is a little less than 1%

1398  
00:50:04,320 --> 00:50:09,809  
the composition of the Sun it's also

1399  
00:50:05,909 --> 00:50:12,719  
ancient and metal-poor so just for

1400  
00:50:09,809 --> 00:50:14,849  
another way to compare these data these

1401  
00:50:12,719 --> 00:50:16,859  
are the data from Hercules I'm zooming

1402  
00:50:14,849 --> 00:50:18,000  
in here now on the clock so the little

1403  
00:50:16,860 --> 00:50:19,680  
kink right here again this brightness

1404  
00:50:18,000 --> 00:50:21,090  
versus color and I'm going to take the

1405  
00:50:19,679 --> 00:50:22,619  
data from all the other galaxies and

1406  
00:50:21,090 --> 00:50:24,390  
superimpose them on here just to show

1407  
00:50:22,619 --> 00:50:28,259  
how similar they are so this is Hercules

1408  
00:50:24,389 --> 00:50:29,369  
in yellow that's Leo four in green and

1409  
00:50:28,260 --> 00:50:30,300  
as you said well I can't really see it

1410  
00:50:29,369 --> 00:50:34,799  
that well to us they're right on top of

1411  
00:50:30,300 --> 00:50:37,620

each other that's CVN - and purple that

1412

00:50:34,800 --> 00:50:40,320

sort some major one in blue that's

1413

00:50:37,619 --> 00:50:42,359

bootys one in red and that's cone barren

1414

00:50:40,320 --> 00:50:43,769

brown so if you put all these galaxies

1415

00:50:42,360 --> 00:50:45,510

in the same reference frame their data

1416

00:50:43,769 --> 00:50:47,250

fall right on top of each other these

1417

00:50:45,510 --> 00:50:49,230

are six satellite galaxies of the Milky

1418

00:50:47,250 --> 00:50:51,179

Way all at different distances from the

1419

00:50:49,230 --> 00:50:52,949

Milky Way all different parts of the sky

1420

00:50:51,179 --> 00:50:55,379

and they all look exactly the same to

1421

00:50:52,949 --> 00:50:57,329

the eye so that implies some kind of

1422

00:50:55,380 --> 00:50:58,890

global influence effected all of them

1423

00:50:57,329 --> 00:51:00,449

and there's a lot of things going on

1424

00:50:58,889 --> 00:51:01,949

with galaxies form supernovae blow off

1425

00:51:00,449 --> 00:51:03,089

all the gas out of the stars new

1426  
00:51:01,949 --> 00:51:04,949  
generations of stars are born

1427  
00:51:03,090 --> 00:51:07,050  
it's a chaotic process but something

1428  
00:51:04,949 --> 00:51:08,699  
synchronized the star formation in all

1429  
00:51:07,050 --> 00:51:11,010  
six of these galaxies to a very high

1430  
00:51:08,699 --> 00:51:12,179  
degree and one possible thing that's

1431  
00:51:11,010 --> 00:51:13,380  
obvious here after you've heard the

1432  
00:51:12,179 --> 00:51:14,519  
pitch in the beginning is that it was

1433  
00:51:13,380 --> 00:51:15,869  
Rihanna's ation in the universe that

1434  
00:51:14,519 --> 00:51:18,480  
would be a global influence that

1435  
00:51:15,869 --> 00:51:20,309  
affected all the galaxies this is where

1436  
00:51:18,480 --> 00:51:21,900  
theory tells us the star should fall if

1437  
00:51:20,309 --> 00:51:23,460  
all the stars were between 12 and 13

1438  
00:51:21,900 --> 00:51:25,200  
billion years old they would fall on

1439  
00:51:23,460 --> 00:51:26,970  
this great curve here which is a good

1440  
00:51:25,199 --> 00:51:28,169  
match to the data the data spread out a

1441  
00:51:26,969 --> 00:51:29,909  
little bit more down here because there

1442  
00:51:28,170 --> 00:51:31,320  
are a little noisier as you go faint but

1443  
00:51:29,909 --> 00:51:35,730  
this is where the stars would have been

1444  
00:51:31,320 --> 00:51:36,600  
born right along this curve so just to

1445  
00:51:35,730 --> 00:51:38,699  
show you now a little more

1446  
00:51:36,599 --> 00:51:42,179  
quantitatively this is the zoom in now

1447  
00:51:38,699 --> 00:51:43,829  
on the clock for Hercules and the

1448  
00:51:42,179 --> 00:51:45,029  
theoretical prediction a random draw on

1449  
00:51:43,829 --> 00:51:46,590  
the theoretical prediction of where the

1450  
00:51:45,030 --> 00:51:48,269  
star should fall so one of these panels

1451  
00:51:46,590 --> 00:51:49,829  
is the data one is the model I won't

1452  
00:51:48,269 --> 00:51:51,329  
make you guess which one is which but

1453  
00:51:49,829 --> 00:51:53,279  
you can see the model and the data look

1454

00:51:51,329 --> 00:51:54,960  
very similar the green curve is there 92

1455  
00:51:53,280 --> 00:51:58,290  
again just for comparison so that's

1456  
00:51:54,960 --> 00:52:01,619  
Hercules ones data ones the model that's

1457  
00:51:58,289 --> 00:52:03,029  
all six of the galaxies so in one panel

1458  
00:52:01,619 --> 00:52:04,170  
I'm showing you the theoretical

1459  
00:52:03,030 --> 00:52:05,640  
prediction for how the Stars should be

1460  
00:52:04,170 --> 00:52:06,960  
scattered around a diagram like this and

1461  
00:52:05,639 --> 00:52:08,849  
other ones the real data from Hubble and

1462  
00:52:06,960 --> 00:52:10,349  
each panel here they look very similar

1463  
00:52:08,849 --> 00:52:12,989  
right the distribution of stars is very

1464  
00:52:10,349 --> 00:52:14,519  
similar in each case and so what is in

1465  
00:52:12,989 --> 00:52:17,849  
each case is the models on the right and

1466  
00:52:14,519 --> 00:52:19,320  
the data on the left and the theoretical

1467  
00:52:17,849 --> 00:52:20,880  
prediction for where the stars ripple in

1468  
00:52:19,320 --> 00:52:23,280

this diagram matches the data very well

1469

00:52:20,880 --> 00:52:24,780

I can show it this way to the grey

1470

00:52:23,280 --> 00:52:26,910

shading here is where the month the

1471

00:52:24,780 --> 00:52:28,410

theory says the star should fall and the

1472

00:52:26,909 --> 00:52:30,059

other points are where the stars do fall

1473

00:52:28,409 --> 00:52:32,549

and there's excellent agreement in all

1474

00:52:30,059 --> 00:52:34,139

six galaxies so this really tells us

1475

00:52:32,550 --> 00:52:35,490

that these are fossil galaxies now it

1476

00:52:34,139 --> 00:52:37,170

may not be true that the reorganization

1477

00:52:35,489 --> 00:52:40,199

of the universe is what made them old

1478

00:52:37,170 --> 00:52:41,820

but we were testing that theory we said

1479

00:52:40,199 --> 00:52:43,199

if there are ancient fossil galaxies

1480

00:52:41,820 --> 00:52:44,820

these would be excellent candidates for

1481

00:52:43,199 --> 00:52:45,929

being fossil galaxies we looked at them

1482

00:52:44,820 --> 00:52:47,309

closely with Hubble and they do seem

1483  
00:52:45,929 --> 00:52:49,109  
like they're very pristine and they're

1484  
00:52:47,309 --> 00:52:50,699  
metallicity and they're very very old

1485  
00:52:49,110 --> 00:52:52,980  
they're about 13 billion years old the

1486  
00:52:50,699 --> 00:52:54,329  
average age in each of these fits here

1487  
00:52:52,980 --> 00:52:56,070  
this is thirteen point three billion

1488  
00:52:54,329 --> 00:52:57,630  
years old thirteen point six billion

1489  
00:52:56,070 --> 00:52:58,830  
years old this is thirteen point nine

1490  
00:52:57,630 --> 00:52:59,970  
billion years old and I know some of

1491  
00:52:58,829 --> 00:53:00,809  
you're going to go wait a minute Frank a

1492  
00:52:59,969 --> 00:53:02,489  
little while ago to start my the

1493  
00:53:00,809 --> 00:53:04,259  
universe is only 13.8 billion years old

1494  
00:53:02,489 --> 00:53:06,299  
there's about half a billion years of

1495  
00:53:04,260 --> 00:53:08,280  
uncertainty and these fits do to the

1496  
00:53:06,300 --> 00:53:09,210  
models so it's consistent with the age

1497  
00:53:08,280 --> 00:53:10,440  
of the universe it's not like we're

1498  
00:53:09,210 --> 00:53:12,300  
saying this galaxy is older than the

1499  
00:53:10,440 --> 00:53:13,950  
universe but within the uncertainties

1500  
00:53:12,300 --> 00:53:14,880  
these galaxies were all born right after

1501  
00:53:13,949 --> 00:53:16,739  
the Big Bang

1502  
00:53:14,880 --> 00:53:18,570  
this one's 13 point 1 billion

1503  
00:53:16,739 --> 00:53:20,779  
years old 13 point 1 billion years old

1504  
00:53:18,570 --> 00:53:23,100  
12 point 7 billion years old on average

1505  
00:53:20,780 --> 00:53:25,140  
so these are the oldest known galaxies

1506  
00:53:23,099 --> 00:53:26,969  
these 6 use the only galaxies where

1507  
00:53:25,139 --> 00:53:29,549  
we've measured ages to this accuracy and

1508  
00:53:26,969 --> 00:53:33,419  
all of them are older than any galaxy

1509  
00:53:29,550 --> 00:53:34,380  
we've ever measured before this is

1510  
00:53:33,420 --> 00:53:36,539  
another way of showing the same thing

1511

00:53:34,380 --> 00:53:39,360  
this is a fraction of stars born in the

1512  
00:53:36,539 --> 00:53:40,800  
galaxy versus time on the x axis so what

1513  
00:53:39,360 --> 00:53:42,570  
happens here so this is looking back in

1514  
00:53:40,800 --> 00:53:45,060  
time to the early universe 14 billion

1515  
00:53:42,570 --> 00:53:47,309  
years ago or so and star formation

1516  
00:53:45,059 --> 00:53:49,230  
starts very quickly 80% of the stars are

1517  
00:53:47,309 --> 00:53:51,360  
formed in the very first billion years

1518  
00:53:49,230 --> 00:53:52,860  
and then they kind of tapers off and

1519  
00:53:51,360 --> 00:53:54,539  
there's the width here is just the

1520  
00:53:52,860 --> 00:53:55,950  
uncertainty in the model so this would

1521  
00:53:54,539 --> 00:53:58,289  
be a narrow curve of our models were

1522  
00:53:55,949 --> 00:53:59,609  
better but so the star creation comes on

1523  
00:53:58,289 --> 00:54:01,650  
very suddenly and then this little tail

1524  
00:53:59,610 --> 00:54:03,510  
as realization starts to shut things

1525  
00:54:01,650 --> 00:54:05,039

down in these galaxies so this is the

1526

00:54:03,510 --> 00:54:07,080

this is a fit to the data for Hercules

1527

00:54:05,039 --> 00:54:08,460

this is what it looks like for all six

1528

00:54:07,079 --> 00:54:10,139

galaxies the star form and they all look

1529

00:54:08,460 --> 00:54:11,849

very similar star formation comes on

1530

00:54:10,139 --> 00:54:13,529

very rapidly if none of the stars are

1531

00:54:11,849 --> 00:54:15,299

formed right after the Big Bang and then

1532

00:54:13,530 --> 00:54:16,619

there's a little tail going on for a few

1533

00:54:15,300 --> 00:54:18,180

billion years afterwards as it the

1534

00:54:16,619 --> 00:54:22,608

realisation the universe shuts off the

1535

00:54:18,179 --> 00:54:24,599

galaxies and their stars so

1536

00:54:22,608 --> 00:54:25,739

unfortunately for where we live or maybe

1537

00:54:24,599 --> 00:54:27,358

fortunately maybe it wouldn't be such a

1538

00:54:25,739 --> 00:54:29,039

great place to live we live in kind of a

1539

00:54:27,358 --> 00:54:30,989

cosmological backwater there's not a lot

1540  
00:54:29,039 --> 00:54:33,358  
going on in the local group so this is a

1541  
00:54:30,989 --> 00:54:35,279  
box here showing us part of the local

1542  
00:54:33,358 --> 00:54:37,079  
universe 80 million light years on aside

1543  
00:54:35,280 --> 00:54:39,269  
and the kind of work I'm talking about

1544  
00:54:37,079 --> 00:54:42,059  
here where you can use Hubble to measure

1545  
00:54:39,269 --> 00:54:43,019  
ages of stars very very accurately there

1546  
00:54:42,059 --> 00:54:44,880  
are a lot of ways to measure stellar

1547  
00:54:43,019 --> 00:54:46,679  
ages that you could do less accurately

1548  
00:54:44,880 --> 00:54:48,059  
you can do them far away but for doing

1549  
00:54:46,679 --> 00:54:50,009  
really accurate ages you can only do it

1550  
00:54:48,059 --> 00:54:51,659  
relatively nearby and Hubble can do this

1551  
00:54:50,010 --> 00:54:53,700  
kind of work in this yellow sphere right

1552  
00:54:51,659 --> 00:54:54,989  
here so that's where we can do the kind

1553  
00:54:53,699 --> 00:54:56,849  
of work I'm talking about right now and

1554  
00:54:54,989 --> 00:54:57,779  
it's not a really interesting patch of

1555  
00:54:56,849 --> 00:55:00,630  
the universe where we live unfortunately

1556  
00:54:57,780 --> 00:55:02,220  
so the symbols here these paperclip

1557  
00:55:00,630 --> 00:55:03,269  
looking things that I drew here is my

1558  
00:55:02,219 --> 00:55:05,309  
lame attempt to make a spiral galaxy

1559  
00:55:03,269 --> 00:55:06,659  
these are giant spiral galaxies the

1560  
00:55:05,309 --> 00:55:08,940  
Milky Way's right here at the center

1561  
00:55:06,659 --> 00:55:11,190  
Andromeda is our only other nearby giant

1562  
00:55:08,940 --> 00:55:12,780  
spiral these big red things are

1563  
00:55:11,190 --> 00:55:14,250  
elliptical galaxies giant elliptical

1564  
00:55:12,780 --> 00:55:15,510  
galaxies and the little brown dots are

1565  
00:55:14,250 --> 00:55:17,340  
dwarf galaxies like I've been talking

1566  
00:55:15,510 --> 00:55:18,869  
about tonight so we live in kind of a

1567  
00:55:17,340 --> 00:55:20,369  
boring part of the universe it's out in

1568

00:55:18,869 --> 00:55:22,320  
the boonies there's not a lot going on

1569  
00:55:20,369 --> 00:55:24,570  
here it's the Milky Way Andromeda and a

1570  
00:55:22,320 --> 00:55:27,300  
few dozens Dorf galaxies and Hubble can

1571  
00:55:24,570 --> 00:55:29,130  
measure the ages of these galaxies the

1572  
00:55:27,300 --> 00:55:30,480  
James Webb Space Telescope is launching

1573  
00:55:29,130 --> 00:55:31,858  
in 2018

1574  
00:55:30,480 --> 00:55:33,210  
it could do the kind of work I'm talking

1575  
00:55:31,858 --> 00:55:34,889  
about tonight and volume three times

1576  
00:55:33,210 --> 00:55:36,329  
larger so it gets a lot more dwarf

1577  
00:55:34,889 --> 00:55:38,159  
galaxies who starts to get to the spiral

1578  
00:55:36,329 --> 00:55:39,900  
galaxy that's not what it was built for

1579  
00:55:38,159 --> 00:55:41,399  
though it looks in the infrared it's got

1580  
00:55:39,900 --> 00:55:42,930  
a much bigger mirror it's going to

1581  
00:55:41,400 --> 00:55:44,608  
measure the ages of galaxies by looking

1582  
00:55:42,929 --> 00:55:46,379

directly back in time at high redshift

1583

00:55:44,608 --> 00:55:48,509

so you know if you look very far away

1584

00:55:46,380 --> 00:55:49,800

you're looking in time so James Webb is

1585

00:55:48,510 --> 00:55:51,630

going to look at the most distant

1586

00:55:49,800 --> 00:55:53,130

galaxies and observe them evolving

1587

00:55:51,630 --> 00:55:53,910

directly it's not going to do the kind

1588

00:55:53,130 --> 00:55:55,680

of stuff I'm talking about tonight

1589

00:55:53,909 --> 00:55:56,759

primarily but it will do some of that

1590

00:55:55,679 --> 00:55:59,669

kind of work and it could do it a little

1591

00:55:56,760 --> 00:56:01,589

better than Hubble folks are also

1592

00:55:59,670 --> 00:56:03,000

looking at building much bigger versions

1593

00:56:01,588 --> 00:56:04,949

of Hubble's this is an active thing

1594

00:56:03,000 --> 00:56:06,119

going on right now there's a lot of

1595

00:56:04,949 --> 00:56:07,769

folks looking to see what are the next

1596

00:56:06,119 --> 00:56:09,390

big NASA missions in the next couple

1597  
00:56:07,769 --> 00:56:11,190  
decades and people are talking about

1598  
00:56:09,389 --> 00:56:12,539  
building a UV optical telescope like

1599  
00:56:11,190 --> 00:56:15,450  
Hubble that it would have an 8 meter

1600  
00:56:12,539 --> 00:56:18,000  
mirror so Hubble's got a two point four

1601  
00:56:15,449 --> 00:56:19,500  
meter mirror people are looking at an 8

1602  
00:56:18,000 --> 00:56:21,690  
meter mirror that would get out of our

1603  
00:56:19,500 --> 00:56:23,159  
little you know middle of nowhere patch

1604  
00:56:21,690 --> 00:56:25,320  
of the universe you could start doing

1605  
00:56:23,159 --> 00:56:26,819  
this kind of work in spiral galaxies out

1606  
00:56:25,320 --> 00:56:28,260  
in the nearest towns you can actually

1607  
00:56:26,820 --> 00:56:30,570  
pick up an elliptical galaxy and lots of

1608  
00:56:28,260 --> 00:56:32,070  
other types of galaxies there are folks

1609  
00:56:30,570 --> 00:56:33,570  
who are really ambitious who are talking

1610  
00:56:32,070 --> 00:56:35,490  
about building a 16 meter version or

1611  
00:56:33,570 --> 00:56:36,990  
Hubble and this is really something that

1612  
00:56:35,489 --> 00:56:38,578  
people are looking at right now the

1613  
00:56:36,989 --> 00:56:40,529  
primary motivation for this is to look

1614  
00:56:38,579 --> 00:56:42,030  
for life around other stars so this is

1615  
00:56:40,530 --> 00:56:43,560  
the kind of telescope you need if you

1616  
00:56:42,030 --> 00:56:45,480  
want to be able to detect life directly

1617  
00:56:43,559 --> 00:56:46,559  
on planets orbiting other stars and if

1618  
00:56:45,480 --> 00:56:47,639  
you're going to build such a telescope

1619  
00:56:46,559 --> 00:56:49,199  
people can use your further stuff too

1620  
00:56:47,639 --> 00:56:50,190  
and people like me out the light looking

1621  
00:56:49,199 --> 00:56:51,659  
for life around other stars it's

1622  
00:56:50,190 --> 00:56:53,608  
obviously very exciting I measure the

1623  
00:56:51,659 --> 00:56:55,440  
ages of stars you could do what I'm

1624  
00:56:53,608 --> 00:56:56,639  
talking about tonight in this volume of

1625

00:56:55,440 --> 00:56:58,588  
the universe and that would be a true

1626  
00:56:56,639 --> 00:57:00,299  
census of the local universe you get

1627  
00:56:58,588 --> 00:57:02,039  
lots of giant elliptical galaxies these

1628  
00:57:00,300 --> 00:57:03,480  
red things you get tons of spiral

1629  
00:57:02,039 --> 00:57:05,250  
galaxies many more hundreds of dwarf

1630  
00:57:03,480 --> 00:57:07,199  
galaxies you could really get a sense of

1631  
00:57:05,250 --> 00:57:08,670  
how the universe has formed it stars in

1632  
00:57:07,199 --> 00:57:10,230  
the nearby University of that kind of

1633  
00:57:08,670 --> 00:57:11,490  
telescope I probably would not get a

1634  
00:57:10,230 --> 00:57:12,568  
gigantic fraction of the time most the

1635  
00:57:11,489 --> 00:57:14,250  
time it will be looking for life front

1636  
00:57:12,568 --> 00:57:16,889  
other stars but you could get some time

1637  
00:57:14,250 --> 00:57:18,599  
doing this type of work so this is the

1638  
00:57:16,889 --> 00:57:19,429  
Hubble Space Telescope and low-earth

1639  
00:57:18,599 --> 00:57:21,480

orbit

1640

00:57:19,429 --> 00:57:23,608

most of our carbon torment tonight comes

1641

00:57:21,480 --> 00:57:25,530

from Hubble also comes from Keck I

1642

00:57:23,608 --> 00:57:27,150

worked previously up until a few months

1643

00:57:25,530 --> 00:57:29,460

ago on the James Webb Space Telescope

1644

00:57:27,150 --> 00:57:30,599

for the last eight years so I'll just

1645

00:57:29,460 --> 00:57:32,460

give you a little update on that this is

1646

00:57:30,599 --> 00:57:34,200

James Webb it has unlike a two point

1647

00:57:32,460 --> 00:57:36,240

four meter mirror it has a six and a

1648

00:57:34,199 --> 00:57:38,279

half meter mirror coated in gold it's a

1649

00:57:36,239 --> 00:57:39,868

beryllium mirror and then just to give

1650

00:57:38,280 --> 00:57:42,000

you a sense of scale this is the light

1651

00:57:39,869 --> 00:57:43,470

shield this is the Sun shield it's about

1652

00:57:42,000 --> 00:57:45,119

the size of a tennis court

1653

00:57:43,469 --> 00:57:47,368

made of a material similar to like candy

1654  
00:57:45,119 --> 00:57:48,900  
wrappers it's got five layers here keeps

1655  
00:57:47,369 --> 00:57:50,700  
the instruments in the telescope in the

1656  
00:57:48,900 --> 00:57:54,139  
shade while it's orbiting out around the

1657  
00:57:50,699 --> 00:57:56,669  
Sun we're launching that in October 2018

1658  
00:57:54,139 --> 00:57:58,230  
these are the main science goals of

1659  
00:57:56,670 --> 00:57:59,820  
James Webb so it's going to look at the

1660  
00:57:58,230 --> 00:58:01,199  
first galaxies in the universe so again

1661  
00:57:59,820 --> 00:58:02,490  
it will be measuring the evolution of

1662  
00:58:01,199 --> 00:58:03,929  
galaxies but in a very different way

1663  
00:58:02,489 --> 00:58:06,089  
it's going to look directly back in time

1664  
00:58:03,929 --> 00:58:07,769  
of the most distant galaxies it's going

1665  
00:58:06,090 --> 00:58:09,780  
to watch over that cosmic time how

1666  
00:58:07,769 --> 00:58:11,340  
galaxies evolve because it's looking in

1667  
00:58:09,780 --> 00:58:13,950  
the infrared it can peer through dust

1668  
00:58:11,340 --> 00:58:15,570  
and gas to see stars and Galant planets

1669  
00:58:13,949 --> 00:58:17,429  
being born and it's gonna be able to

1670  
00:58:15,570 --> 00:58:20,660  
look for the origin of life so these are

1671  
00:58:17,429 --> 00:58:23,669  
the main science themes of James Webb

1672  
00:58:20,659 --> 00:58:25,710  
just for comparison Hubble is in

1673  
00:58:23,670 --> 00:58:26,940  
low-earth orbit you know on this scale

1674  
00:58:25,710 --> 00:58:28,199  
you wouldn't be able to see how far away

1675  
00:58:26,940 --> 00:58:30,000  
from Earth it is it'd be orbiting right

1676  
00:58:28,199 --> 00:58:32,098  
there James Webb is going to go out here

1677  
00:58:30,000 --> 00:58:33,539  
to a point we called Lagrange two it's

1678  
00:58:32,099 --> 00:58:37,650  
four times further away than the moon

1679  
00:58:33,539 --> 00:58:38,820  
one and a half kilometers away and then

1680  
00:58:37,650 --> 00:58:43,230  
just here's a comparison of the

1681  
00:58:38,820 --> 00:58:45,630  
telescope sizes here's a person 1.75

1682

00:58:43,230 --> 00:58:47,480  
meters tall here's Hubble's meter 2.4

1683  
00:58:45,630 --> 00:58:52,170  
meters tall and here's James Webb

1684  
00:58:47,480 --> 00:58:54,570  
six-and-a-half meters tall in 18

1685  
00:58:52,170 --> 00:58:56,280  
segments that's ground testing down a

1686  
00:58:54,570 --> 00:58:57,838  
NASA of some of the mirror segments

1687  
00:58:56,280 --> 00:58:58,920  
again coated in gold people freaked out

1688  
00:58:57,838 --> 00:59:00,630  
a little bit you say the mirror is made

1689  
00:58:58,920 --> 00:59:02,700  
of gold oh my god that's it's wasting so

1690  
00:59:00,630 --> 00:59:04,410  
much money the whole mirror has about

1691  
00:59:02,699 --> 00:59:05,848  
this much gold on the coating of it okay

1692  
00:59:04,409 --> 00:59:10,348  
so just for comparison so it's a very

1693  
00:59:05,849 --> 00:59:12,210  
thin layer on the surface here are the

1694  
00:59:10,349 --> 00:59:13,740  
instruments so we were testing the

1695  
00:59:12,210 --> 00:59:15,510  
instruments individually at different

1696  
00:59:13,739 --> 00:59:16,769

locations around the world up until a

1697

00:59:15,510 --> 00:59:18,150

few years ago and then we started

1698

00:59:16,769 --> 00:59:19,530

integrating them into the integrated

1699

00:59:18,150 --> 00:59:21,420

science instrument module that got

1700

00:59:19,530 --> 00:59:23,519

tested last year Goddard so it's near

1701

00:59:21,420 --> 00:59:25,108

cam which is a near infrared camera Miri

1702

00:59:23,519 --> 00:59:27,509

which is a mid infrared instrument also

1703

00:59:25,108 --> 00:59:29,489

camera and a spectrograph near spec and

1704

00:59:27,510 --> 00:59:32,310

your infrared spectrograph and near us

1705

00:59:29,489 --> 00:59:33,959

also a near infrared camera hence

1706

00:59:32,309 --> 00:59:38,130

spectrograph specifically designed for

1707

00:59:33,960 --> 00:59:39,720

exoplanet searches and here's the test

1708

00:59:38,130 --> 00:59:41,160

chamber at Goddard where we were just

1709

00:59:39,719 --> 00:59:44,959

testing we wrapped up testing of the

1710

00:59:41,159 --> 00:59:47,608

instruments this last year in February

1711  
00:59:44,960 --> 00:59:48,990  
this is the chamber that will be used to

1712  
00:59:47,608 --> 00:59:51,690  
test the instruments and the mirror

1713  
00:59:48,989 --> 00:59:53,039  
together next year in April this is the

1714  
00:59:51,690 --> 00:59:54,599  
same chamber that was used for the

1715  
00:59:53,039 --> 00:59:56,190  
Apollo Lunar Module

1716  
00:59:54,599 --> 00:59:56,849  
I walked around inside this a few years

1717  
00:59:56,190 --> 00:59:57,900  
ago before they

1718  
00:59:56,849 --> 00:59:59,309  
started cleaning it out and for the

1719  
00:59:57,900 --> 01:00:00,720  
testing I have to say it's crazy

1720  
00:59:59,309 --> 01:00:02,339  
impressive and those are people standing

1721  
01:00:00,719 --> 01:00:03,808  
here so you walk around inside the

1722  
01:00:02,338 --> 01:00:05,578  
scaffolding it's the same chamber those

1723  
01:00:03,809 --> 01:00:07,019  
used to test the Apollo missions and

1724  
01:00:05,579 --> 01:00:10,109  
we'll it's at Johnson Space Center will

1725  
01:00:07,018 --> 01:00:11,548  
be starting testing there next year and

1726  
01:00:10,108 --> 01:00:12,719  
that's what it look like so James Webb

1727  
01:00:11,548 --> 01:00:14,699  
will be what we call the cup up

1728  
01:00:12,719 --> 01:00:16,169  
configuration so the mirror is facing up

1729  
01:00:14,699 --> 01:00:17,848  
the instruments are sitting here facing

1730  
01:00:16,170 --> 01:00:19,349  
down and we'll do some simulations of

1731  
01:00:17,849 --> 01:00:22,950  
the conditions in space to test it

1732  
01:00:19,349 --> 01:00:24,989  
before we launch it so just to summarize

1733  
01:00:22,949 --> 01:00:26,969  
the ultra faint dwarf galaxies are

1734  
01:00:24,989 --> 01:00:28,798  
extremely metal-poor some of the most

1735  
01:00:26,969 --> 01:00:30,419  
metal-poor stars in the universe that we

1736  
01:00:28,798 --> 01:00:31,650  
know about are found in these ultra

1737  
01:00:30,420 --> 01:00:33,059  
faint dwarf galaxies and their chemical

1738  
01:00:31,650 --> 01:00:34,650  
abundances and most of the stars are a

1739

01:00:33,059 --> 01:00:36,778  
tenth of a percent to one percent of

1740  
01:00:34,650 --> 01:00:38,059  
those we found in the Sun the ultra

1741  
01:00:36,778 --> 01:00:40,889  
faint dwarf galaxies are ancient

1742  
01:00:38,059 --> 01:00:42,359  
three-quarters of the stars formed their

1743  
01:00:40,889 --> 01:00:44,219  
star three-quarters of the stars were

1744  
01:00:42,358 --> 01:00:46,409  
formed more than 13 billion years ago

1745  
01:00:44,219 --> 01:00:48,778  
so these galaxies are truly ancient

1746  
01:00:46,409 --> 01:00:50,219  
there are known as far as we can tell

1747  
01:00:48,778 --> 01:00:51,568  
intermediate stars are nothing really

1748  
01:00:50,219 --> 01:00:53,488  
younger than 10 billion years old on

1749  
01:00:51,568 --> 01:00:54,808  
these stars and that's very distinct

1750  
01:00:53,489 --> 01:00:56,159  
from pretty much not only the classical

1751  
01:00:54,809 --> 01:00:57,778  
dwarf galaxies every other galaxies that

1752  
01:00:56,159 --> 01:01:00,868  
ever been studied most galaxies have a

1753  
01:00:57,778 --> 01:01:02,159

young stars and old stars star formation

1754

01:01:00,869 --> 01:01:03,599

appears to be synchronised in these

1755

01:01:02,159 --> 01:01:05,009

objects even though there's six

1756

01:01:03,599 --> 01:01:06,869

different galaxies spread out on the sky

1757

01:01:05,009 --> 01:01:07,858

they all have pretty much the same star

1758

01:01:06,869 --> 01:01:09,059

formation history it's like a guillotine

1759

01:01:07,858 --> 01:01:10,228

came along and shut off the star

1760

01:01:09,059 --> 01:01:12,028

information in all these at the same

1761

01:01:10,228 --> 01:01:13,348

time and that's what you would expect if

1762

01:01:12,028 --> 01:01:14,789

they were all snuffed out by the

1763

01:01:13,349 --> 01:01:16,650

reorganization of the universe shortly

1764

01:01:14,789 --> 01:01:18,450

after the Big Bang and this is

1765

01:01:16,650 --> 01:01:20,009

consistent with pollutions that are

1766

01:01:18,449 --> 01:01:22,108

opposed to the missing satellite problem

1767

01:01:20,009 --> 01:01:23,699

most of the missing satellites are there

1768  
01:01:22,108 --> 01:01:25,828  
but they just have fewer know stars so

1769  
01:01:23,699 --> 01:01:28,139  
we can't see them thanks and I'll show

1770  
01:01:25,829 --> 01:01:29,160  
this video of the j2 ST deployment in

1771  
01:01:28,139 --> 01:01:31,879  
two years while I answer questions

1772  
01:01:29,159 --> 01:01:31,879  
thanks

1773  
01:02:05,759 --> 01:02:10,639  
so dark matters just matter that's not

1774  
01:02:07,579 --> 01:02:14,068  
luminous so I mean dark matter is it

1775  
01:02:10,639 --> 01:02:15,538  
right but people are trying to figure

1776  
01:02:14,068 --> 01:02:16,920  
out what dark matter is so we don't

1777  
01:02:15,539 --> 01:02:18,569  
really have a good handle on what dark

1778  
01:02:16,920 --> 01:02:19,920  
matter is people are searching for there

1779  
01:02:18,568 --> 01:02:21,869  
and we know it's there from its

1780  
01:02:19,920 --> 01:02:23,369  
gravitational effects but you can't

1781  
01:02:21,869 --> 01:02:32,969  
observe it directly you just see it's in

1782  
01:02:23,369 --> 01:02:34,140  
dirt you know well in these galaxies

1783  
01:02:32,969 --> 01:02:35,729  
they're dark but we call it dark matter

1784  
01:02:34,139 --> 01:02:37,259  
dominated so the ones I showed you

1785  
01:02:35,728 --> 01:02:38,968  
tonight there's very little like so

1786  
01:02:37,259 --> 01:02:40,228  
there's only a few stars and then you

1787  
01:02:38,969 --> 01:02:41,789  
know there's dark matter there because

1788  
01:02:40,228 --> 01:02:42,838  
of the orbits of those stars but then

1789  
01:02:41,789 --> 01:02:44,130  
there are other clumps of dark matter

1790  
01:02:42,838 --> 01:02:46,228  
out there where there's no stars in them

1791  
01:02:44,130 --> 01:02:53,219  
at all we just infer their presence from

1792  
01:02:46,228 --> 01:02:55,679  
from the gravitational pull the clumping

1793  
01:02:53,219 --> 01:02:56,579  
looks very similar in theory to that

1794  
01:02:55,679 --> 01:02:57,778  
simulation I showed in the beginning

1795  
01:02:56,579 --> 01:02:59,640  
with all the hundreds of little blue

1796

01:02:57,778 --> 01:03:00,690  
points around the Milky Way but people

1797  
01:02:59,639 --> 01:03:03,900  
have been searching for dark matter

1798  
01:03:00,690 --> 01:03:05,429  
pretty strenuous ly and you know not

1799  
01:03:03,900 --> 01:03:07,019  
finding a lot of it so that's the

1800  
01:03:05,429 --> 01:03:08,940  
theoretical prediction of how it clumps

1801  
01:03:07,018 --> 01:03:10,078  
you know but how it actually clumps we

1802  
01:03:08,940 --> 01:03:13,458  
don't have a good handle on yet because

1803  
01:03:10,079 --> 01:03:13,459  
it's very difficult to observe directly

1804  
01:03:20,268 --> 01:03:24,448  
yeah B since we can't observe the clumps

1805  
01:03:23,039 --> 01:03:25,589  
that have no stars we really can't

1806  
01:03:24,449 --> 01:03:27,088  
observe those directly so what I'm

1807  
01:03:25,588 --> 01:03:29,489  
looking at here are the ones that just

1808  
01:03:27,088 --> 01:03:31,920  
formed a few stars and that's that gives

1809  
01:03:29,489 --> 01:03:33,059  
us credence to the theory that why the

1810  
01:03:31,920 --> 01:03:34,739

missing silence are there would be great

1811

01:03:33,059 --> 01:03:36,410

if we actually observe those hundreds of

1812

01:03:34,739 --> 01:03:39,739

clumps that we don't have any stars in

1813

01:03:36,409 --> 01:03:39,739

so yeah

1814

01:03:42,300 --> 01:03:46,690

so the oldest stars in those galaxies go

1815

01:03:45,130 --> 01:03:48,220

back to the Big Bang within the error

1816

01:03:46,690 --> 01:03:49,780

bars so back to the thirteen half

1817

01:03:48,219 --> 01:03:51,039

billion years old or so so that was the

1818

01:03:49,780 --> 01:03:52,480

image that's on the David Bowie album

1819

01:03:51,039 --> 01:03:54,130

that was the goal of that program was to

1820

01:03:52,480 --> 01:03:56,349

measure the range of Ages in Andromeda

1821

01:03:54,130 --> 01:03:58,059

out and it's halo stars and so we found

1822

01:03:56,349 --> 01:03:59,289

stars over 13 1/2 million years old we

1823

01:03:58,059 --> 01:04:00,789

found stars there were just a billion

1824

01:03:59,289 --> 01:04:03,429

years old know everything in between and

1825  
01:04:00,789 --> 01:04:04,630  
that's the case for the Milky Way that's

1826  
01:04:03,429 --> 01:04:06,069  
the case for Andromeda that's the case

1827  
01:04:04,630 --> 01:04:07,599  
for the satellite galaxies that we've

1828  
01:04:06,070 --> 01:04:09,640  
known about it's these Ultra faint

1829  
01:04:07,599 --> 01:04:11,319  
dwarfs that only have ancient stars

1830  
01:04:09,639 --> 01:04:12,670  
every other galaxy we've looked at as

1831  
01:04:11,320 --> 01:04:14,950  
young stars only young for an astronomer

1832  
01:04:12,670 --> 01:04:17,289  
you know it's definitely less than 10

1833  
01:04:14,949 --> 01:04:23,469  
billion years old and old stars as

1834  
01:04:17,289 --> 01:04:25,360  
well is that the structure the Milky Way

1835  
01:04:23,469 --> 01:04:28,299  
believed to have formed around ten

1836  
01:04:25,360 --> 01:04:31,329  
billion years ago the structure of the

1837  
01:04:28,300 --> 01:04:34,150  
disk of the galaxy right so some stars

1838  
01:04:31,329 --> 01:04:41,049  
are as well as the universe but the

1839  
01:04:34,150 --> 01:04:42,849  
structure itself is believed to be about

1840  
01:04:41,050 --> 01:04:44,620  
ten billion years old and we can see

1841  
01:04:42,849 --> 01:04:45,909  
that by looking at higher retro so if

1842  
01:04:44,619 --> 01:04:47,139  
you look at varied in the very distant

1843  
01:04:45,909 --> 01:04:48,789  
universe which is looking back in time

1844  
01:04:47,139 --> 01:04:50,139  
you can see mostly Universal smaller

1845  
01:04:48,789 --> 01:04:52,059  
galaxies and then they start clumping

1846  
01:04:50,139 --> 01:05:03,309  
together and forming more massive

1847  
01:04:52,059 --> 01:05:06,329  
galaxies as they merge so yeah well yeah

1848  
01:05:03,309 --> 01:05:25,119  
I mean there's one technical reason so

1849  
01:05:06,329 --> 01:05:26,769  
I'm yeah yeah right here yeah yeah I

1850  
01:05:25,119 --> 01:05:28,960  
mean is it Commission's commissioning on

1851  
01:05:26,769 --> 01:05:34,659  
James Webb last six months so it's a six

1852  
01:05:28,960 --> 01:05:36,099  
month process steps I mean hundreds and

1853

01:05:34,659 --> 01:05:38,159  
hundreds of steps right oh so there's a

1854  
01:05:36,099 --> 01:05:44,199  
lot of steps different things unfurling

1855  
01:05:38,159 --> 01:05:46,449  
the folks yeah so it'll commit it'll

1856  
01:05:44,199 --> 01:05:48,429  
it'll be deploying on its way to the

1857  
01:05:46,449 --> 01:05:49,689  
Lagrangian right so and then we'll be

1858  
01:05:48,429 --> 01:05:50,739  
able monitoring it the whole time and

1859  
01:05:49,690 --> 01:05:51,840  
there's some things you don't want to do

1860  
01:05:50,739 --> 01:05:53,039  
until you tell

1861  
01:05:51,840 --> 01:05:55,320  
hope is cooled significantly it's

1862  
01:05:53,039 --> 01:05:57,239  
cooling off on the way there there's a

1863  
01:05:55,320 --> 01:05:58,470  
careful orchestration of events there as

1864  
01:05:57,239 --> 01:05:59,759  
well so you don't have like Isis

1865  
01:05:58,469 --> 01:06:01,319  
accumulating on the instruments and

1866  
01:05:59,760 --> 01:06:03,030  
their optics and so forth so it's a very

1867  
01:06:01,320 --> 01:06:04,769

careful choreographic series of events

1868

01:06:03,030 --> 01:06:06,030

as it goes out to the crunch - and then

1869

01:06:04,769 --> 01:06:09,269

after the first six months is over we

1870

01:06:06,030 --> 01:06:11,660

start doing science that's the plan all

1871

01:06:09,269 --> 01:06:11,659

the way in the back

1872

01:06:29,309 --> 01:06:33,880

yeah so we use it because this that's a

1873

01:06:32,079 --> 01:06:35,859

very good explanation so the James Webb

1874

01:06:33,880 --> 01:06:37,449

Space Telescope works primarily in the

1875

01:06:35,858 --> 01:06:39,518

infrared at wavelengths longer than our

1876

01:06:37,449 --> 01:06:41,229

eyes work and a very good substance to

1877

01:06:39,518 --> 01:06:44,168

work with for reflectivity at those

1878

01:06:41,228 --> 01:06:46,088

wavelengths is gold right it's crazy

1879

01:06:44,168 --> 01:06:50,098

other week we in back sure okay wait

1880

01:06:46,088 --> 01:06:50,099

it's always so hard to see them yeah

1881

01:06:55,048 --> 01:06:59,768

sure so the lights come on so when the

1882  
01:06:58,028 --> 01:07:01,449  
very first stars in galaxies form you

1883  
01:06:59,768 --> 01:07:03,488  
have these massive stars and universe

1884  
01:07:01,449 --> 01:07:05,229  
gets flooded with ultraviolet light so

1885  
01:07:03,489 --> 01:07:06,699  
it's very very energetic like x-ray

1886  
01:07:05,228 --> 01:07:08,259  
light as well even higher energy light

1887  
01:07:06,699 --> 01:07:09,400  
and what it goes it goes sweeping

1888  
01:07:08,259 --> 01:07:11,889  
through the universe and all this

1889  
01:07:09,400 --> 01:07:13,509  
neutral gas gets energized and rely on

1890  
01:07:11,889 --> 01:07:16,028  
eyes so basically the electrons get

1891  
01:07:13,509 --> 01:07:17,559  
stripped off the atoms and so that's a

1892  
01:07:16,028 --> 01:07:19,778  
very energetic process when the universe

1893  
01:07:17,559 --> 01:07:21,640  
very earlier on is much much hotter than

1894  
01:07:19,778 --> 01:07:22,809  
it is today today the temperature the

1895  
01:07:21,639 --> 01:07:25,478  
universe the Cosmic Microwave Background

1896  
01:07:22,809 --> 01:07:27,548  
is 2.7 Kelvin above you know so it's

1897  
01:07:25,478 --> 01:07:28,899  
three degrees above absolute zero back

1898  
01:07:27,548 --> 01:07:30,639  
in the early universe is much much

1899  
01:07:28,900 --> 01:07:31,959  
hotter and so what happens is this

1900  
01:07:30,639 --> 01:07:33,879  
energy goes sweeping through the

1901  
01:07:31,958 --> 01:07:34,958  
universe you have these clumps of dark

1902  
01:07:33,880 --> 01:07:36,249  
matter which are like little

1903  
01:07:34,958 --> 01:07:37,868  
gravitational wells

1904  
01:07:36,248 --> 01:07:39,518  
they have gas sitting there in the dark

1905  
01:07:37,869 --> 01:07:41,858  
with the dark matter and then this

1906  
01:07:39,518 --> 01:07:43,718  
energy comes sweeping through and sweeps

1907  
01:07:41,858 --> 01:07:45,880  
the gas out of those clumps of dark

1908  
01:07:43,719 --> 01:07:47,318  
matter it doesn't do that for the really

1909  
01:07:45,880 --> 01:07:48,579  
big clumps of dark matter so the really

1910

01:07:47,318 --> 01:07:50,558  
big clumps of dark matter they don't

1911  
01:07:48,579 --> 01:07:52,509  
lose all their gas and also because they

1912  
01:07:50,559 --> 01:07:54,069  
have more gravity they react Yuma late

1913  
01:07:52,509 --> 01:07:56,139  
that ground quick gas and sweep it back

1914  
01:07:54,068 --> 01:07:57,900  
up but these small clumps of dark matter

1915  
01:07:56,139 --> 01:08:00,518  
the ones that don't really form stars

1916  
01:07:57,900 --> 01:08:02,858  
the gas is swept up and never comes back

1917  
01:08:00,518 --> 01:08:03,968  
and so they don't form stars and it's

1918  
01:08:02,858 --> 01:08:06,848  
just a clump of dark matter they've been

1919  
01:08:03,969 --> 01:08:09,219  
stripped of their gas so have it right

1920  
01:08:06,849 --> 01:08:11,579  
over here to the right you in the red

1921  
01:08:09,219 --> 01:08:11,579  
shirt yeah

1922  
01:08:31,399 --> 01:08:37,460  
I find it yeah maybe you could repeat

1923  
01:08:35,630 --> 01:08:39,199  
one more time I'm actually not asking

1924  
01:08:37,460 --> 01:08:41,359

why do we get the globular structures

1925

01:08:39,199 --> 01:08:51,979

and some some galaxies and the disk

1926

01:08:41,359 --> 01:08:54,530

structures and other galaxies so the

1927

01:08:51,979 --> 01:08:56,088

dark matters is driving the large-scale

1928

01:08:54,529 --> 01:08:57,199

structure of the universe if like I said

1929

01:08:56,088 --> 01:08:59,180

it's kind of like the scaffolding that

1930

01:08:57,199 --> 01:09:01,099

all the gas and matter in the universe

1931

01:08:59,180 --> 01:09:03,200

accretes along it and then much more

1932

01:09:01,100 --> 01:09:05,359

complex things happen on small scales

1933

01:09:03,199 --> 01:09:07,460

like like the Andromeda galaxy or the

1934

01:09:05,359 --> 01:09:09,020

Milky Way basically you have things

1935

01:09:07,460 --> 01:09:10,789

they're spinning and then they start to

1936

01:09:09,020 --> 01:09:12,440

collapse perpendicular to the direction

1937

01:09:10,789 --> 01:09:14,088

of spinning it makes a disc there's

1938

01:09:12,439 --> 01:09:15,559

still a swarm of stars kind of like a

1939  
01:09:14,088 --> 01:09:17,420  
bee swarm around that that's called the

1940  
01:09:15,560 --> 01:09:19,760  
halo so it's a very very complex

1941  
01:09:17,420 --> 01:09:21,560  
hydrodynamic oppresses I mean they don't

1942  
01:09:19,760 --> 01:09:23,390  
have a simulation new on my computer but

1943  
01:09:21,560 --> 01:09:24,830  
basically you have a lot of interactions

1944  
01:09:23,390 --> 01:09:26,750  
between the matter on the small scales

1945  
01:09:24,829 --> 01:09:28,579  
of a galaxy I'm galaxy is small for our

1946  
01:09:26,750 --> 01:09:30,439  
purposes here on the large scale of the

1947  
01:09:28,579 --> 01:09:32,239  
universe you have these filamentary

1948  
01:09:30,439 --> 01:09:34,099  
structure these filaments of dark matter

1949  
01:09:32,239 --> 01:09:35,539  
where everything all the matter kind of

1950  
01:09:34,100 --> 01:09:36,829  
collapses along those filaments and

1951  
01:09:35,539 --> 01:09:39,500  
we're a couple filaments come together

1952  
01:09:36,829 --> 01:09:40,789  
you have a galaxy form there so okay

1953  
01:09:39,500 --> 01:09:43,460  
Tom we've got a question from online

1954  
01:09:40,789 --> 01:09:45,350  
sure our ancient stars metal-poor

1955  
01:09:43,460 --> 01:09:48,109  
because there hasn't been a lot of star

1956  
01:09:45,350 --> 01:09:50,150  
recycling yet yes well ancients start if

1957  
01:09:48,109 --> 01:09:51,740  
you're if a star is ancient if it was

1958  
01:09:50,149 --> 01:09:54,710  
born in the early universe it won't have

1959  
01:09:51,739 --> 01:09:56,359  
many metals period then if stars are

1960  
01:09:54,710 --> 01:09:58,100  
born more recently they could be born

1961  
01:09:56,359 --> 01:09:59,630  
from pristine gas if they just happen to

1962  
01:09:58,100 --> 01:10:01,250  
be in a lucky patch of the universe but

1963  
01:09:59,630 --> 01:10:02,750  
more often than not because they've been

1964  
01:10:01,250 --> 01:10:04,729  
multiple generations of stars those

1965  
01:10:02,750 --> 01:10:06,229  
stars have pulled the oldest the stars

1966  
01:10:04,729 --> 01:10:08,029  
that have already blown up in supernovae

1967

01:10:06,229 --> 01:10:09,469  
they've polluted the gas and then new

1968  
01:10:08,029 --> 01:10:15,729  
generations of stars are born they have

1969  
01:10:09,470 --> 01:10:15,730  
many more metals so I've it right here

1970  
01:10:20,810 --> 01:10:24,539  
yeah I don't have opinion on it cuz I'm

1971  
01:10:23,279 --> 01:10:25,829  
not a theorist rep but people are still

1972  
01:10:24,539 --> 01:10:27,899  
arguing about it until we can actually

1973  
01:10:25,829 --> 01:10:29,429  
you know measure it more directly

1974  
01:10:27,899 --> 01:10:36,658  
there's not oh there's a lot of theories

1975  
01:10:29,429 --> 01:10:39,810  
out there right so yeah right here so

1976  
01:10:36,658 --> 01:10:41,698  
dark matters around 20-25 percent dark

1977  
01:10:39,810 --> 01:10:42,750  
energies around seventy percent or

1978  
01:10:41,698 --> 01:10:43,919  
something like that and then there's

1979  
01:10:42,750 --> 01:10:45,988  
just a few percent is baryonic matter

1980  
01:10:43,920 --> 01:10:50,239  
like you know we're made out of in what

1981  
01:10:45,988 --> 01:10:50,238

stars are made out yeah right here

1982

01:11:01,760 --> 01:11:05,610

because most of the matter in the

1983

01:11:03,960 --> 01:11:15,359

universe is dark so they're the biggest

1984

01:11:05,609 --> 01:11:17,250

source of gravity in the universe so not

1985

01:11:15,359 --> 01:11:18,839

that we know of in fact dark matter

1986

01:11:17,250 --> 01:11:20,219

itself doesn't we don't really even know

1987

01:11:18,840 --> 01:11:21,840

how much it interacts with normal matter

1988

01:11:20,219 --> 01:11:23,579

in fact I mean you have it we see the

1989

01:11:21,840 --> 01:11:25,380

effects of its gravity you can see the

1990

01:11:23,579 --> 01:11:27,118

motions of stars in the Milky Way are

1991

01:11:25,380 --> 01:11:29,279

moving in a way that implies there's a

1992

01:11:27,118 --> 01:11:30,750

lot more mass there than the mass of the

1993

01:11:29,279 --> 01:11:31,979

stars we can see so we know the dark

1994

01:11:30,750 --> 01:11:34,109

matter is there we know it has a

1995

01:11:31,979 --> 01:11:35,250

gravitational effect on things but other

1996  
01:11:34,109 --> 01:11:36,329  
than that we don't know a lot about it

1997  
01:11:35,250 --> 01:11:37,649  
we don't know how much it interacts with

1998  
01:11:36,329 --> 01:11:39,929  
itself how much it interact with other

1999  
01:11:37,649 --> 01:11:41,759  
matter yeah I figure to think about is

2000  
01:11:39,929 --> 01:11:44,460  
about eighty-five percent of the mass of

2001  
01:11:41,760 --> 01:11:46,949  
the gravity in the universe is dark

2002  
01:11:44,460 --> 01:11:51,679  
matter okay only ten to fifteen percent

2003  
01:11:46,948 --> 01:11:51,678  
of it would be normal matter yeah

2004  
01:11:59,719 --> 01:12:03,109  
just us it's pretty accessible and

2005  
01:12:01,399 --> 01:12:06,469  
stable so this is a good place to put it

2006  
01:12:03,109 --> 01:12:08,779  
out there we put other we oh okay sorry

2007  
01:12:06,469 --> 01:12:11,408  
yeah so the Lagrangian was chosen she

2008  
01:12:08,779 --> 01:12:14,630  
the the question was why was the

2009  
01:12:11,408 --> 01:12:16,009  
Lagrangian for JWST s orbit we actually

2010

01:12:14,630 --> 01:12:17,900

put a lot of satellites out there

2011

01:12:16,010 --> 01:12:19,670

because it's a relatively stable point

2012

01:12:17,899 --> 01:12:21,259

it doesn't take a lot of fuel to keep a

2013

01:12:19,670 --> 01:12:23,149

satellite in orbit around that LaGrant

2014

01:12:21,260 --> 01:12:24,800

and it's fairly accessible compared to

2015

01:12:23,149 --> 01:12:26,210

some Dettol L'Orange points which are on

2016

01:12:24,800 --> 01:12:41,840

the other side of the Sun and so forth

2017

01:12:26,210 --> 01:12:44,300

oh yeah hmm Wow there we go into space

2018

01:12:41,840 --> 01:12:46,100

they don't go swept away and forever I'm

2019

01:12:44,300 --> 01:12:48,020

saying that the gas in a local sense

2020

01:12:46,100 --> 01:12:50,000

becomes so hot that the protons

2021

01:12:48,020 --> 01:12:51,170

electrons separate but it's not like

2022

01:12:50,000 --> 01:12:52,158

they're going to different parts of the

2023

01:12:51,170 --> 01:12:58,039

universe they're all local they're

2024

01:12:52,158 --> 01:12:59,149  
together and get oh well okay it's a

2025  
01:12:58,039 --> 01:13:02,689  
couple different things going on in

2026  
01:12:59,149 --> 01:13:04,309  
there so the gas gets very energized by

2027  
01:13:02,689 --> 01:13:06,979  
the Stars coming on so it becomes

2028  
01:13:04,310 --> 01:13:08,630  
ionized and then also it basically boils

2029  
01:13:06,979 --> 01:13:10,729  
out of the gravitational wells of these

2030  
01:13:08,630 --> 01:13:12,409  
Dark Matter clumps so the escape

2031  
01:13:10,729 --> 01:13:14,359  
velocity basically becomes such that it

2032  
01:13:12,408 --> 01:13:16,488  
escapes these Dark Matter clumps if the

2033  
01:13:14,359 --> 01:13:17,630  
Dark Matter clump is large enough the

2034  
01:13:16,488 --> 01:13:19,069  
gas will fall back into the

2035  
01:13:17,630 --> 01:13:21,350  
gravitational well and continue forming

2036  
01:13:19,069 --> 01:13:23,179  
stars which is what most galaxies do but

2037  
01:13:21,350 --> 01:13:24,409  
if it's not the gas just goes on into

2038  
01:13:23,179 --> 01:13:26,029

the intergalactic medium between the

2039

01:13:24,408 --> 01:13:27,529

galaxies so there is a lot of gas out

2040

01:13:26,029 --> 01:13:28,939

there I mean one of the press releases

2041

01:13:27,529 --> 01:13:31,130

Frank talked about people even look for

2042

01:13:28,939 --> 01:13:32,479

galaxies by looking for neutral gas and

2043

01:13:31,130 --> 01:13:36,010

so forth so there's gas between the

2044

01:13:32,479 --> 01:13:36,009

galaxies in between the stars as well

2045

01:13:41,229 --> 01:13:44,868

it does it's no longer in those dark

2046

01:13:43,670 --> 01:13:59,359

matter clumps it gets swept out in

2047

01:13:44,868 --> 01:14:01,219

between the clumps yeah yeah I have no

2048

01:13:59,359 --> 01:14:03,170

idea off the top of my head I mean some

2049

01:14:01,219 --> 01:14:04,760

of these things some of these things you

2050

01:14:03,170 --> 01:14:05,690

know there's an economy of scale that

2051

01:14:04,760 --> 01:14:06,980

you know that people are trying to

2052

01:14:05,689 --> 01:14:08,388

leverage when they look at these future

2053  
01:14:06,979 --> 01:14:09,738  
missions but it would be very expensive

2054  
01:14:08,389 --> 01:14:11,599  
I'm not saying it would be

2055  
01:14:09,738 --> 01:14:12,979  
technologically trivial either we would

2056  
01:14:11,599 --> 01:14:14,090  
have to work very hard on it as well

2057  
01:14:12,979 --> 01:14:16,309  
it's not it's not like it would be a

2058  
01:14:14,090 --> 01:14:18,230  
piece of cake but uh but it's within the

2059  
01:14:16,310 --> 01:14:20,060  
grasp of today's technology you know if

2060  
01:14:18,229 --> 01:14:22,779  
if the money was there but it would be a

2061  
01:14:20,060 --> 01:14:26,599  
lot more expensive than James Webb Rahal

2062  
01:14:22,779 --> 01:14:30,259  
8 billion okay another question from

2063  
01:14:26,599 --> 01:14:32,569  
online would a 16 meter mirror telescope

2064  
01:14:30,260 --> 01:14:34,789  
be able to directly image low mass

2065  
01:14:32,569 --> 01:14:36,439  
worlds such as Earth or Mars

2066  
01:14:34,789 --> 01:14:37,880  
yeah that's the goal I mean depends on

2067  
01:14:36,439 --> 01:14:40,339  
how well separated they are from their

2068  
01:14:37,880 --> 01:14:43,130  
host star but if they were separated

2069  
01:14:40,340 --> 01:14:45,139  
enough then does that be the goal to see

2070  
01:14:43,130 --> 01:14:53,150  
you know habitable worlds with such a

2071  
01:14:45,139 --> 01:14:54,618  
telescope to directly image them yeah as

2072  
01:14:53,149 --> 01:14:55,848  
far as we know we don't think I mean

2073  
01:14:54,618 --> 01:14:57,289  
darknet we again we don't know how much

2074  
01:14:55,849 --> 01:14:58,880  
dark matter interacts with normal matter

2075  
01:14:57,289 --> 01:15:00,050  
and energy and so forth so it has a

2076  
01:14:58,880 --> 01:15:01,760  
gravitational effect other than that I

2077  
01:15:00,050 --> 01:15:03,170  
don't know a lot about dark matter you

2078  
01:15:01,760 --> 01:15:05,090  
know there's a lot of theories about it

2079  
01:15:03,170 --> 01:15:06,079  
but no mostly the realization when you

2080  
01:15:05,090 --> 01:15:08,779  
talk about randomization you talk about

2081

01:15:06,079 --> 01:15:11,889  
the baryonic matter this gentleman over

2082  
01:15:08,779 --> 01:15:11,889  
here has had his hand up sure

2083  
01:15:16,488 --> 01:15:20,189  
so the question is how do black holes

2084  
01:15:18,599 --> 01:15:21,779  
interact with dark matter black holes

2085  
01:15:20,189 --> 01:15:23,638  
are a form of dark matter we don't think

2086  
01:15:21,779 --> 01:15:25,259  
they make up a large part of the budget

2087  
01:15:23,639 --> 01:15:26,909  
of dark matter but they interact

2088  
01:15:25,260 --> 01:15:29,730  
gravitationally with dark matter as well

2089  
01:15:26,908 --> 01:15:31,138  
so you know dark matter can interact

2090  
01:15:29,729 --> 01:15:32,488  
with a black hole gravitationally other

2091  
01:15:31,139 --> 01:15:34,889  
than that we don't know how dark matter

2092  
01:15:32,488 --> 01:15:36,209  
interacts with ordinary matter yeah we

2093  
01:15:34,889 --> 01:15:38,099  
actually had a discussion about dark

2094  
01:15:36,210 --> 01:15:39,630  
matter online during your talk okay

2095  
01:15:38,099 --> 01:15:41,550

people wanting to know well what is dark

2096

01:15:39,630 --> 01:15:48,618

matter I said it if I knew that I'd be

2097

01:15:41,550 --> 01:15:48,619

on track for a Nobel Prize yes I think

2098

01:15:53,210 --> 01:15:56,210

yep

2099

01:16:04,689 --> 01:16:09,678

well I mean I could use another analogy

2100

01:16:07,069 --> 01:16:11,269

but to me the dark matter is traced

2101

01:16:09,679 --> 01:16:13,760

throughout the universe in these

2102

01:16:11,270 --> 01:16:16,280

filaments and then the thin layer of gas

2103

01:16:13,760 --> 01:16:17,389

and the leftover matter that the kind of

2104

01:16:16,279 --> 01:16:19,250

matter of matter kind of falls

2105

01:16:17,389 --> 01:16:20,779

gravitationally on top of that and where

2106

01:16:19,250 --> 01:16:23,179

it collapses together due to gravity it

2107

01:16:20,779 --> 01:16:24,559

starts forming stars so to me it's the

2108

01:16:23,179 --> 01:16:25,730

structure upon which everything else is

2109

01:16:24,559 --> 01:16:27,110

built when you see the large scale

2110  
01:16:25,729 --> 01:16:29,029  
structure in the universe it's defined

2111  
01:16:27,109 --> 01:16:30,469  
by dark matter the same way that the

2112  
01:16:29,029 --> 01:16:32,149  
scaffolding of a building defines the

2113  
01:16:30,469 --> 01:17:00,050  
structure of a building but I mean there

2114  
01:16:32,149 --> 01:17:01,719  
might be better analogies try and

2115  
01:17:00,050 --> 01:17:04,340  
summarize that question for the yeah so

2116  
01:17:01,719 --> 01:17:05,960  
for the online folks how confident we

2117  
01:17:04,340 --> 01:17:08,719  
are in the algorithms that allow us to

2118  
01:17:05,960 --> 01:17:10,309  
reduce the data basically so pretty

2119  
01:17:08,719 --> 01:17:11,750  
confident because we came at this a

2120  
01:17:10,309 --> 01:17:14,119  
couple different ways as I showed in the

2121  
01:17:11,750 --> 01:17:16,429  
talk we have comparison populations that

2122  
01:17:14,118 --> 01:17:18,049  
are very very well studied so we use

2123  
01:17:16,429 --> 01:17:19,520  
this camera there's a very very sense of

2124  
01:17:18,050 --> 01:17:21,409  
camera Hubble we measure the brightness

2125  
01:17:19,520 --> 01:17:23,659  
is in the colors of the stars and then

2126  
01:17:21,408 --> 01:17:25,069  
we use the same exact camryn filters to

2127  
01:17:23,658 --> 01:17:26,479  
measure a well-studied object and that's

2128  
01:17:25,069 --> 01:17:28,698  
our controls in this case I showed them

2129  
01:17:26,479 --> 01:17:30,649  
92 we've actually used it for loads of

2130  
01:17:28,698 --> 01:17:32,629  
Studies on Hubble but I'm going to do is

2131  
01:17:30,649 --> 01:17:34,219  
the best comparison here so you can do

2132  
01:17:32,630 --> 01:17:35,480  
an apples-to-apples comparison where a

2133  
01:17:34,219 --> 01:17:36,500  
lot of the systematics you might be

2134  
01:17:35,479 --> 01:17:37,669  
worried about just dropped by the

2135  
01:17:36,500 --> 01:17:39,618  
wayside because you're doing the same

2136  
01:17:37,670 --> 01:17:41,539  
exact thing with both our 92 and these

2137  
01:17:39,618 --> 01:17:42,738  
galaxies and then we also come at it

2138

01:17:41,539 --> 01:17:45,198  
from a different angle we take the

2139  
01:17:42,738 --> 01:17:46,968  
theory of how stars evolved that pattern

2140  
01:17:45,198 --> 01:17:49,279  
they trace out in the diagram and we

2141  
01:17:46,969 --> 01:17:50,689  
calibrate those theoretical models to

2142  
01:17:49,279 --> 01:17:51,800  
the data that we've taken with this

2143  
01:17:50,689 --> 01:17:53,118  
camera over and over and over again so

2144  
01:17:51,800 --> 01:17:54,170  
that's another way of doing it so now

2145  
01:17:53,118 --> 01:17:55,819  
we're pretty confident and then

2146  
01:17:54,170 --> 01:17:58,039  
measuring the stars the signal noise for

2147  
01:17:55,819 --> 01:17:59,420  
to get this accuracy in the ages we got

2148  
01:17:58,039 --> 01:18:01,189  
two solenoids of 100 since you mentioned

2149  
01:17:59,420 --> 01:18:02,929  
signal noise so the signal noise ratio

2150  
01:18:01,189 --> 01:18:04,939  
is 100 so it's very very you know what

2151  
01:18:02,929 --> 01:18:07,118  
percent photometry and let me just say

2152  
01:18:04,939 --> 01:18:10,009

the folks in this building are brilliant

2153

01:18:07,118 --> 01:18:12,769

I'm not an observer ok you guys are

2154

01:18:10,010 --> 01:18:14,340

absolutely brilliant at characterizing

2155

01:18:12,770 --> 01:18:16,340

all of the artifacts

2156

01:18:14,340 --> 01:18:19,860

could be possible in Hubble images okay

2157

01:18:16,340 --> 01:18:21,449

they have I mean they've had 25 years to

2158

01:18:19,859 --> 01:18:23,639

work at this and really understand all

2159

01:18:21,449 --> 01:18:25,649

the stuff and they do amazing stuff at

2160

01:18:23,640 --> 01:18:28,079

being able to really pull out what

2161

01:18:25,649 --> 01:18:29,879

signal and what's noise out of these out

2162

01:18:28,079 --> 01:18:31,289

of the datasets and a lot of the sources

2163

01:18:29,880 --> 01:18:32,819

of systematic error like for example

2164

01:18:31,289 --> 01:18:35,340

this object right here that I'm moving

2165

01:18:32,819 --> 01:18:40,439

to well I probably blew past it just now

2166

01:18:35,340 --> 01:18:42,029

but uh m92 m92 is a very crowded star

2167  
01:18:40,439 --> 01:18:44,549  
field so it gets a little noisier in the

2168  
01:18:42,029 --> 01:18:46,949  
data well I'll show you this these are

2169  
01:18:44,550 --> 01:18:48,810  
very this is a very sparse scar field so

2170  
01:18:46,949 --> 01:18:51,599  
it's pretty easy to measure the here me

2171  
01:18:48,810 --> 01:18:54,030  
show you again here that's a very sparse

2172  
01:18:51,600 --> 01:18:55,470  
image and if i zoom in on it here it's

2173  
01:18:54,029 --> 01:18:56,759  
pretty easy to measure the brightness of

2174  
01:18:55,470 --> 01:18:58,260  
this star the brightness of this star

2175  
01:18:56,760 --> 01:18:59,550  
and so forth because they're not

2176  
01:18:58,260 --> 01:19:00,989  
stepping on top of each other you know

2177  
01:18:59,550 --> 01:19:03,119  
it's just a nice way so well isolated

2178  
01:19:00,989 --> 01:19:04,439  
star so really this is we tried to make

2179  
01:19:03,119 --> 01:19:05,970  
this measurement a turkey shoot we did

2180  
01:19:04,439 --> 01:19:08,219  
very long exposures left the shutter

2181  
01:19:05,970 --> 01:19:09,449  
open for 16 orbits really get accurate

2182  
01:19:08,220 --> 01:19:10,800  
measurements of each of these stars and

2183  
01:19:09,449 --> 01:19:13,019  
there they're not crowding on top of

2184  
01:19:10,800 --> 01:19:14,460  
each other or anything so I'm like m92

2185  
01:19:13,020 --> 01:19:23,460  
it's a little harder because the stars

2186  
01:19:14,460 --> 01:19:25,079  
are crowding yeah gravity itself so self

2187  
01:19:23,460 --> 01:19:26,779  
gravity it's just it has a gravitational

2188  
01:19:25,079 --> 01:19:36,210  
influence on the rest of the dark matter

2189  
01:19:26,779 --> 01:19:40,859  
so it just collapses on itself Albert

2190  
01:19:36,210 --> 01:19:52,109  
Einstein to care all right any last

2191  
01:19:40,859 --> 01:19:54,059  
questions back corner up there I mean it

2192  
01:19:52,109 --> 01:19:56,099  
could happen if Elon Musk wants to you

2193  
01:19:54,060 --> 01:19:57,870  
know say must wants to say hey I want

2194  
01:19:56,100 --> 01:19:59,250  
you to launch a satellite on the SpaceX

2195

01:19:57,869 --> 01:20:01,680  
for you guys or whatever you know it's

2196  
01:19:59,250 --> 01:20:02,670  
possible right now the discussions that

2197  
01:20:01,680 --> 01:20:04,170  
you know people are talking about

2198  
01:20:02,670 --> 01:20:05,279  
they're all talking about NASA launches

2199  
01:20:04,170 --> 01:20:06,480  
but you know it could happen in

2200  
01:20:05,279 --> 01:20:12,989  
partnership with private industry who

2201  
01:20:06,479 --> 01:20:14,009  
knows it's possible yeah so what which

2202  
01:20:12,989 --> 01:20:15,869  
many like to see the two newest

2203  
01:20:14,010 --> 01:20:21,480  
degeneracy videos or the deployment

2204  
01:20:15,869 --> 01:20:23,130  
video sure yeah there's a better one

2205  
01:20:21,479 --> 01:20:25,019  
available on the web now since I put

2206  
01:20:23,130 --> 01:20:26,909  
that one in the slide that is a little

2207  
01:20:25,020 --> 01:20:28,890  
more exciting this one is almost like

2208  
01:20:26,909 --> 01:20:30,059  
you know scale equals one time it almost

2209  
01:20:28,890 --> 01:20:34,829

happens you have to it almost takes like

2210

01:20:30,060 --> 01:20:36,270

six months to watch it but uh we both is

2211

01:20:34,829 --> 01:20:37,829

this is why I don't put transitions in

2212

01:20:36,270 --> 01:20:43,890

my slides most of the time because I

2213

01:20:37,829 --> 01:20:46,309

hate waiting for those okay well well

2214

01:20:43,890 --> 01:20:50,610

while you play the video one more time

2215

01:20:46,310 --> 01:20:52,560

here's a question from online is it

2216

01:20:50,609 --> 01:20:54,509

possible that there could be planets

2217

01:20:52,560 --> 01:20:56,280

orbiting the stars in these small

2218

01:20:54,510 --> 01:20:58,350

galaxies these galaxies were formed

2219

01:20:56,279 --> 01:21:01,409

thirteen billion years ago they're low

2220

01:20:58,350 --> 01:21:03,380

metallicity the problem are you are we

2221

01:21:01,409 --> 01:21:05,369

going to find planets around them so

2222

01:21:03,380 --> 01:21:08,159

astronomers when they look for planets

2223

01:21:05,369 --> 01:21:09,539

around stars they you know planets are

2224  
01:21:08,159 --> 01:21:10,859  
very abundant and we're finding out that

2225  
01:21:09,539 --> 01:21:12,840  
they're that we find them around stars

2226  
01:21:10,859 --> 01:21:15,659  
all over the place on nearby stars but

2227  
01:21:12,840 --> 01:21:17,850  
the as Frank was just saying these stars

2228  
01:21:15,659 --> 01:21:19,769  
were born in clouds of gas that were

2229  
01:21:17,850 --> 01:21:22,170  
very pristine not a lot of material for

2230  
01:21:19,770 --> 01:21:23,520  
building planets so there's not a lot of

2231  
01:21:22,170 --> 01:21:25,529  
likelihood here that there would be

2232  
01:21:23,520 --> 01:21:27,600  
planets around the stars in these ultra

2233  
01:21:25,529 --> 01:21:29,929  
faint dwarf galaxies the analogy I can

2234  
01:21:27,600 --> 01:21:32,250  
make is that Hubble did a very very

2235  
01:21:29,930 --> 01:21:33,810  
thorough search for planets in a

2236  
01:21:32,250 --> 01:21:36,630  
globular cluster I guess it was around

2237  
01:21:33,810 --> 01:21:38,070  
15 years ago now 47 talk which is not

2238  
01:21:36,630 --> 01:21:39,960  
even as metal-poor as these ultra faint

2239  
01:21:38,069 --> 01:21:41,609  
dwarf galaxies it's a little bit it's a

2240  
01:21:39,960 --> 01:21:43,529  
little more metallicity than 10% solar

2241  
01:21:41,609 --> 01:21:45,299  
so it's not like 1% or a thousandth of

2242  
01:21:43,529 --> 01:21:47,239  
solar like these and they didn't find

2243  
01:21:45,300 --> 01:21:48,680  
any planets around

2244  
01:21:47,239 --> 01:21:50,210  
so really if you want to look for

2245  
01:21:48,680 --> 01:21:51,860  
planets you look for stars that are

2246  
01:21:50,210 --> 01:21:53,359  
closer and metallicity to the Sun

2247  
01:21:51,859 --> 01:21:55,159  
because those are more likely to be born

2248  
01:21:53,359 --> 01:21:56,449  
from material with a lot of enriched gas

2249  
01:21:55,159 --> 01:21:58,340  
and so forth around where you have the

2250  
01:21:56,449 --> 01:21:59,689  
building blocks of planets as well so

2251  
01:21:58,340 --> 01:22:01,250  
there's probably not a lot of planets in

2252

01:21:59,689 --> 01:22:04,009  
these galaxies and these ultra faint

2253  
01:22:01,250 --> 01:22:05,750  
door galaxies okay well thank you all

2254  
01:22:04,010 --> 01:22:08,390  
for coming tonight if you have any last

2255  
01:22:05,750 --> 01:22:11,329  
questions come up and see if we can chat

2256  
01:22:08,390 --> 01:22:14,050  
next month um bill Blair will be talking

2257  
01:22:11,329 --> 01:22:16,489  
about Stella populations in Messier III

2258  
01:22:14,050 --> 01:22:18,199  
remember that next month you must

2259  
01:22:16,489 --> 01:22:21,319  
approach from the south not from the

2260  
01:22:18,199 --> 01:22:23,889  
north and let us give Tom another warm

2261  
01:22:21,319 --> 01:22:23,889  
round of applause

2262  
01:22:28,140 --> 01:22:45,570  
I went when I got out of graduate school

2263  
01:22:43,229 --> 01:22:48,469  
went to Corning research we had to give

2264  
01:22:45,569 --> 01:22:48,469  
up once they talk