

Hubble Public Lecture Series

Topic: On the Trail of the Missing Galaxies:
The Oldest Stars in the Neighborhood

Speaker: Tom Brown,
Space Telescope Science Institute



1
00:00:04,070 --> 00:00:02,270
good evening ladies and gentlemen and

2
00:00:06,559 --> 00:00:04,080
welcome to the Space Telescope Science

3
00:00:08,299 --> 00:00:06,569
Institute I'm your host dr. Frank

4
00:00:12,140 --> 00:00:08,309
summers and it is my pleasure to welcome

5
00:00:14,539 --> 00:00:12,150
you for our public lecture series when

6
00:00:16,460 --> 00:00:14,549
you came in I hope that you are

7
00:00:19,370 --> 00:00:16,470
accustomed now to getting pretty

8
00:00:21,370 --> 00:00:19,380
pictures either on that table or I got

9
00:00:24,019 --> 00:00:21,380
smart I put them on this side as well so

10
00:00:26,810 --> 00:00:24,029
tonight's pretty picture that we have is

11
00:00:29,450 --> 00:00:26,820
the core of the globular cluster omega

12
00:00:30,679 --> 00:00:29,460
centauri if that doesn't make any sense

13
00:00:32,450 --> 00:00:30,689

to you turnover

14

00:00:34,639 --> 00:00:32,460

there are a few hundred words to explain

15

00:00:37,310 --> 00:00:34,649

it on the back and if you want to know

16

00:00:40,369 --> 00:00:37,320

even more tom says he's going to be

17

00:00:42,350 --> 00:00:40,379

featuring this in part of his talk

18

00:00:46,279 --> 00:00:42,360

tonight you didn't get it on your way in

19

00:00:48,740 --> 00:00:46,289

please grab one on the way out our talk

20

00:00:50,840 --> 00:00:48,750

tonight is on the trail of the missing

21

00:00:54,979 --> 00:00:50,850

galaxies the oldest stars in the

22

00:00:57,590 --> 00:00:54,989

neighborhood by Tom Brown coming up next

23

00:01:00,439 --> 00:00:57,600

month we have a multi-wavelength view of

24

00:01:03,650 --> 00:01:00,449

stellar life in death in the galaxy

25

00:01:05,560 --> 00:01:03,660

Messier 83 by Bill Blair who's from

26

00:01:08,420 --> 00:01:05,570

across the street at Johns Hopkins

27

00:01:11,810 --> 00:01:08,430

November first we have the infinite the

28

00:01:14,090 --> 00:01:11,820

infamous TBA which means I'm trying to

29

00:01:15,679 --> 00:01:14,100

get somebody to talk I was hoping

30

00:01:17,840 --> 00:01:15,689

somebody will come in and do a talk like

31

00:01:21,289 --> 00:01:17,850

make the universe great again right

32

00:01:23,240 --> 00:01:21,299

because of course this is one week

33

00:01:25,880 --> 00:01:23,250

before Election Day it's not election

34

00:01:27,590 --> 00:01:25,890

night usually in election years my

35

00:01:29,870 --> 00:01:27,600

November talk has to be pushed back a

36

00:01:33,740 --> 00:01:29,880

week here it's just fine because

37

00:01:37,100 --> 00:01:33,750

election is actually on November 8th on

38

00:01:39,050 --> 00:01:37,110

December 6 the talk is to be a to be

39

00:01:41,450 --> 00:01:39,060

decided upon but the speaker is

40

00:01:42,740 --> 00:01:41,460

Christine Chen who will be giving she's

41

00:01:45,469 --> 00:01:42,750

given a talk here before she does

42

00:01:48,249 --> 00:01:45,479

wonderful talks she just hasn't told me

43

00:01:52,010 --> 00:01:48,259

what she's going to talk about this time

44

00:01:53,539 --> 00:01:52,020

hahaha or one of our one of our one of

45

00:01:55,399 --> 00:01:53,549

the campaign surrogates can go and give

46

00:01:57,859 --> 00:01:55,409

the November first talk I'm sure this is

47

00:01:59,630 --> 00:01:57,869

a very coveted audience yeah Maryland it

48

00:02:07,069 --> 00:01:59,640

Maryland is a state that could go either

49

00:02:08,900 --> 00:02:07,079

way right all right construction update

50

00:02:12,559 --> 00:02:08,910

and there really is an update this month

51
00:02:13,730 --> 00:02:12,569
okay it has been closed this is phase 1

52
00:02:17,480 --> 00:02:13,740
has been closed since

53
00:02:20,690 --> 00:02:17,490
of 2016 however next week

54
00:02:22,550 --> 00:02:20,700
phase two and phase three at the north

55
00:02:25,820 --> 00:02:22,560
and south ends the project will begin on

56
00:02:27,800 --> 00:02:25,830
Monday September 12th okay so this is

57
00:02:29,360 --> 00:02:27,810
the last public lecture series of this

58
00:02:31,520 --> 00:02:29,370
year that you could approach from the

59
00:02:33,890 --> 00:02:31,530
north you'll now have to approach from

60
00:02:37,220 --> 00:02:33,900
the south let me show you the map okay

61
00:02:39,530 --> 00:02:37,230
so you see this blue area here this is

62
00:02:41,180 --> 00:02:39,540
what's currently under construction that

63
00:02:45,890 --> 00:02:41,190

will stop being under construction

64

00:02:49,280 --> 00:02:45,900

as of next Monday okay then the part in

65

00:02:51,350 --> 00:02:49,290

red up here from our building here up to

66

00:02:54,410 --> 00:02:51,360

the north up up to University Parkway

67

00:02:56,630 --> 00:02:54,420

and down here in yellow along Wyman Park

68

00:03:00,860 --> 00:02:56,640

Drive those will be closed from

69

00:03:02,990 --> 00:03:00,870

September to December okay so next month

70

00:03:03,560 --> 00:03:03,000

in October when you come to the lecture

71

00:03:07,730 --> 00:03:03,570

series

72

00:03:10,010 --> 00:03:07,740

you must come via the South Gate into

73

00:03:12,800 --> 00:03:10,020

johns hopkins come up Weinman park drive

74

00:03:14,990 --> 00:03:12,810

to get to us here you cannot approach by

75

00:03:16,940 --> 00:03:15,000

a University Parkway this will all be

76

00:03:20,420 --> 00:03:16,950

closed through tool for the rest of this

77

00:03:25,460 --> 00:03:20,430

year okay if you need to know more about

78

00:03:27,140 --> 00:03:25,470

it here is the website I don't know have

79

00:03:29,060 --> 00:03:27,150

a way to memorize that just look for the

80

00:03:32,750 --> 00:03:29,070

San Martin project on the Johns Hopkins

81

00:03:34,850 --> 00:03:32,760

University website okay so next month

82

00:03:38,230 --> 00:03:34,860

north of st 2sc i will be closed

83

00:03:40,850 --> 00:03:38,240

approach STScl from the south all right

84

00:03:44,510 --> 00:03:40,860

hopefully I will see you all here next

85

00:03:47,540 --> 00:03:44,520

next month and you won't get lost our

86

00:03:51,140 --> 00:03:47,550

website if you need to check on things

87

00:03:53,660 --> 00:03:51,150

we have you can do our Hubbell site go

88

00:03:55,310 --> 00:03:53,670

tox link or just use your favorite

89

00:03:57,920 --> 00:03:55,320

search engine look for Hubble public

90

00:04:01,100 --> 00:03:57,930

talks you'll find this you have a list

91

00:04:03,770 --> 00:04:01,110

of the upcoming lectures you can watch

92

00:04:05,450 --> 00:04:03,780

the links to the live online webcasting

93

00:04:07,850 --> 00:04:05,460

from both on YouTube and SD s CI

94

00:04:11,390 --> 00:04:07,860

webcasting you can watch our past

95

00:04:13,100 --> 00:04:11,400

lectures all the way back to 2005 these

96

00:04:14,900 --> 00:04:13,110

wonderful folks have been webcasting it

97

00:04:17,120 --> 00:04:14,910

so there's lots of stuff and you can

98

00:04:19,370 --> 00:04:17,130

sign up for our public lecture series

99

00:04:21,650 --> 00:04:19,380

announcements a couple times a month we

100

00:04:23,720 --> 00:04:21,660

send out reminders of what's up and we

101
00:04:25,850 --> 00:04:23,730
tell you where the webcasts are posted

102
00:04:27,140 --> 00:04:25,860
if you want to see that a lecture that

103
00:04:29,659 --> 00:04:27,150
you missed

104
00:04:32,060 --> 00:04:29,669
um these are the announcements you can

105
00:04:34,010 --> 00:04:32,070
sign up at mail list at STScl to ddu

106
00:04:36,379 --> 00:04:34,020
it's easier to go to our web page

107
00:04:38,330 --> 00:04:36,389
actually we've gotten a ton of signups

108
00:04:41,300 --> 00:04:38,340
from our web page so that's probably the

109
00:04:43,340 --> 00:04:41,310
best thing to do if you need to if you

110
00:04:44,719 --> 00:04:43,350
would like to have a question i tom says

111
00:04:46,939 --> 00:04:44,729
something absolutely brilliant you want

112
00:04:50,210 --> 00:04:46,949
to ask him another question send it to

113
00:04:52,249 --> 00:04:50,220

public lecture at STScl to edu give us

114

00:04:53,659 --> 00:04:52,259

your comment and yet another way you

115

00:04:57,230 --> 00:04:53,669

could even sign up for the announcements

116

00:04:59,990 --> 00:04:57,240

alright on social media Hubble has

117

00:05:02,659 --> 00:05:00,000

Facebook to Twitter accounts it's on

118

00:05:04,159 --> 00:05:02,669

Google+ it's on Pinterest and maybe on a

119

00:05:07,490 --> 00:05:04,169

couple other places that I don't know

120

00:05:10,460 --> 00:05:07,500

about I myself am on Facebook Google+

121

00:05:13,010 --> 00:05:10,470

and Twitter when I have time I don't do

122

00:05:16,279 --> 00:05:13,020

a heck of a lot of social media but I

123

00:05:18,860 --> 00:05:16,289

try to do a couple times a week uh there

124

00:05:21,409 --> 00:05:18,870

will not be an observatory tonight it

125

00:05:22,969 --> 00:05:21,419

probably is clear enough but the person

126

00:05:25,909 --> 00:05:22,979

running the observatory technician is

127

00:05:28,010 --> 00:05:25,919

out of town at the time okay so you will

128

00:05:30,260 --> 00:05:28,020

not have a Observatory but for those of

129

00:05:32,360 --> 00:05:30,270

you who are new usually after the

130

00:05:34,400 --> 00:05:32,370

lecture someone from the Maryland Space

131

00:05:35,570 --> 00:05:34,410

Grant observatory comes and will take

132

00:05:38,930 --> 00:05:35,580

you across the street to do some

133

00:05:42,640 --> 00:05:38,940

observing they do have a website MD

134

00:05:45,830 --> 00:05:42,650

space grant o RG and I believe they do

135

00:05:47,960 --> 00:05:45,840

open nights at the telescope every

136

00:05:49,550 --> 00:05:47,970

mostly every Friday okay so check their

137

00:05:51,080 --> 00:05:49,560

website to find out when their next

138

00:05:52,750 --> 00:05:51,090

observing session is because

139

00:05:56,089 --> 00:05:52,760

unfortunately we won't have it tonight

140

00:05:59,110 --> 00:05:56,099

okay now my favorite part of the night

141

00:06:03,680 --> 00:05:59,120

news from the universe for September

142

00:06:07,790 --> 00:06:03,690

2016 now everybody knows that August is

143

00:06:11,060 --> 00:06:07,800

a slow news month right not this month

144

00:06:12,860 --> 00:06:11,070

not for astronomy we had so much that I

145

00:06:14,659 --> 00:06:12,870

actually had to cut down so there's a

146

00:06:16,969 --> 00:06:14,669

bunch of cool news that I'm not going to

147

00:06:18,379 --> 00:06:16,979

get to tonight okay so let me just go

148

00:06:21,860 --> 00:06:18,389

through what I do have relatively

149

00:06:25,879 --> 00:06:21,870

quickly my top story or I guess I should

150

00:06:29,540 --> 00:06:25,889

say my top nan story is from curious to

151
00:06:32,029 --> 00:06:29,550
spurious I am talking about a something

152
00:06:34,250 --> 00:06:32,039
I noticed on Saturday August 27th an

153
00:06:38,570 --> 00:06:34,260
interesting set it SETI candidate in

154
00:06:40,760 --> 00:06:38,580
Hercules this was on a I noticed this on

155
00:06:42,950 --> 00:06:40,770
social media and that was

156
00:06:46,040 --> 00:06:42,960
to comment that there was a signal in

157
00:06:49,790 --> 00:06:46,050
the direction of the star HD 164 five

158
00:06:53,119 --> 00:06:49,800
nine five and that star is known to have

159
00:06:55,430 --> 00:06:53,129
an extrasolar planet around it okay and

160
00:06:58,219 --> 00:06:55,440
it came from the Ratan 600 radio

161
00:07:03,860 --> 00:06:58,229
telescope in some unpronounceable place

162
00:07:07,279 --> 00:07:03,870
in Russia okay um and so here is the

163
00:07:09,469 --> 00:07:07,289

signal that was published that you can

164

00:07:13,279 --> 00:07:09,479

see that the pink line is the actual

165

00:07:17,089 --> 00:07:13,289

signal and the green line is a fit for a

166

00:07:21,469 --> 00:07:17,099

point source located in the position of

167

00:07:23,899 --> 00:07:21,479

HD one six four five nine five so the

168

00:07:26,809 --> 00:07:23,909

conclusion of this article was not that

169

00:07:30,469 --> 00:07:26,819

oh my god we found aliens but it was

170

00:07:34,089 --> 00:07:30,479

rather softly stated the signal is

171

00:07:38,450 --> 00:07:34,099

interesting and merits further scrutiny

172

00:07:42,439 --> 00:07:38,460

however once the internet gets hold of

173

00:07:43,510 --> 00:07:42,449

it what do we get we get this SETI is

174

00:07:45,350 --> 00:07:43,520

investigating a possible

175

00:07:48,469 --> 00:07:45,360

extraterrestrial signal from deep space

176

00:07:52,249 --> 00:07:48,479

a strong signal that may originate from

177

00:07:57,110 --> 00:07:52,259

a sun-like star aliens sunlight being

178

00:07:59,170 --> 00:07:57,120

verified by SETI now okay so and it got

179

00:08:01,850 --> 00:07:59,180

off into all sorts of interesting

180

00:08:03,589 --> 00:08:01,860

conversations about extraterrestrial

181

00:08:05,540 --> 00:08:03,599

civilizations that have built a Dyson

182

00:08:08,029 --> 00:08:05,550

Sphere around their star and are

183

00:08:10,159 --> 00:08:08,039

capturing all the light from That star

184

00:08:12,080 --> 00:08:10,169

and for some reason then beaming all

185

00:08:13,969 --> 00:08:12,090

that energy right back out into space

186

00:08:17,089 --> 00:08:13,979

I'm not sure exactly why you would do

187

00:08:19,790 --> 00:08:17,099

that um I got home Monday night and my

188

00:08:22,969 --> 00:08:19,800

wife started telling me about an

189

00:08:25,399 --> 00:08:22,979

astronomy discovery my friends on

190

00:08:26,990 --> 00:08:25,409

Facebook my high school friends who I'm

191

00:08:28,309 --> 00:08:27,000

friends with on Facebook they always

192

00:08:29,330 --> 00:08:28,319

start to tag me whenever they see

193

00:08:32,690 --> 00:08:29,340

something interesting say Frank

194

00:08:35,029 --> 00:08:32,700

explained and explained so I had to kick

195

00:08:36,740 --> 00:08:35,039

in and I put up something a little less

196

00:08:38,480 --> 00:08:36,750

glamorous that said something like a

197

00:08:41,690 --> 00:08:38,490

single worth investigating but it's

198

00:08:43,159 --> 00:08:41,700

probably not aliens I wrote about ten or

199

00:08:45,079 --> 00:08:43,169

twelve paragraphs about it on my

200

00:08:46,340 --> 00:08:45,089

Facebook page so that I get explained to

201
00:08:48,310 --> 00:08:46,350
people well you know here's what's

202
00:08:51,980 --> 00:08:48,320
really going on

203
00:08:53,240 --> 00:08:51,990
meanwhile the folks who are actually

204
00:08:54,410 --> 00:08:53,250
going to follow up this investigation

205
00:08:57,949 --> 00:08:54,420
we're due

206
00:09:00,860 --> 00:08:57,959
to follow up this is the SETI folks here

207
00:09:02,540 --> 00:09:00,870
in the United States and this is their

208
00:09:05,389 --> 00:09:02,550
webpage that they put up to talk about

209
00:09:06,710 --> 00:09:05,399
this solar system 94 light-years away as

210
00:09:09,440 --> 00:09:06,720
a possible candidate

211
00:09:12,290 --> 00:09:09,450
well they immediately started turning

212
00:09:14,449 --> 00:09:12,300
their telescopes on to this star looking

213
00:09:17,030 --> 00:09:14,459

for something and they had ten times

214

00:09:19,100 --> 00:09:17,040

better sensitivity and they didn't find

215

00:09:23,780 --> 00:09:19,110

anything so they were pretty doubtful

216

00:09:25,460 --> 00:09:23,790

and then two days later on August 31st a

217

00:09:28,220 --> 00:09:25,470

press release came out from the Russian

218

00:09:29,960 --> 00:09:28,230

news agency Tass that said an additional

219

00:09:32,269 --> 00:09:29,970

check showed that it was emanating from

220

00:09:36,550 --> 00:09:32,279

a Soviet military satellite which had

221

00:09:40,160 --> 00:09:36,560

not be entered into any of the catalogs

222

00:09:41,870 --> 00:09:40,170

now we look at this we say Oh everyone's

223

00:09:42,379 --> 00:09:41,880

yo-yo everyone's making a big fuss over

224

00:09:46,389 --> 00:09:42,389

nothing

225

00:09:48,259 --> 00:09:46,399

um but this is how science is done okay

226

00:09:50,120 --> 00:09:48,269

astronomers who find something

227

00:09:52,579 --> 00:09:50,130

interesting and don't have enough

228

00:09:55,040 --> 00:09:52,589

sensitivity to really check it out tell

229

00:09:56,509 --> 00:09:55,050

others about it and then those go in and

230

00:09:58,310 --> 00:09:56,519

check it and see mmm and they

231

00:09:59,870 --> 00:09:58,320

cross-check it it has to be observed by

232

00:10:01,519 --> 00:09:59,880

multiple people using multiple

233

00:10:03,920 --> 00:10:01,529

instruments in order for people to

234

00:10:05,960 --> 00:10:03,930

really take it seriously so the science

235

00:10:07,880 --> 00:10:05,970

was done right because they said look

236

00:10:08,930 --> 00:10:07,890

we're not claiming extraterrestrials

237

00:10:09,470 --> 00:10:08,940

here we're just saying this is

238

00:10:11,780 --> 00:10:09,480

interesting

239

00:10:14,389 --> 00:10:11,790

somebody please follow up and the follow

240

00:10:17,180 --> 00:10:14,399

ups showed you oh sorry it isn't

241

00:10:21,170 --> 00:10:17,190

actually interesting okay however in the

242

00:10:24,250 --> 00:10:21,180

Internet age we have a moral to to go by

243

00:10:26,840 --> 00:10:24,260

here and the moral of the story is

244

00:10:29,900 --> 00:10:26,850

scientists must strive not to cry wolf

245

00:10:35,780 --> 00:10:29,910

because that's the job of the internet

246

00:10:38,360 --> 00:10:35,790

okay all right our second story we're

247

00:10:40,880 --> 00:10:38,370

doing to do some interplanetary mission

248

00:10:44,389 --> 00:10:40,890

updates the first update comes from the

249

00:10:46,490 --> 00:10:44,399

Juno mission to Jupiter and if you're

250

00:10:48,500 --> 00:10:46,500

here in July I told you about the Juno

251
00:10:50,900 --> 00:10:48,510
mission inserting itself into orbit

252
00:10:52,730 --> 00:10:50,910
around Jupiter the beginning of the Juno

253
00:10:54,559 --> 00:10:52,740
mission and the fact that it's going to

254
00:10:56,240 --> 00:10:54,569
go into this very tight orbit and go

255
00:10:58,269 --> 00:10:56,250
very far away and it's going to sample

256
00:11:01,939 --> 00:10:58,279
the full range of the magnetic field

257
00:11:04,840 --> 00:11:01,949
well it's on a very long orbit initially

258
00:11:08,360 --> 00:11:04,850
and it just got back for its first pass

259
00:11:10,850 --> 00:11:08,370
so in July 2016 is the insertion

260
00:11:12,710 --> 00:11:10,860
it's going to do two orbits with 53 and

261
00:11:15,200 --> 00:11:12,720
a half day period then it's going to

262
00:11:18,350 --> 00:11:15,210
follow that by 35 orbits with a 14-day

263
00:11:21,260 --> 00:11:18,360

period so on August 27th it made its

264

00:11:24,230 --> 00:11:21,270

first fly by of Jupiter and this image

265

00:11:27,230 --> 00:11:24,240

right here is as it's approaching for

266

00:11:28,730 --> 00:11:27,240

its first flyby okay and what we're

267

00:11:31,730 --> 00:11:28,740

going to get at least in the visible

268

00:11:35,060 --> 00:11:31,740

light images come from a camera called

269

00:11:37,579 --> 00:11:35,070

Juno cam and Juno cam is not a science

270

00:11:39,920 --> 00:11:37,589

camera all right I want to dent lesson

271

00:11:41,750 --> 00:11:39,930

your expectations here because it is an

272

00:11:43,880 --> 00:11:41,760

outreach camera it's just a 2 megapixel

273

00:11:45,829 --> 00:11:43,890

it's like a webcam sitting on the

274

00:11:48,110 --> 00:11:45,839

science a satellite ok it's going to get

275

00:11:50,690 --> 00:11:48,120

some cool pictures but it's not a

276

00:11:53,090 --> 00:11:50,700

science a real science deep science

277

00:11:54,860 --> 00:11:53,100

based eyes camera most of the science

278

00:11:56,390 --> 00:11:54,870

going to be done from Juno is about on

279

00:11:57,980 --> 00:11:56,400

the atmosphere and the magnetosphere

280

00:11:59,930 --> 00:11:57,990

it's going to have some ultraviolet

281

00:12:01,190 --> 00:11:59,940

imaging and some infrared imaging and

282

00:12:03,410 --> 00:12:01,200

it's going to look at the Aurora and

283

00:12:06,260 --> 00:12:03,420

such but the visible light images from

284

00:12:08,360 --> 00:12:06,270

Juno they aren't the highlight they are

285

00:12:11,140 --> 00:12:08,370

at the science goal of the mission ok

286

00:12:14,510 --> 00:12:11,150

but it did get some cool pictures

287

00:12:17,180 --> 00:12:14,520

because we have not studied the poles of

288

00:12:19,930 --> 00:12:17,190

Jupiter very very much the last time we

289

00:12:25,100 --> 00:12:19,940

saw the North Pole of Jupiter was in

290

00:12:27,590 --> 00:12:25,110

1974 well now we have these images okay

291

00:12:29,480 --> 00:12:27,600

so this is Jupiter's North Pole alright

292

00:12:31,040 --> 00:12:29,490

let me just go back to this one here you

293

00:12:32,480 --> 00:12:31,050

can see that most of Jupiter is this

294

00:12:34,490 --> 00:12:32,490

banded structure ok

295

00:12:36,620 --> 00:12:34,500

that's the stuff we're used to if we go

296

00:12:38,329 --> 00:12:36,630

look at the North Pole however you can

297

00:12:39,860 --> 00:12:38,339

start to see especially in this enhanced

298

00:12:42,260 --> 00:12:39,870

image that you've got all sorts of

299

00:12:45,140 --> 00:12:42,270

storminess going on in here you do not

300

00:12:47,390 --> 00:12:45,150

have that banded structure alright and

301
00:12:49,250 --> 00:12:47,400
what's really cool not just to see that

302
00:12:52,840 --> 00:12:49,260
the North Pole but they got this

303
00:12:55,310 --> 00:12:52,850
gorgeous picture of Jupiter's South Pole

304
00:12:57,920 --> 00:12:55,320
all right now can you see the amazing

305
00:12:59,630 --> 00:12:57,930
number of storms and there's still a

306
00:13:01,370 --> 00:12:59,640
little bit of banded nough stu the

307
00:13:02,900 --> 00:13:01,380
structure but there's a lot more

308
00:13:05,840 --> 00:13:02,910
turbulence going on

309
00:13:08,510 --> 00:13:05,850
there's slower speeds down here okay in

310
00:13:11,570 --> 00:13:08,520
a motion of it and so you can see that

311
00:13:14,570 --> 00:13:11,580
you've got an entire a different pattern

312
00:13:16,100 --> 00:13:14,580
on Jupiter at the poles than you do in

313
00:13:18,110 --> 00:13:16,110

that space star standard banded

314

00:13:20,210 --> 00:13:18,120

structure that runs around most of the

315

00:13:21,420 --> 00:13:20,220

planet so this is really cool because

316

00:13:23,820 --> 00:13:21,430

we've really not

317

00:13:25,980 --> 00:13:23,830

in the polls of Jupiter and we will get

318

00:13:28,920 --> 00:13:25,990

more of these as the mission continues

319

00:13:30,930 --> 00:13:28,930

okay but the next pass won't be until

320

00:13:33,660 --> 00:13:30,940

October at that time they're going to do

321

00:13:36,570 --> 00:13:33,670

a burn to go into the 14-day orbit so

322

00:13:39,540 --> 00:13:36,580

Juno has gone into it's serious science

323

00:13:41,460 --> 00:13:39,550

mode all right it's getting great great

324

00:13:43,650 --> 00:13:41,470

observations and we look forward to more

325

00:13:45,840 --> 00:13:43,660

cool pictures but really a lot more

326

00:13:49,590 --> 00:13:45,850

serious science about the atmosphere to

327

00:13:52,889 --> 00:13:49,600

come our second mission update is about

328

00:13:56,250 --> 00:13:52,899

Rosetta the Rosetta mission and the

329

00:13:58,530 --> 00:13:56,260

lander feel a now if you remember how

330

00:14:01,370 --> 00:13:58,540

many of you were you he we're coming to

331

00:14:05,570 --> 00:14:01,380

the public lecture series back in 2014

332

00:14:10,199 --> 00:14:05,580

okay do you remember November 2014

333

00:14:11,550 --> 00:14:10,209

because that's when we had a particular

334

00:14:13,740 --> 00:14:11,560

event now let me just go through his

335

00:14:16,590 --> 00:14:13,750

throw over this okay so the Rosetta

336

00:14:22,050 --> 00:14:16,600

mission its final goal was to comment

337

00:14:24,389 --> 00:14:22,060

67p churyumov-gerasimenko okay or just

338

00:14:29,160 --> 00:14:24,399

to make it easier we like to call it

339

00:14:32,220 --> 00:14:29,170

Comet rubber ducky simply because of its

340

00:14:35,640 --> 00:14:32,230

shape now so 67p was the target of it

341

00:14:40,829 --> 00:14:35,650

okay and the Rosetta main orbiter went

342

00:14:46,040 --> 00:14:40,839

into orbit around 67p the feel a lander

343

00:14:48,150 --> 00:14:46,050

was released in November 2014 to land on

344

00:14:51,480 --> 00:14:48,160

actually uh what would be the head of

345

00:14:54,630 --> 00:14:51,490

the duck okay and it dropped on down for

346

00:14:56,490 --> 00:14:54,640

seven hours and when it hit two harpoons

347

00:14:59,970 --> 00:14:56,500

were supposed to dig into the ice and

348

00:15:02,850 --> 00:14:59,980

hold it on well the harpoons didn't go

349

00:15:05,250 --> 00:15:02,860

so instead fillet bounced it bounced a

350

00:15:07,170 --> 00:15:05,260

kilometer upward okay

351
00:15:08,880 --> 00:15:07,180
relatively low gravity you know it could

352
00:15:12,480 --> 00:15:08,890
jump really high and actually did a

353
00:15:15,540 --> 00:15:12,490
second bounce and settled into a an

354
00:15:18,240 --> 00:15:15,550
unknown region on the surface of the

355
00:15:20,090 --> 00:15:18,250
comet it was obviously not pointed

356
00:15:22,800 --> 00:15:20,100
upward because it couldn't communicate

357
00:15:25,590 --> 00:15:22,810
it got they got a few pictures from it

358
00:15:27,840 --> 00:15:25,600
but they couldn't keep it alive and the

359
00:15:29,960 --> 00:15:27,850
feel a lander was declared a loss in

360
00:15:32,580 --> 00:15:29,970
March of 2016

361
00:15:34,650 --> 00:15:32,590
however they

362
00:15:36,870 --> 00:15:34,660
knew where it was and the rosetta

363
00:15:38,700 --> 00:15:36,880

mission main orbiter kept orbiting

364

00:15:40,800 --> 00:15:38,710

around it and actually moved into closer

365

00:15:43,820 --> 00:15:40,810

and closer orbits as the mission

366

00:15:49,110 --> 00:15:43,830

continued and they searched for it and

367

00:15:52,560 --> 00:15:49,120

just a few days ago they found it now

368

00:15:54,270 --> 00:15:52,570

can you spot the feel a lander those of

369

00:16:00,270 --> 00:15:54,280

you who know where it is yes it's

370

00:16:02,160 --> 00:16:00,280

actually over there all right let me

371

00:16:04,010 --> 00:16:02,170

give you the blow-up okay this is an

372

00:16:07,650 --> 00:16:04,020

amazing image by the way it's 5

373

00:16:09,870 --> 00:16:07,660

centimeters per pixel okay 5 centimeters

374

00:16:10,530 --> 00:16:09,880

per pixel amazing stuff of the surface

375

00:16:12,720 --> 00:16:10,540

of a comet

376

00:16:15,570 --> 00:16:12,730

here is the feel a lander they found it

377

00:16:17,340 --> 00:16:15,580

ok and you can see it's tipped over on

378

00:16:19,590 --> 00:16:17,350

its side so of course it's not going to

379

00:16:22,170 --> 00:16:19,600

have good communication with the with

380

00:16:24,420 --> 00:16:22,180

the orbiter all right and here is a

381

00:16:27,630 --> 00:16:24,430

diagram annotated diagram to help you

382

00:16:31,800 --> 00:16:27,640

understand that the there the legs of

383

00:16:34,400 --> 00:16:31,810

the lander on huh where's the ice the

384

00:16:37,530 --> 00:16:34,410

whole the whole comet is is ice and rock

385

00:16:39,120 --> 00:16:37,540

yes but if you know the the surface of a

386

00:16:42,420 --> 00:16:39,130

comet is generally a sort of a tar-like

387

00:16:45,390 --> 00:16:42,430

substance ok because the volatiles have

388

00:16:47,460 --> 00:16:45,400

have gone away all right this one this

389

00:16:50,130 --> 00:16:47,470

comment only gets into about 1.2

390

00:16:52,410 --> 00:16:50,140

astronomical units as closest approach

391

00:16:56,160 --> 00:16:52,420

to the Sun but still the volatiles will

392

00:16:57,960 --> 00:16:56,170

will go away you get inside 3a you then

393

00:17:01,560 --> 00:16:57,970

the volatiles on the surface will

394

00:17:03,330 --> 00:17:01,570

definitely definitely go away ok so it

395

00:17:06,510 --> 00:17:03,340

actually one of the reasons why the

396

00:17:08,220 --> 00:17:06,520

field a lander bounced was at the

397

00:17:11,699 --> 00:17:08,230

surface was was harder than they

398

00:17:13,110 --> 00:17:11,709

expected it to be okay based on pron

399

00:17:16,199 --> 00:17:13,120

previous things the deep impact they

400

00:17:17,550 --> 00:17:16,209

expected a softer surface alright so

401

00:17:19,860 --> 00:17:17,560

this is the feel a lander here

402

00:17:27,110 --> 00:17:19,870

unfortunately it's unrecoverable all

403

00:17:30,960 --> 00:17:27,120

right ah call Bruce Willis there you go

404

00:17:32,670 --> 00:17:30,970

alright so here's what I just I just

405

00:17:35,390 --> 00:17:32,680

want to recap for you the rosetta

406

00:17:39,450 --> 00:17:35,400

mission okay it was launched in March of

407

00:17:42,270 --> 00:17:39,460

2004 it had flybys of Earth three times

408

00:17:45,810 --> 00:17:42,280

it flew by Mars once it flew by two

409

00:17:48,230 --> 00:17:45,820

different asteroids it

410

00:17:51,150 --> 00:17:48,240

five dat 67p in August the feel a

411

00:17:54,840 --> 00:17:51,160

landing was in November 2014

412

00:17:56,400 --> 00:17:54,850

Rosetta stayed with 67p as it went came

413

00:17:59,850 --> 00:17:56,410

up approached the Sun went through

414

00:18:02,970 --> 00:17:59,860

perihelion last August and two years

415

00:18:05,100 --> 00:18:02,980

later now all right it's still with it

416

00:18:08,010 --> 00:18:05,110

and it's moved down to that very close

417

00:18:08,970 --> 00:18:08,020

orbit and the mission is finally going

418

00:18:12,810 --> 00:18:08,980

to end this month

419

00:18:15,120 --> 00:18:12,820

on September 30th they're going to take

420

00:18:18,060 --> 00:18:15,130

the main orbiter and have that also land

421

00:18:21,780 --> 00:18:18,070

on the comet now I say land in a general

422

00:18:25,410 --> 00:18:21,790

sense because as one one blog put it

423

00:18:27,420 --> 00:18:25,420

it'll be more like a soft crash because

424

00:18:29,880 --> 00:18:27,430

it doesn't have the kind of landing gear

425

00:18:33,030 --> 00:18:29,890

that file was built with so it will

426

00:18:35,820 --> 00:18:33,040

effectively crash into 67p at the time

427

00:18:37,920 --> 00:18:35,830

and will continue to orbit with 67p for

428

00:18:40,470 --> 00:18:37,930

the rest of history alright so we can

429

00:18:41,910 --> 00:18:40,480

look for some really cool images from

430

00:18:44,220 --> 00:18:41,920

the Rosetta mission the end of this

431

00:18:46,050 --> 00:18:44,230

month on September 30th because as this

432

00:18:48,450 --> 00:18:46,060

main orbiter gets in close to the comet

433

00:18:50,400 --> 00:18:48,460

it's got a lot more science instruments

434

00:18:52,710 --> 00:18:50,410

that it can take all sorts of cool

435

00:18:55,440 --> 00:18:52,720

readings and get a lot of interesting

436

00:18:59,250 --> 00:18:55,450

science as it comes in for landing the

437

00:19:01,530 --> 00:18:59,260

end of this month okay alright I had to

438

00:19:03,060 --> 00:19:01,540

throw in one Hubble story I'm sorry Tom

439

00:19:05,250 --> 00:19:03,070

I'm taking so long but I had to throw it

440

00:19:07,350 --> 00:19:05,260

once one Hubble story because the rest

441

00:19:09,540 --> 00:19:07,360

of the stuff was from from elsewhere and

442

00:19:13,080 --> 00:19:09,550

our final story tonight is galaxies late

443

00:19:15,930 --> 00:19:13,090

bloomers okay so Hubble release these

444

00:19:20,730 --> 00:19:15,940

two cool images of this this month of

445

00:19:23,970 --> 00:19:20,740

Pisces a and Pisces B two dwarf galaxies

446

00:19:25,890 --> 00:19:23,980

alright and what's one of the really

447

00:19:28,620 --> 00:19:25,900

cool things was how these galaxies were

448

00:19:30,030 --> 00:19:28,630

discovered so when I say galaxies you

449

00:19:32,040 --> 00:19:30,040

probably think of something like the

450

00:19:36,560 --> 00:19:32,050

Whirlpool Galaxy sort of the standard

451
00:19:39,570 --> 00:19:36,570
big giant spiral galaxies okay but the

452
00:19:41,610 --> 00:19:39,580
Whirlpool Galaxy is actually bigger than

453
00:19:44,280 --> 00:19:41,620
you think because this is the visible

454
00:19:46,020 --> 00:19:44,290
light view if we go into the radio and

455
00:19:49,950 --> 00:19:46,030
search for the hydrogen gas the

456
00:19:53,460 --> 00:19:49,960
Whirlpool Galaxy looks like that there

457
00:19:55,980 --> 00:19:53,470
is a lot more hydrogen gas up there that

458
00:19:58,920 --> 00:19:55,990
we can see in radio than can be seen in

459
00:20:02,010 --> 00:19:58,930
the visible eye of stars so these

460
00:20:04,950 --> 00:20:02,020
or galaxies here were actually found in

461
00:20:07,800 --> 00:20:04,960
by radio searches looking for blobs of

462
00:20:09,780 --> 00:20:07,810
hydrogen it was actually a survey of the

463
00:20:13,410 --> 00:20:09,790

Milky Way galaxy looking for hydrogen

464

00:20:15,480 --> 00:20:13,420
clouds and they found 30 to 50

465

00:20:18,090 --> 00:20:15,490
candidates that might actually be

466

00:20:20,100 --> 00:20:18,100
external galaxies they went through and

467

00:20:22,620 --> 00:20:20,110
they narrowed them down to the top 10 or

468

00:20:24,540 --> 00:20:22,630
12 and they chose two of them that had

469

00:20:26,400 --> 00:20:24,550
the highest probability of actually

470

00:20:28,470 --> 00:20:26,410
being galaxies they didn't know they

471

00:20:30,120 --> 00:20:28,480
couldn't see the stars in these galaxies

472

00:20:32,340 --> 00:20:30,130
they could just see there was a blob of

473

00:20:35,190 --> 00:20:32,350
hydrogen there and when they looked with

474

00:20:37,950 --> 00:20:35,200
Hubble they found the two dwarf galaxies

475

00:20:40,260 --> 00:20:37,960
and with Hubble being able to resolve

476

00:20:43,050 --> 00:20:40,270

the stars and be able to do the stellar

477

00:20:45,600 --> 00:20:43,060

populations of it they were actually

478

00:20:49,140 --> 00:20:45,610

able to tell that these these dwarf

479

00:20:51,540 --> 00:20:49,150

galaxies are late bloomers they had a

480

00:20:53,850 --> 00:20:51,550

burst of star formation only a hundred

481

00:20:56,820 --> 00:20:53,860

million years ago all right now I know

482

00:20:59,280 --> 00:20:56,830

100 million years is really long to you

483

00:21:02,940 --> 00:20:59,290

and me but in terms of the cosmos that's

484

00:21:06,420 --> 00:21:02,950

13.8 billion years old 100 million years

485

00:21:09,540 --> 00:21:06,430

ago is way late in universe to have such

486

00:21:11,880 --> 00:21:09,550

a burst of star formation okay so these

487

00:21:13,560 --> 00:21:11,890

are galaxies that have been hanging out

488

00:21:16,260 --> 00:21:13,570

in what we call in what we call a void

489

00:21:18,720 --> 00:21:16,270

region of the universe they're very very

490

00:21:21,090 --> 00:21:18,730

slow developers they're late developers

491

00:21:23,130 --> 00:21:21,100

and only in the last hundred million

492

00:21:25,580 --> 00:21:23,140

years have they had a burst a

493

00:21:29,430 --> 00:21:25,590

significant amount of star formation

494

00:21:31,920 --> 00:21:29,440

okay so by using the radio to then

495

00:21:36,060 --> 00:21:31,930

follow up with optical we can actually

496

00:21:40,170 --> 00:21:36,070

find these rare small galaxies out in

497

00:21:41,940 --> 00:21:40,180

universe okay they're in the direction

498

00:21:43,680 --> 00:21:41,950

of Pisces they're not in the local group

499

00:21:45,720 --> 00:21:43,690

okay there's they're far enough away

500

00:21:48,840 --> 00:21:45,730

that that they're there they're outside

501
00:21:51,810 --> 00:21:48,850
the local group okay all right we got to

502
00:21:55,890 --> 00:21:51,820
get to our featured speaker all right

503
00:21:58,830 --> 00:21:55,900
let me switch over and our speaker

504
00:22:01,050 --> 00:21:58,840
tonight is Tom Brown and I want to thank

505
00:22:02,850 --> 00:22:01,060
him for postponing his talk from May so

506
00:22:05,490 --> 00:22:02,860
I could bring in sandy Faber back then

507
00:22:07,710 --> 00:22:05,500
and I know you guys enjoyed her talk

508
00:22:10,140 --> 00:22:07,720
you're definitely gonna enjoy Tom Tom

509
00:22:12,160 --> 00:22:10,150
got his degree across the street at

510
00:22:14,590 --> 00:22:12,170
Johns Hopkins University

511
00:22:16,810 --> 00:22:14,600
he did hippo stock down in Goddard Space

512
00:22:19,600 --> 00:22:16,820
Flight Center and then he came to work

513
00:22:22,660 --> 00:22:19,610

here at Space Telescope a very Maryland

514

00:22:25,570 --> 00:22:22,670

career here at Space Telescope he's done

515

00:22:27,130 --> 00:22:25,580

some amazing things he's worked on the

516

00:22:29,980 --> 00:22:27,140

Hubble Space Telescope he's worked on

517

00:22:33,070 --> 00:22:29,990

the James Webb Space Telescope and he is

518

00:22:36,730 --> 00:22:33,080

now the head of the Hubble mission here

519

00:22:39,039 --> 00:22:36,740

and he is a famous in astronomy circles

520

00:22:43,510 --> 00:22:39,049

for having taken the deepest visible

521

00:22:44,980 --> 00:22:43,520

light image ever of a star field in the

522

00:22:47,860 --> 00:22:44,990

andromeda galaxy

523

00:22:51,310 --> 00:22:47,870

we call it the stellar deep field and it

524

00:22:56,140 --> 00:22:51,320

was recently honored by being on the

525

00:22:59,049 --> 00:22:56,150

cover of david bowie's last album so a

526

00:23:07,390 --> 00:22:59,059

true true famous guy ladies and

527

00:23:08,770 --> 00:23:07,400

gentlemen Tom Brown all right thank you

528

00:23:09,640 --> 00:23:08,780

Frank thanks for that introduction can

529

00:23:11,409 --> 00:23:09,650

everyone hear me all right with the

530

00:23:12,820 --> 00:23:11,419

microphone all right and another thing

531

00:23:14,919 --> 00:23:12,830

you got to remind me now and then is I'm

532

00:23:16,299 --> 00:23:14,929

both a little hyperactive and I'm from

533

00:23:17,560 --> 00:23:16,309

New York so you got to slow me down now

534

00:23:20,140 --> 00:23:17,570

and then if I start going too quickly

535

00:23:22,180 --> 00:23:20,150

okay so again as Frank said I'll be

536

00:23:23,409 --> 00:23:22,190

talking today about the missing galaxies

537

00:23:25,120 --> 00:23:23,419

and the nearby universe this is

538

00:23:26,650 --> 00:23:25,130

something known as the missing satellite

539

00:23:28,390 --> 00:23:26,660

problem that astronomers have been

540

00:23:29,860 --> 00:23:28,400

studying for decades and one way to

541

00:23:32,860 --> 00:23:29,870

attack this problem is by looking at the

542

00:23:34,870 --> 00:23:32,870

oldest stars in the nearby universe so

543

00:23:36,460 --> 00:23:34,880

this is work I'm doing with the Hubble

544

00:23:37,900 --> 00:23:36,470

Space Telescope it's a program I put

545

00:23:40,539 --> 00:23:37,910

together a few years ago it was about

546

00:23:42,460 --> 00:23:40,549

113 orbits on Hubble and the team of

547

00:23:44,110 --> 00:23:42,470

folks I show here from around the world

548

00:23:45,669 --> 00:23:44,120

worked on it with me I've listed their

549

00:23:47,049 --> 00:23:45,679

names I won't go through them all but

550

00:23:48,700 --> 00:23:47,059

some of them are observers on Hubble

551
00:23:50,200 --> 00:23:48,710
like myself there's some folks here who

552
00:23:52,240 --> 00:23:50,210
had time on the Keck telescope in Hawaii

553
00:23:53,919 --> 00:23:52,250
and then there are also some theorists

554
00:23:56,080 --> 00:23:53,929
on this program who study both the

555
00:23:57,430 --> 00:23:56,090
evolution of galaxies and time the

556
00:23:59,140 --> 00:23:57,440
evolution of the universe and the

557
00:24:00,430 --> 00:23:59,150
evolution of stars so it's a good mix of

558
00:24:04,930 --> 00:24:00,440
people who use telescopes on the ground

559
00:24:06,669 --> 00:24:04,940
in space and then also theorists so this

560
00:24:08,860 --> 00:24:06,679
is a simulation from been more

561
00:24:10,840 --> 00:24:08,870
universities Uruk of how the structure

562
00:24:12,549 --> 00:24:10,850
of the universe evolved with time on the

563
00:24:14,169 --> 00:24:12,559

right hand side here so this little

564

00:24:15,250 --> 00:24:14,179

number cutting down here is red ship to

565

00:24:16,810 --> 00:24:15,260

those who are familiar with it so this

566

00:24:18,130 --> 00:24:16,820

is red shift going into the present and

567

00:24:20,380 --> 00:24:18,140

the beginning of the simulation I'll

568

00:24:21,580 --> 00:24:20,390

back up here when it stops so you can

569

00:24:24,100 --> 00:24:21,590

see it again the begin the simulation

570

00:24:25,660 --> 00:24:24,110

starts right after the Big Bang and then

571

00:24:27,640 --> 00:24:25,670

the matter in the universe call

572

00:24:30,040 --> 00:24:27,650

les is in this filamentary structure you

573

00:24:32,230 --> 00:24:30,050

see here this is how theorists predict

574

00:24:34,030 --> 00:24:32,240

the universe evolved under the paradigm

575

00:24:35,200 --> 00:24:34,040

of cold dark matter and the assumption

576

00:24:37,270 --> 00:24:35,210

here is that there is dark matter

577

00:24:37,750 --> 00:24:37,280

permeating the universe it's cold and

578

00:24:42,370 --> 00:24:37,760

dark

579

00:24:44,380 --> 00:24:42,380

and you can't see it but you do see are

580

00:24:45,700 --> 00:24:44,390

the galaxies that form in the filaments

581

00:24:48,670 --> 00:24:45,710

along the structure of cold dark matter

582

00:24:51,220 --> 00:24:48,680

so dark matter is the scaffolding upon

583

00:24:52,480 --> 00:24:51,230

which galaxies are built so the dark

584

00:24:53,710 --> 00:24:52,490

matter permeates the universe and then

585

00:24:55,540 --> 00:24:53,720

these filaments are where you have large

586

00:24:57,700 --> 00:24:55,550

galaxies so these bright red points here

587

00:24:59,110 --> 00:24:57,710

are galaxies like the Milky Way giant

588

00:25:00,790 --> 00:24:59,120

spiral galaxies are giant elliptical

589

00:25:04,690 --> 00:25:00,800

galaxies and the little tiny dots are

590

00:25:07,420 --> 00:25:04,700

satellite galaxies the cold egg matter

591

00:25:08,800 --> 00:25:07,430

theory confirm conforms with a lot of

592

00:25:11,470 --> 00:25:08,810

the observable phenomena in the universe

593

00:25:13,510 --> 00:25:11,480

but one thing it strikes out on is it

594

00:25:15,190 --> 00:25:13,520

over predicts the number of tiny little

595

00:25:17,040 --> 00:25:15,200

galaxies so that's Ana long-standing

596

00:25:19,960 --> 00:25:17,050

problem with the cold dark matter theory

597

00:25:21,910 --> 00:25:19,970

so here's a zoom in of an environment

598

00:25:23,650 --> 00:25:21,920

like our own Milky Way this is from my

599

00:25:25,630 --> 00:25:23,660

collaborator Jason Tomlinson who also

600

00:25:28,000 --> 00:25:25,640

works here at the Institute he's a

601
00:25:29,680 --> 00:25:28,010
theorist and observer and the simulation

602
00:25:31,750 --> 00:25:29,690
I'm showing here is about a million

603
00:25:33,430 --> 00:25:31,760
light years on aside and so this is the

604
00:25:35,410 --> 00:25:33,440
environment around a galaxy like our own

605
00:25:37,480 --> 00:25:35,420
Milky Way and this shows in his

606
00:25:39,310 --> 00:25:37,490
simulation here in Jason simulation the

607
00:25:41,080 --> 00:25:39,320
expectations for the distribution of

608
00:25:42,430 --> 00:25:41,090
dark matter in the nearby universe the

609
00:25:43,570 --> 00:25:42,440
very nearby universe within a million

610
00:25:45,820 --> 00:25:43,580
light years I might not sound that

611
00:25:47,380 --> 00:25:45,830
nearby but this is roughly the the

612
00:25:48,550 --> 00:25:47,390
sphere of influence of the Milky Way

613
00:25:50,290 --> 00:25:48,560

so the Milky Way would be sitting here

614

00:25:52,480 --> 00:25:50,300

at the center and we know there's a

615

00:25:53,710 --> 00:25:52,490

galaxy there it's the Milky Way and then

616

00:25:55,810 --> 00:25:53,720

there's all these little clumps of dark

617

00:25:57,820 --> 00:25:55,820

matter orbiting the gravitational well

618

00:26:00,220 --> 00:25:57,830

of the Milky Way and there are hundreds

619

00:26:01,600 --> 00:26:00,230

of them in this simulation and when you

620

00:26:02,740 --> 00:26:01,610

look at the number of galaxies actually

621

00:26:05,380 --> 00:26:02,750

orbiting the Milky Way there's only a

622

00:26:07,200 --> 00:26:05,390

few dozen so it's off by a large amount

623

00:26:09,730 --> 00:26:07,210

it's grossly off the number of observed

624

00:26:10,810 --> 00:26:09,740

satellite galaxies compared to the

625

00:26:13,030 --> 00:26:10,820

predictions of the cold dark matter

626
00:26:14,710 --> 00:26:13,040
theory so this is the missing satellite

627
00:26:16,000 --> 00:26:14,720
problem that call dark matter says

628
00:26:17,980 --> 00:26:16,010
there's lots of little clumps of dark

629
00:26:19,900 --> 00:26:17,990
matter out here and yet we only see a

630
00:26:21,730 --> 00:26:19,910
few dozen galaxies and these clumps to

631
00:26:23,500 --> 00:26:21,740
dark matter are the seeds of galaxy

632
00:26:25,120 --> 00:26:23,510
formation so this was a big shock when

633
00:26:27,730 --> 00:26:25,130
people started doing censuses of

634
00:26:28,990 --> 00:26:27,740
galaxies comparing them to theory and so

635
00:26:33,190 --> 00:26:29,000
things are off by more than an order of

636
00:26:34,540 --> 00:26:33,200
magnitude so that's it a summary theory

637
00:26:36,280 --> 00:26:34,550
predicts more dark matter clumps

638
00:26:38,020 --> 00:26:36,290

orbiting the Milky Way than the number

639

00:26:40,870 --> 00:26:38,030

of dwarf satellites we actually

640

00:26:43,390 --> 00:26:40,880

that's the missing satellite problem so

641

00:26:44,980 --> 00:26:43,400

a solution to this was proposed a while

642

00:26:47,500 --> 00:26:44,990

back and has to do with the realization

643

00:26:49,000 --> 00:26:47,510

of the universe so this is a cartoon I'm

644

00:26:50,980 --> 00:26:49,010

showing here with the big bang on the

645

00:26:52,390 --> 00:26:50,990

left and the modern era on the right and

646

00:26:54,130 --> 00:26:52,400

time is just progressing from left to

647

00:26:56,110 --> 00:26:54,140

right here in this cartoon this is the

648

00:26:58,720 --> 00:26:56,120

evolution of the universe so the Big

649

00:27:01,180 --> 00:26:58,730

Bang is right here right after the Big

650

00:27:03,250 --> 00:27:01,190

Bang there's a short pier here called

651
00:27:05,110 --> 00:27:03,260
the Dark Ages where the universe cooled

652
00:27:06,700 --> 00:27:05,120
enough to become neutral so you have

653
00:27:07,930 --> 00:27:06,710
hydrogen is neutral

654
00:27:10,480 --> 00:27:07,940
you just have electron orbiting the

655
00:27:13,480 --> 00:27:10,490
proton things have cooled down those

656
00:27:15,280 --> 00:27:13,490
stars have not yet come on then the

657
00:27:17,160 --> 00:27:15,290
first stars and galaxies are born right

658
00:27:19,090 --> 00:27:17,170
here shortly after the Big Bang and

659
00:27:20,590 --> 00:27:19,100
ironically what happens is when the

660
00:27:22,150 --> 00:27:20,600
first stars and galaxies come on they

661
00:27:24,370 --> 00:27:22,160
illuminate everything that actually

662
00:27:25,720 --> 00:27:24,380
snuffs out a lot of star formation all

663
00:27:27,070 --> 00:27:25,730

around the universe because that light

664

00:27:28,510 --> 00:27:27,080

comes on it's a very strong source of

665

00:27:30,130 --> 00:27:28,520

ultraviolet light and it blows out the

666

00:27:31,540 --> 00:27:30,140

gas out of a lot of little dark matter

667

00:27:33,550 --> 00:27:31,550

clumps and turns off the star formation

668

00:27:34,840 --> 00:27:33,560

that's the theory here so you have the

669

00:27:36,340 --> 00:27:34,850

first stars and galaxies come on they

670

00:27:37,840 --> 00:27:36,350

come on so rapidly they actually shut

671

00:27:40,330 --> 00:27:37,850

off the star formation in a lot of parts

672

00:27:42,100 --> 00:27:40,340

of the universe so this is the era of

673

00:27:43,900 --> 00:27:42,110

reionisation when the universe gets

674

00:27:47,260 --> 00:27:43,910

ionized from those first stars and

675

00:27:49,300 --> 00:27:47,270

galaxies forming then after that era is

676
00:27:51,160 --> 00:27:49,310
done galaxies continued evolve new stars

677
00:27:52,330 --> 00:27:51,170
are born from a rich enriched gas you've

678
00:27:54,100 --> 00:27:52,340
heard this before we're all made from

679
00:27:55,420 --> 00:27:54,110
star stuff so stars explode their

680
00:27:56,950 --> 00:27:55,430
material goes out into the interstellar

681
00:27:59,890 --> 00:27:56,960
medium new stars are born from that

682
00:28:01,870 --> 00:27:59,900
enriched gas and time goes on and here's

683
00:28:04,420 --> 00:28:01,880
when the Sun would be born at this point

684
00:28:05,440 --> 00:28:04,430
in history and here we are today so the

685
00:28:07,210 --> 00:28:05,450
Sun was born about four-and-a-half

686
00:28:08,380 --> 00:28:07,220
billion years ago here we are sitting

687
00:28:11,830 --> 00:28:08,390
here in the modern universe and we look

688
00:28:13,330 --> 00:28:11,840

back in time so now we return to Jason

689

00:28:15,070 --> 00:28:13,340

simulation so this is the Dark Matter

690

00:28:19,060 --> 00:28:15,080

distribution around a galaxy like our

691

00:28:21,010 --> 00:28:19,070

Milky Way and the theory goes he's

692

00:28:23,020 --> 00:28:21,020

highlighted here in green those are the

693

00:28:24,490 --> 00:28:23,030

satellite galaxies that formed lots of

694

00:28:26,410 --> 00:28:24,500

stars and that's why we know about them

695

00:28:28,540 --> 00:28:26,420

so for decades we've known about these

696

00:28:30,340 --> 00:28:28,550

satellite dwarf galaxies these clumps of

697

00:28:32,980 --> 00:28:30,350

dark matter were large enough to

698

00:28:34,930 --> 00:28:32,990

accumulate a bunch of gas have stars

699

00:28:36,970 --> 00:28:34,940

form and then they continued forming

700

00:28:39,490 --> 00:28:36,980

stars until the present era so these

701
00:28:40,990 --> 00:28:39,500
little clumps here all continued forming

702
00:28:42,430 --> 00:28:41,000
stars to the present day and this is

703
00:28:43,810 --> 00:28:42,440
what we knew about galaxies up until the

704
00:28:44,920 --> 00:28:43,820
stuff I'll show you tonight this is the

705
00:28:46,930 --> 00:28:44,930
assumption that's been made about all

706
00:28:49,030 --> 00:28:46,940
galaxies that galaxies are groups of

707
00:28:51,280 --> 00:28:49,040
stars built upon dark matter that have a

708
00:28:51,520 --> 00:28:51,290
wide range of Ages as stars born in the

709
00:28:53,080 --> 00:28:51,530
early

710
00:28:54,640 --> 00:28:53,090
University of Stars continuing to form

711
00:28:56,320 --> 00:28:54,650
up until today I mean Frank just showed

712
00:28:58,570 --> 00:28:56,330
this press release with these galaxies

713
00:29:01,090 --> 00:28:58,580

form stars very recently so until

714

00:29:02,850 --> 00:29:01,100

recently every single galaxy had not

715

00:29:06,460 --> 00:29:02,860

only old stars but younger stars as well

716

00:29:08,920 --> 00:29:06,470

what's that okay that's I thought maybe

717

00:29:10,840 --> 00:29:08,930

it was me sorry I thought I'd turn off

718

00:29:12,160 --> 00:29:10,850

my phone as a string okay so so anyway

719

00:29:14,620 --> 00:29:12,170

this is the theory this is the

720

00:29:16,360 --> 00:29:14,630

theoretical prediction for the kinds of

721

00:29:17,850 --> 00:29:16,370

galaxies we've known about forever for

722

00:29:19,840 --> 00:29:17,860

decades orbiting the Milky Way the

723

00:29:21,370 --> 00:29:19,850

problem is here you see that a lot of

724

00:29:22,840 --> 00:29:21,380

these little clumps of dark matter don't

725

00:29:24,550 --> 00:29:22,850

aren't highlighted they just stay dark

726

00:29:25,990 --> 00:29:24,560

this is what the theory predicts that

727

00:29:27,310 --> 00:29:26,000

most of this guy most of these Dark

728

00:29:28,150 --> 00:29:27,320

Matter clumps and never form stars and

729

00:29:29,920 --> 00:29:28,160

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

730

00:29:31,630 --> 00:29:29,930

but they are there it's just clumps of

731

00:29:34,330 --> 00:29:31,640

dark matter orbiting the Milky Way if

732

00:29:36,430 --> 00:29:34,340

this is true here are these red ones

733

00:29:38,080 --> 00:29:36,440

I've highlighted there should be fossil

734

00:29:40,210 --> 00:29:38,090

galaxies out there that we didn't know

735

00:29:41,560 --> 00:29:40,220

about that are just ancient and are made

736

00:29:43,720 --> 00:29:41,570

from pristine gas the early universe

737

00:29:45,220 --> 00:29:43,730

form stars and then we're shut off by

738

00:29:47,290 --> 00:29:45,230

the realisation universe so these ones

739

00:29:48,580 --> 00:29:47,300

are on the cusp you have the galaxies

740

00:29:50,110 --> 00:29:48,590

that kept forming stars because they

741

00:29:52,210 --> 00:29:50,120

were big then you have these smaller

742

00:29:53,350 --> 00:29:52,220

guys that started to form stars in the

743

00:29:54,940 --> 00:29:53,360

early universe and then with the lights

744

00:29:56,740 --> 00:29:54,950

came on and they snuffed them out and

745

00:29:58,090 --> 00:29:56,750

they never formed stars again so these

746

00:30:00,310 --> 00:29:58,100

are ones a kind of like a transition

747

00:30:01,720 --> 00:30:00,320

between the galaxies that kept forming

748

00:30:04,780 --> 00:30:01,730

stars and the ones that never form stars

749

00:30:06,220 --> 00:30:04,790

at all and then here I'm highlighting

750

00:30:07,690 --> 00:30:06,230

both so in green now these are the

751

00:30:09,070 --> 00:30:07,700

galaxies that continue to form stars

752

00:30:10,660 --> 00:30:09,080

these are the classical satellites we've

753

00:30:12,970 --> 00:30:10,670

known about for decades in red and pink

754

00:30:14,800 --> 00:30:12,980

here these are the galaxies that got

755

00:30:16,810 --> 00:30:14,810

snuffed out right after the Big Bang and

756

00:30:18,790 --> 00:30:16,820

then most of these little clumps never

757

00:30:21,160 --> 00:30:18,800

form stars at all and that's the

758

00:30:22,450 --> 00:30:21,170

possible theoretical solution to the

759

00:30:23,680 --> 00:30:22,460

missing satellite problem is that these

760

00:30:24,850 --> 00:30:23,690

dark matter clumps are just sitting out

761

00:30:26,980 --> 00:30:24,860

there orbiting around they didn't form

762

00:30:30,640 --> 00:30:26,990

enough stars for us to see them so this

763

00:30:32,530 --> 00:30:30,650

is true if this is true we need to find

764

00:30:34,240 --> 00:30:32,540

these fossil galaxies these ones in red

765

00:30:35,920 --> 00:30:34,250

we've known about these ones in green

766

00:30:37,060 --> 00:30:35,930

for a long time and Frank showed some of

767

00:30:39,490 --> 00:30:37,070

those tonight I'll show you some

768

00:30:40,840 --> 00:30:39,500

pictures of other ones the key here

769

00:30:42,760 --> 00:30:40,850

since we can't see the dark matter

770

00:30:44,080 --> 00:30:42,770

clumps without stars to prove this

771

00:30:45,490 --> 00:30:44,090

theory you got to look at these pink

772

00:30:47,260 --> 00:30:45,500

ones and find evidence for fossil

773

00:30:48,750 --> 00:30:47,270

galaxies so that was the goal of a

774

00:30:53,170 --> 00:30:48,760

Hubble program we decided to undertake

775

00:30:54,790 --> 00:30:53,180

so if this theory is true we should have

776

00:30:55,840 --> 00:30:54,800

ancient dwarf galaxies besides the

777

00:30:57,490 --> 00:30:55,850

bright galaxies we've known about for

778

00:30:58,900 --> 00:30:57,500

decades this is Fornax one of the

779

00:31:01,930 --> 00:30:58,910

brightest satellite galaxies of the

780

00:31:04,840 --> 00:31:01,940

Milky Way it's a group of stars millions

781

00:31:07,630 --> 00:31:04,850

of stars with a very wide range of rage

782

00:31:09,310 --> 00:31:07,640

of ranges a range of Ages and a wide

783

00:31:10,570 --> 00:31:09,320

range of chemistry so I talk about

784

00:31:12,040 --> 00:31:10,580

chemistry I'm always talking irrelevant

785

00:31:14,200 --> 00:31:12,050

to the Sun so there's some stars that

786

00:31:16,780 --> 00:31:14,210

have just as many chemical but chemists

787

00:31:18,550 --> 00:31:16,790

chemical abundances as the Sun and we

788

00:31:19,990 --> 00:31:18,560

have some stars that are much much more

789

00:31:21,910 --> 00:31:20,000

metal-poor than the Sun there's like one

790

00:31:23,500 --> 00:31:21,920

percent of the metals the Sun has so

791

00:31:25,270 --> 00:31:23,510

wide range in chemistry wide range in

792

00:31:27,250 --> 00:31:25,280

ages from right after the Big Bang 13

793

00:31:28,810 --> 00:31:27,260

billion years old to up to just a few

794

00:31:33,400 --> 00:31:28,820

hundred million years old so this is

795

00:31:34,660 --> 00:31:33,410

Fornax has a wide range of Ages so a big

796

00:31:36,070 --> 00:31:34,670

step forward in the missing satellite

797

00:31:38,290 --> 00:31:36,080

problem is the Sloan Digital Sky Survey

798

00:31:39,970 --> 00:31:38,300

this was a survey of a wide range of the

799

00:31:42,010 --> 00:31:39,980

sky done with a small telescope on the

800

00:31:43,780 --> 00:31:42,020

ground New Mexico it's done from the

801

00:31:45,520 --> 00:31:43,790

ground this patch of sky is the

802

00:31:47,350 --> 00:31:45,530

summation of all the data from the

803

00:31:50,110 --> 00:31:47,360

Digital Sky Survey from a paper from

804

00:31:51,490 --> 00:31:50,120

Bella Cerf at all in 2007 this is tens

805

00:31:52,990 --> 00:31:51,500

of degrees across in the sky and they

806

00:31:55,210 --> 00:31:53,000

basically he basically summed up all the

807

00:31:57,280 --> 00:31:55,220

data from this scan of the sky and this

808

00:31:58,300 --> 00:31:57,290

scan revealed a lot of structure in the

809

00:31:59,380 --> 00:31:58,310

nearby universe we didn't know about

810

00:32:00,940 --> 00:31:59,390

before and you're like is already

811

00:32:03,310 --> 00:32:00,950

probably picking up on some of it but

812

00:32:05,170 --> 00:32:03,320

I'll highlight it here so in white I've

813

00:32:07,090 --> 00:32:05,180

highlighted three streams of tidal

814

00:32:09,490 --> 00:32:07,100

debris so this is the Sagittarii stream

815

00:32:10,750 --> 00:32:09,500

along here this is the orphan stream

816

00:32:13,570 --> 00:32:10,760

over here and this is the Montessori

817

00:32:15,280 --> 00:32:13,580

ring these are debris streams from

818

00:32:16,660 --> 00:32:15,290

satellite galaxies that fell into the

819

00:32:18,340 --> 00:32:16,670

gravitational well the Milky Way and

820

00:32:20,350 --> 00:32:18,350

then got disrupted by the tidal forces

821

00:32:22,480 --> 00:32:20,360

so the GAT the galaxies not really there

822

00:32:24,400 --> 00:32:22,490

anymore it's getting eaten alive by the

823

00:32:26,170 --> 00:32:24,410

Milky Way's gravitational well and it's

824

00:32:29,020 --> 00:32:26,180

just strewn across the sky this stream

825

00:32:30,580 --> 00:32:29,030

of stars here then they also found a lot

826

00:32:32,020 --> 00:32:30,590

of other little satellite galaxies which

827

00:32:33,550 --> 00:32:32,030

I've highlighted here in pink so these

828

00:32:34,660 --> 00:32:33,560

are new galaxies that were too faint to

829

00:32:36,880 --> 00:32:34,670

be noticed before but they're little

830

00:32:38,710 --> 00:32:36,890

over densities of stars so this went

831

00:32:40,210 --> 00:32:38,720

part of the way towards solving the

832

00:32:42,190 --> 00:32:40,220

missing satellite problems we had a few

833

00:32:43,690 --> 00:32:42,200

dozen galaxies and this found that well

834

00:32:44,980 --> 00:32:43,700

okay some of them are being disrupted

835

00:32:46,690 --> 00:32:44,990

which is making them hard to see these

836

00:32:48,640 --> 00:32:46,700

big streams and then other little ones

837

00:32:50,920 --> 00:32:48,650

were too faint to see these little faint

838

00:32:52,510 --> 00:32:50,930

ones are excellent candidates for these

839

00:32:53,830 --> 00:32:52,520

fossil galaxies that the theorists

840

00:32:55,570 --> 00:32:53,840

predicted they said okay well we didn't

841

00:32:57,580 --> 00:32:55,580

know about this ones before maybe these

842

00:32:59,830 --> 00:32:57,590

are these ancient fossil galaxies and

843

00:33:02,020 --> 00:32:59,840

there should be a big support for this

844

00:33:03,390 --> 00:33:02,030

theory so these ones we decided at

845

00:33:05,530 --> 00:33:03,400

Target with Hubble

846

00:33:07,420 --> 00:33:05,540

before I go on to that this is the dark

847

00:33:09,520 --> 00:33:07,430

energy survey this came out with results

848

00:33:11,620 --> 00:33:09,530

last year it found nine new satellite

849

00:33:12,970 --> 00:33:11,630

galaxies this is a projection on the sky

850

00:33:15,250 --> 00:33:12,980

of where they found them highlighted in

851
00:33:16,540 --> 00:33:15,260
blue here here's where they are in a

852
00:33:17,690 --> 00:33:16,550
different projection from two different

853
00:33:19,160 --> 00:33:17,700
papers that came out last year

854
00:33:20,780 --> 00:33:19,170
there are a lot of surveys right now

855
00:33:22,340 --> 00:33:20,790
from the ground this is a really active

856
00:33:23,660 --> 00:33:22,350
subfield of astronomer people are

857
00:33:25,250 --> 00:33:23,670
banging away it's mapping the whole sky

858
00:33:26,270 --> 00:33:25,260
trying to find the missing satellites

859
00:33:27,800 --> 00:33:26,280
but they're not coming up to the

860
00:33:29,150 --> 00:33:27,810
hundreds of satellites that theory

861
00:33:30,500 --> 00:33:29,160
predicts they're getting out there

862
00:33:32,540 --> 00:33:30,510
increasing the number from you know a

863
00:33:33,710 --> 00:33:32,550

few dozen to several more dozen but

864

00:33:35,300 --> 00:33:33,720

they're not coming up to the hundreds

865

00:33:37,100 --> 00:33:35,310

and that's because most of those

866

00:33:39,200 --> 00:33:37,110

galaxies are probably dark they have no

867

00:33:41,860 --> 00:33:39,210

stars that just comes to Dark Matter but

868

00:33:43,790 --> 00:33:41,870

we are finding more and more satellites

869

00:33:45,530 --> 00:33:43,800

so just to put things in perspective

870

00:33:47,480 --> 00:33:45,540

just to give you a sense of scale here

871

00:33:48,860 --> 00:33:47,490

here's a giant spiral galaxy of about a

872

00:33:50,990 --> 00:33:48,870

hundred billion stars in the upper left

873

00:33:53,720 --> 00:33:51,000

this is like the Milky Way or in

874

00:33:54,950 --> 00:33:53,730

Andromeda and down here is New York City

875

00:33:56,330 --> 00:33:54,960

I'm from New York's is the comparison

876

00:33:59,320 --> 00:33:56,340

going to use so this is 10 million

877

00:34:01,670 --> 00:33:59,330

people okay in the city of New York

878

00:34:03,380 --> 00:34:01,680

typical galaxies that orbit the Milky

879

00:34:05,090 --> 00:34:03,390

Way that we've known about for decades I

880

00:34:07,100 --> 00:34:05,100

like this here like for next 10 million

881

00:34:08,480 --> 00:34:07,110

stars scale down New York City you're

882

00:34:10,550 --> 00:34:08,490

talking about one theater showing The

883

00:34:11,600 --> 00:34:10,560

Lion King in New York City so this is

884

00:34:14,680 --> 00:34:11,610

the relative scale here we're talking

885

00:34:17,300 --> 00:34:14,690

about these ultra faint dwarf galaxies

886

00:34:18,980 --> 00:34:17,310

go down even further so they only have

887

00:34:20,600 --> 00:34:18,990

10,000 stars in them they're barely a

888

00:34:22,460 --> 00:34:20,610

galaxy at all and now you're talking

889

00:34:23,960 --> 00:34:22,470

about one guy in New York the host of

890

00:34:25,070 --> 00:34:23,970

the Jimmy Fallon show that sounds the

891

00:34:27,890 --> 00:34:25,080

relative scales here we're talking about

892

00:34:29,690 --> 00:34:27,900

so the Giants file like Andromeda or the

893

00:34:31,580 --> 00:34:29,700

Milky Way a classical dwarf like Fornax

894

00:34:35,419 --> 00:34:31,590

and these new ultra faint dwarf galaxies

895

00:34:37,190 --> 00:34:35,429

that were only recently discovered so

896

00:34:38,570 --> 00:34:37,200

when you show people the especially

897

00:34:39,830 --> 00:34:38,580

astronomers when I give this talk to

898

00:34:41,210 --> 00:34:39,840

professional astronomers in particular I

899

00:34:42,530 --> 00:34:41,220

sometimes get into arguments afterwards

900

00:34:44,270 --> 00:34:42,540

they say well why is that even a galaxy

901
00:34:45,440 --> 00:34:44,280
if it only has 10 mm stars in it because

902
00:34:47,990 --> 00:34:45,450
there are star clusters that have many

903
00:34:49,700 --> 00:34:48,000
more stars and that's true so this is a

904
00:34:51,050 --> 00:34:49,710
globular star cluster like the picture

905
00:34:53,150 --> 00:34:51,060
the Frank handed out tonight like a mega

906
00:34:54,710 --> 00:34:53,160
sin this one's actually a picture from

907
00:34:56,900 --> 00:34:54,720
that Andromeda image I took awhile ago

908
00:34:58,100 --> 00:34:56,910
that's a star cluster and Andromeda it's

909
00:34:59,780 --> 00:34:58,110
a cloud of the star cluster of a hundred

910
00:35:01,610 --> 00:34:59,790
thousand stars and this is an ultra

911
00:35:03,500 --> 00:35:01,620
faint dwarf galaxy of 10,000 stars so

912
00:35:04,880 --> 00:35:03,510
why is this a galaxy and that's a star

913
00:35:06,860 --> 00:35:04,890

cluster and the reason is because it's

914

00:35:08,990 --> 00:35:06,870

dark matter as well as talked about

915

00:35:10,700 --> 00:35:09,000

earlier globular clusters as far as we

916

00:35:12,440 --> 00:35:10,710

can tell have little to no dark matter

917

00:35:13,730 --> 00:35:12,450

so if you measure the mass to light

918

00:35:16,070 --> 00:35:13,740

ratio which is something astronomers

919

00:35:18,710 --> 00:35:16,080

doing these objects in units of the Sun

920

00:35:20,390 --> 00:35:18,720

you can amass the light ratio of about

921

00:35:21,740 --> 00:35:20,400

two which is consistent with an old

922

00:35:23,330 --> 00:35:21,750

population of stars that means there's

923

00:35:25,040 --> 00:35:23,340

compared to the Sun there's a you know

924

00:35:27,320 --> 00:35:25,050

the ratio of mass to light in the Sun

925

00:35:28,250 --> 00:35:27,330

these globular clusters have about twice

926
00:35:29,720 --> 00:35:28,260
as much mass to

927
00:35:31,310 --> 00:35:29,730
ratio and that's because most of the

928
00:35:33,230 --> 00:35:31,320
stars are really faint and dim compared

929
00:35:34,580 --> 00:35:33,240
to the Sun most stars and universe are

930
00:35:37,340 --> 00:35:34,590
really faint endemic compared to the Sun

931
00:35:40,010 --> 00:35:37,350
in contrast these ultra faint Dwarf

932
00:35:41,360 --> 00:35:40,020
galaxies have a lot of dark matter again

933
00:35:43,250 --> 00:35:41,370
because dark matter is the scaffolding

934
00:35:44,570 --> 00:35:43,260
upon which galaxies are built so

935
00:35:46,370 --> 00:35:44,580
galaxies have significant dark matter

936
00:35:47,630 --> 00:35:46,380
the classical dwarf galaxies we've known

937
00:35:50,300 --> 00:35:47,640
about for decades have mass-to-light

938
00:35:51,980 --> 00:35:50,310

ratios exceeding 10 and the ultra faint

939

00:35:54,320 --> 00:35:51,990

dwarf galaxies have master light ratios

940

00:35:56,030 --> 00:35:54,330

exceeding 100 so these new galaxies are

941

00:35:57,320 --> 00:35:56,040

almost entirely dark matter this is the

942

00:35:59,030 --> 00:35:57,330

big clump of dark matter there with a

943

00:36:00,410 --> 00:35:59,040

few stars sprinkled on top which is

944

00:36:02,090 --> 00:36:00,420

consistent with this theory that the

945

00:36:03,380 --> 00:36:02,100

theorists used to predict you know the

946

00:36:04,910 --> 00:36:03,390

solutions the missing satellite problem

947

00:36:06,590 --> 00:36:04,920

is that they had the Dark Matter they're

948

00:36:07,760 --> 00:36:06,600

a few stars formed and then things were

949

00:36:09,380 --> 00:36:07,770

turned off the lights were turned off

950

00:36:12,260 --> 00:36:09,390

when when the most of the universe came

951

00:36:13,790 --> 00:36:12,270

out in the star formation another big

952

00:36:15,020 --> 00:36:13,800

difference is that globular clusters are

953

00:36:17,330 --> 00:36:15,030

usually what we call simple stellar

954

00:36:18,620 --> 00:36:17,340

populations all the stars to first order

955

00:36:20,540 --> 00:36:18,630

are just one age and one chemical

956

00:36:24,140 --> 00:36:20,550

composition you have a cloud out there

957

00:36:25,760 --> 00:36:24,150

in space it collapses you form a bunch

958

00:36:27,770 --> 00:36:25,770

of stars they all have one age one

959

00:36:29,660 --> 00:36:27,780

chemical composition galaxies have a

960

00:36:31,070 --> 00:36:29,670

wide range in ages and a wide range of

961

00:36:32,630 --> 00:36:31,080

chemical composition that's true of

962

00:36:35,420 --> 00:36:32,640

every galaxy that we've known about

963

00:36:37,040 --> 00:36:35,430

until the ones I'll show you tonight so

964

00:36:38,030 --> 00:36:37,050

this is a plot now of just put these

965

00:36:40,040 --> 00:36:38,040

things into perspective this is

966

00:36:42,080 --> 00:36:40,050

luminosity relative to the Sun so 10 to

967

00:36:43,820 --> 00:36:42,090

the 6 is a million times luminosity of

968

00:36:46,550 --> 00:36:43,830

the Sun this is diameter in lightyears

969

00:36:47,840 --> 00:36:46,560

from one to a thousand so star clusters

970

00:36:49,520 --> 00:36:47,850

fall over here these are globular

971

00:36:51,020 --> 00:36:49,530

clusters they have up to a million times

972

00:36:52,340 --> 00:36:51,030

the luminosity the Sun or maybe even a

973

00:36:53,720 --> 00:36:52,350

thousand times the luminosity of the Sun

974

00:36:55,730 --> 00:36:53,730

but they're pretty compact than the

975

00:36:57,380 --> 00:36:55,740

left-hand side of this diagram the

976
00:36:58,910 --> 00:36:57,390
classical dwarf galaxies are shown here

977
00:37:00,470 --> 00:36:58,920
in blue so they're much more extended

978
00:37:01,880 --> 00:37:00,480
and they're generally brighter than star

979
00:37:03,980 --> 00:37:01,890
clusters they're up and to the right

980
00:37:05,750 --> 00:37:03,990
these ultra faint dork galaxies are down

981
00:37:07,610 --> 00:37:05,760
here they're an extension of these dwarf

982
00:37:09,620 --> 00:37:07,620
galaxies to faint your luminosities and

983
00:37:11,810 --> 00:37:09,630
smaller sizes but they're not as compact

984
00:37:13,610 --> 00:37:11,820
as globular clusters so they're mostly

985
00:37:15,730 --> 00:37:13,620
dark matter and they're these wispy

986
00:37:18,200 --> 00:37:15,740
things with just a few stars on them and

987
00:37:19,610 --> 00:37:18,210
so we decide to look at these six very

988
00:37:21,230 --> 00:37:19,620

closely with Hubble because Hubble is

989

00:37:25,760 --> 00:37:21,240

excellent in measuring the ages of stars

990

00:37:27,200 --> 00:37:25,770

to test these theories so how do we know

991

00:37:28,610 --> 00:37:27,210

of a group of stars is old well there's

992

00:37:29,900 --> 00:37:28,620

two ways you can go about it one is to

993

00:37:31,190 --> 00:37:29,910

get spectra these stars you take the

994

00:37:33,080 --> 00:37:31,200

light from the stars you've spread it

995

00:37:35,090 --> 00:37:33,090

out into its rainbow and then you look

996

00:37:36,560 --> 00:37:35,100

for features in that spectrum to see

997

00:37:38,510 --> 00:37:36,570

what kind of metal abundances there are

998

00:37:39,890 --> 00:37:38,520

and so if we want to see if it's old it

999

00:37:41,560 --> 00:37:39,900

should have a low abundance of metals if

1000

00:37:42,940 --> 00:37:41,570

it was born in the early universe before

1001
00:37:44,650 --> 00:37:42,950
there are many generations of stars the

1002
00:37:45,790 --> 00:37:44,660
gas should be pretty pristine and so

1003
00:37:48,040 --> 00:37:45,800
there shouldn't be a very high chemical

1004
00:37:49,150 --> 00:37:48,050
composition in these stars we also do

1005
00:37:51,070 --> 00:37:49,160
photometry we measure the brightness

1006
00:37:52,750 --> 00:37:51,080
--is and colors of the stars and when we

1007
00:37:55,750 --> 00:37:52,760
do that we can see what masses are left

1008
00:37:57,250 --> 00:37:55,760
only low mass stars less massive than

1009
00:37:59,500 --> 00:37:57,260
the Sun should be present if it's old

1010
00:38:01,870 --> 00:37:59,510
because massive stars more massive than

1011
00:38:03,250 --> 00:38:01,880
the Sun die very quickly so these are

1012
00:38:07,150 --> 00:38:03,260
the two tests we do to see if these

1013
00:38:09,220 --> 00:38:07,160

things are actually old galaxies so

1014

00:38:11,110 --> 00:38:09,230

here's a spectrum from ultra main Dorf

1015

00:38:12,220 --> 00:38:11,120

galaxies and it tells us a couple

1016

00:38:13,690 --> 00:38:12,230

different things so well you know it

1017

00:38:15,880 --> 00:38:13,700

gets broken into its constituent light

1018

00:38:17,200 --> 00:38:15,890

from blue green to red and these little

1019

00:38:19,060 --> 00:38:17,210

dark patches and their absorption

1020

00:38:21,340 --> 00:38:19,070

features from metals in the atmosphere

1021

00:38:23,830 --> 00:38:21,350

of the star so by usually measuring the

1022

00:38:25,240 --> 00:38:23,840

velocities we from the Doppler effect of

1023

00:38:26,950 --> 00:38:25,250

these absorption features we can measure

1024

00:38:28,450 --> 00:38:26,960

the motions of these stars and the

1025

00:38:30,280 --> 00:38:28,460

motions of the stars and the old faint

1026

00:38:32,950 --> 00:38:30,290

Dorf galaxies imply there's a lot of

1027

00:38:35,230 --> 00:38:32,960

dark matter there so the matter in these

1028

00:38:36,700 --> 00:38:35,240

galaxies the luminous matter is feeling

1029

00:38:39,190 --> 00:38:36,710

the presence of the gravity gravity from

1030

00:38:40,660 --> 00:38:39,200

the dark matter the absorption features

1031

00:38:42,340 --> 00:38:40,670

these little patches here are also very

1032

00:38:44,440 --> 00:38:42,350

weak so it means these stars have a

1033

00:38:46,570 --> 00:38:44,450

hundred to ten thousand times fewer

1034

00:38:48,070 --> 00:38:46,580

metals than the Sun so these stars were

1035

00:38:49,630 --> 00:38:48,080

really born in the early universe when

1036

00:38:51,730 --> 00:38:49,640

the gas was still pretty pristine and

1037

00:38:53,440 --> 00:38:51,740

many this is also a little cottage

1038

00:38:54,790 --> 00:38:53,450

industry in astronomy a lot of people

1039

00:38:56,380 --> 00:38:54,800

are looking for the first stars and the

1040

00:38:57,790 --> 00:38:56,390

earliest stars and oldest stars and

1041

00:38:59,110 --> 00:38:57,800

folks who are looking for the most

1042

00:39:00,640 --> 00:38:59,120

metal-poor stars have found a lot of

1043

00:39:01,870 --> 00:39:00,650

them in these ultra faint dwarf galaxies

1044

00:39:05,560 --> 00:39:01,880

so this is fertile ground for these

1045

00:39:06,910 --> 00:39:05,570

searches so this is the same handout you

1046

00:39:08,590 --> 00:39:06,920

have tonight this Omega sign so it's

1047

00:39:10,480 --> 00:39:08,600

fortunate that Frank came to that hands

1048

00:39:11,710 --> 00:39:10,490

out I'm going to sort this is an image

1049

00:39:13,780 --> 00:39:11,720

from Hubble with the Wide Field Camera 3

1050

00:39:15,250 --> 00:39:13,790

is a camera I worked on before I

1051
00:39:17,080 --> 00:39:15,260
switched over to James Webb for a while

1052
00:39:20,140 --> 00:39:17,090
I'm going to sort this this is from my

1053
00:39:21,820 --> 00:39:20,150
collaborator colleague J Anderson we

1054
00:39:23,890 --> 00:39:21,830
sort this in color first from left to

1055
00:39:25,840 --> 00:39:23,900
right so hotter stars that are blue will

1056
00:39:28,930 --> 00:39:25,850
be on the Left cooler stars that are red

1057
00:39:30,220 --> 00:39:28,940
will be on the right then we're going to

1058
00:39:31,900 --> 00:39:30,230
sort it in luminosity with brighter

1059
00:39:35,380 --> 00:39:31,910
stars at the top fainter stars at the

1060
00:39:37,450 --> 00:39:35,390
bottom when you do that you see that

1061
00:39:39,370 --> 00:39:37,460
stars don't just have random colors and

1062
00:39:40,930 --> 00:39:39,380
random brightnesses it actually traced

1063
00:39:42,490 --> 00:39:40,940

out a very specific pattern my wife

1064

00:39:44,590 --> 00:39:42,500

calls this the duct diagram because our

1065

00:39:46,090 --> 00:39:44,600

minds are of a duct but anyway here's

1066

00:39:48,010 --> 00:39:46,100

the body here's the neck who's the beak

1067

00:39:50,110 --> 00:39:48,020

but main sequence stars like the Sun

1068

00:39:53,260 --> 00:39:50,120

that are burning hydrogen fall down here

1069

00:39:54,460 --> 00:39:53,270

and then have to exhaust their hydrogen

1070

00:39:55,330 --> 00:39:54,470

they go up here and become red giant

1071

00:39:57,370 --> 00:39:55,340

stars

1072

00:39:58,570 --> 00:39:57,380

and then they finally burn helium they

1073

00:40:00,070 --> 00:39:58,580

become this thing called horizontal

1074

00:40:02,260 --> 00:40:00,080

branch stars because this distributions

1075

00:40:04,450 --> 00:40:02,270

horizontal say burn helium then they die

1076

00:40:06,280 --> 00:40:04,460

as white dwarfs so when you sort a

1077

00:40:08,050 --> 00:40:06,290

population of stars by brightness and

1078

00:40:09,490 --> 00:40:08,060

color they're not random they trace had

1079

00:40:11,800 --> 00:40:09,500

a very specific pattern that's the life

1080

00:40:13,330 --> 00:40:11,810

cycle of the star and that's how we can

1081

00:40:15,790 --> 00:40:13,340

use that information to tell how old a

1082

00:40:17,260 --> 00:40:15,800

group of stars of this so that's where

1083

00:40:18,700 --> 00:40:17,270

those stars now fall in that image of a

1084

00:40:24,220 --> 00:40:18,710

magazine which is on the handout over

1085

00:40:25,990 --> 00:40:24,230

here so here's measurements of a galaxy

1086

00:40:27,550 --> 00:40:26,000

this is brightness again on the y axis

1087

00:40:29,650 --> 00:40:27,560

here in these funny hoots astronomers

1088

00:40:32,770 --> 00:40:29,660

use so this is in a filter 8:14 so 800

1089

00:40:35,080 --> 00:40:32,780

nanometer filter 606 minus 814 600

1090

00:40:36,490 --> 00:40:35,090

nanometer minus 800 nanometer filter so

1091

00:40:38,530 --> 00:40:36,500

this is a color with redder stars on the

1092

00:40:40,120 --> 00:40:38,540

right bluer stars on the left brighter

1093

00:40:42,580 --> 00:40:40,130

stars at the top fainter stars at the

1094

00:40:45,520 --> 00:40:42,590

bottom hydrogen burning stars fall along

1095

00:40:47,440 --> 00:40:45,530

here here's this kink and then they

1096

00:40:49,000 --> 00:40:47,450

exhaust hydrogen the core and then you

1097

00:40:51,070 --> 00:40:49,010

become a red giant star and that's how

1098

00:40:54,070 --> 00:40:51,080

you measure the age of a population so

1099

00:40:55,840 --> 00:40:54,080

these are low mass hydrogen burning

1100

00:40:57,520 --> 00:40:55,850

stars more massive hydrogen burning

1101
00:41:00,130 --> 00:40:57,530
stars and then they peel off and become

1102
00:41:02,080 --> 00:41:00,140
red giants so these are stars that are

1103
00:41:03,520 --> 00:41:02,090
still burning hydrogen in the core these

1104
00:41:06,400 --> 00:41:03,530
are stars that exhausted hydrogen the

1105
00:41:08,380 --> 00:41:06,410
quorum become Giants so that's the clock

1106
00:41:09,940 --> 00:41:08,390
that little kink right there tells you

1107
00:41:10,900 --> 00:41:09,950
that's the best clock in astronomy right

1108
00:41:12,250 --> 00:41:10,910
now there's a lot of different ways to

1109
00:41:13,780 --> 00:41:12,260
measure the ages of stars but that's the

1110
00:41:17,410 --> 00:41:13,790
gold standard since Allan Sandage

1111
00:41:19,150 --> 00:41:17,420
started doing this in the 50s so this is

1112
00:41:20,920 --> 00:41:19,160
for you get for a population that's 13

1113
00:41:22,120 --> 00:41:20,930

billion years old an ancient population

1114

00:41:23,550 --> 00:41:22,130

and that's what it would look like for a

1115

00:41:25,600 --> 00:41:23,560

population that's 6 billion years old

1116

00:41:26,470 --> 00:41:25,610

and that's what it is for 13 billion

1117

00:41:28,030 --> 00:41:26,480

years old it's a very dramatic

1118

00:41:29,590 --> 00:41:28,040

difference and the reason why is because

1119

00:41:31,780 --> 00:41:29,600

the massive stars die more quickly than

1120

00:41:32,980 --> 00:41:31,790

the less massive stars ironically if

1121

00:41:34,360 --> 00:41:32,990

you're a massive star you have a lot of

1122

00:41:35,590 --> 00:41:34,370

fuel but you're very bright you burn it

1123

00:41:37,630 --> 00:41:35,600

very quickly so you'll leave the main

1124

00:41:41,560 --> 00:41:37,640

sequence to become a giant more rapidly

1125

00:41:44,020 --> 00:41:41,570

than these stars down here so here's the

1126

00:41:46,780 --> 00:41:44,030

Carina two classical dwarf galaxies is

1127

00:41:48,670 --> 00:41:46,790

out in the local group again a pretty

1128

00:41:51,160 --> 00:41:48,680

massive dwarf galaxy we've known about

1129

00:41:52,750 --> 00:41:51,170

for decades and here's its color

1130

00:41:54,460 --> 00:41:52,760

magnitude diagram so this is brightness

1131

00:41:56,940 --> 00:41:54,470

on the y axis color on the x axis and

1132

00:41:59,350 --> 00:41:56,950

you get these three distinct little

1133

00:42:01,210 --> 00:41:59,360

shapes here each of those is from a

1134

00:42:04,000 --> 00:42:01,220

burst of star formation if I put models

1135

00:42:05,410 --> 00:42:04,010

on top of that this is where stars about

1136

00:42:07,540 --> 00:42:05,420

half a billion years old would lie and

1137

00:42:08,890 --> 00:42:07,550

this brighter curve here stars five

1138

00:42:10,390 --> 00:42:08,900

billion years old with

1139

00:42:12,220 --> 00:42:10,400

along this intermediate curve here and

1140

00:42:14,020 --> 00:42:12,230

really old stars 11 billion years old

1141

00:42:15,550 --> 00:42:14,030

would lie here so this is a kind of

1142

00:42:17,590 --> 00:42:15,560

curious galaxy you don't usually see

1143

00:42:18,910 --> 00:42:17,600

these episodes of star formation but in

1144

00:42:20,140 --> 00:42:18,920

this one you did and it makes it kind of

1145

00:42:22,360 --> 00:42:20,150

interesting to show the clock in three

1146

00:42:24,280 --> 00:42:22,370

different paces one two three and this

1147

00:42:25,600 --> 00:42:24,290

is similar to the stories we've seen for

1148

00:42:27,070 --> 00:42:25,610

a lot of dwarf galaxies there's a wide

1149

00:42:28,120 --> 00:42:27,080

range of Ages you know you don't see

1150

00:42:29,560 --> 00:42:28,130

just old stars you know interesting

1151
00:42:32,980 --> 00:42:29,570
young stars usually see a wide range of

1152
00:42:34,270 --> 00:42:32,990
Ages so here's the ones we decided to

1153
00:42:36,490 --> 00:42:34,280
look at again tonight the ultra main

1154
00:42:39,640 --> 00:42:36,500
doors and again I looked at these with

1155
00:42:41,080 --> 00:42:39,650
Hubble they're kind of a sample of that

1156
00:42:43,390 --> 00:42:41,090
six galaxies out of the recently

1157
00:42:44,650 --> 00:42:43,400
discovered ones from Sloan and this is

1158
00:42:46,120 --> 00:42:44,660
what it looks like when Hubble looks at

1159
00:42:47,920 --> 00:42:46,130
one of these so in the background here

1160
00:42:49,780 --> 00:42:47,930
I'm showing a Digital Sky Survey image

1161
00:42:51,040 --> 00:42:49,790
and then Hubble has a pretty small field

1162
00:42:53,140 --> 00:42:51,050
of view compared to some of these ground

1163
00:42:54,730 --> 00:42:53,150

telescopes so the footprint from Hubble

1164

00:42:56,920 --> 00:42:54,740

from its advanced camera for surveys is

1165

00:42:59,650 --> 00:42:56,930

one of these blue tiles here we kind of

1166

00:43:01,840 --> 00:42:59,660

went and tile that part of the galaxy we

1167

00:43:03,850 --> 00:43:01,850

turned on Wide Field Camera 3 in pink

1168

00:43:05,050 --> 00:43:03,860

here in parallel it kind of missed the

1169

00:43:06,160 --> 00:43:05,060

galaxies here so it was just getting a

1170

00:43:08,950 --> 00:43:06,170

sample of some of the stars in the

1171

00:43:12,400 --> 00:43:08,960

background this is about 200 arc seconds

1172

00:43:14,560 --> 00:43:12,410

on the side this is Leo 4 so this

1173

00:43:15,970 --> 00:43:14,570

galaxies further out from the Milky Way

1174

00:43:17,380 --> 00:43:15,980

so it's a little more compact on the sky

1175

00:43:18,790 --> 00:43:17,390

so if you look carefully you can see

1176

00:43:20,620 --> 00:43:18,800

there's an over density of stars right

1177

00:43:22,480 --> 00:43:20,630

here compared to the background and so

1178

00:43:24,280 --> 00:43:22,490

we stuck a CS the advanced camera for

1179

00:43:25,540 --> 00:43:24,290

surveys right here we stuck will feel

1180

00:43:27,730 --> 00:43:25,550

camera 3 out here it got pretty much

1181

00:43:31,000 --> 00:43:27,740

nothing but this one measured the

1182

00:43:34,450 --> 00:43:31,010

galaxies and so that's the image we got

1183

00:43:37,870 --> 00:43:34,460

of Leo 4 in that patch that's this patch

1184

00:43:39,730 --> 00:43:37,880

of sky right here this is the Hubble

1185

00:43:41,080 --> 00:43:39,740

image it's about 16 orbits we hand out

1186

00:43:42,310 --> 00:43:41,090

time on Hubble and units of orbits

1187

00:43:43,870 --> 00:43:42,320

Hubble goes around the earth every 96

1188

00:43:45,940 --> 00:43:43,880

minutes that's the currency and Hubble

1189

00:43:48,460 --> 00:43:45,950

so you know people asked for 5 orbits 10

1190

00:43:50,140 --> 00:43:48,470

orbits 100 orbits this was 16 orbits on

1191

00:43:52,270 --> 00:43:50,150

this one galaxy we looked at six

1192

00:43:53,860 --> 00:43:52,280

galaxies in total it's a fairly deep

1193

00:43:55,210 --> 00:43:53,870

image like a lot of images with Hubble

1194

00:43:56,020 --> 00:43:55,220

when you're trying to go deep you get

1195

00:43:57,070 --> 00:43:56,030

the rest of the universe in the

1196

00:43:58,990 --> 00:43:57,080

background so there's all these really

1197

00:44:00,190 --> 00:43:59,000

pretty galaxies in the background and a

1198

00:44:01,420 --> 00:44:00,200

lot of people like those because the

1199

00:44:03,070 --> 00:44:01,430

stars are just points that are kind of

1200

00:44:04,000 --> 00:44:03,080

boring but for me it's wasted real

1201
00:44:04,990 --> 00:44:04,010
estate because every one of these

1202
00:44:06,400 --> 00:44:05,000
patches is where I can't make

1203
00:44:07,780 --> 00:44:06,410
measurements of the star so people like

1204
00:44:10,450 --> 00:44:07,790
these galaxies they're just kind of

1205
00:44:12,190 --> 00:44:10,460
irritating to me but I'll zoom in on a

1206
00:44:14,470 --> 00:44:12,200
patch here so here's this yellow box

1207
00:44:15,850 --> 00:44:14,480
that I'm going to zoom in so again you

1208
00:44:17,590 --> 00:44:15,860
have these nice beautiful galaxies in

1209
00:44:19,660 --> 00:44:17,600
the background which I just mask out and

1210
00:44:22,270 --> 00:44:19,670
far away and then you have these points

1211
00:44:24,280 --> 00:44:22,280
which are stars in Leo for

1212
00:44:26,050 --> 00:44:24,290
I like two of them these are the most

1213
00:44:28,570 --> 00:44:26,060

massive hydrogen burning stars in Leo

1214

00:44:29,980 --> 00:44:28,580

four so these tell you the clock so when

1215

00:44:31,780 --> 00:44:29,990

you get measurements of the brightness

1216

00:44:33,520 --> 00:44:31,790

and colors of these stars that tells you

1217

00:44:35,320 --> 00:44:33,530

how well the galaxy is so these are the

1218

00:44:39,310 --> 00:44:35,330

brightest hydrogen burning stars in Leo

1219

00:44:40,900 --> 00:44:39,320

four so here's the image again and what

1220

00:44:43,300 --> 00:44:40,910

I'm going to do now is highlight the

1221

00:44:45,310 --> 00:44:43,310

stars in this image and show you how

1222

00:44:46,660 --> 00:44:45,320

they tell us the clock for the galaxies

1223

00:44:48,580 --> 00:44:46,670

so this is the these are the stars in

1224

00:44:50,740 --> 00:44:48,590

Leo 4 if I sort them in color and

1225

00:44:52,480 --> 00:44:50,750

luminosity that's where they fall at an

1226
00:44:54,880 --> 00:44:52,490
age of around 13 billion years and now I

1227
00:44:56,770 --> 00:44:54,890
can use theory of stellar evolution to

1228
00:44:58,210 --> 00:44:56,780
roll back the clock here so now I'm

1229
00:44:59,710 --> 00:44:58,220
taking the data and just morphing it

1230
00:45:01,390 --> 00:44:59,720
backwards in time towards the Big Bang

1231
00:45:03,040 --> 00:45:01,400
so now this is what the data would look

1232
00:45:05,190 --> 00:45:03,050
like if we made that measurement a

1233
00:45:07,570 --> 00:45:05,200
billion years after the galaxy was born

1234
00:45:09,490 --> 00:45:07,580
so this brightness over here color over

1235
00:45:11,770 --> 00:45:09,500
here and now the clocks rolling forwards

1236
00:45:13,120 --> 00:45:11,780
to the present era so five billion years

1237
00:45:14,710 --> 00:45:13,130
six million years and here's the clock

1238
00:45:17,560 --> 00:45:14,720

is right here this kink this tells you

1239

00:45:18,910 --> 00:45:17,570

how old the population of stars is until

1240

00:45:21,310 --> 00:45:18,920

you get to the galaxy being about 13

1241

00:45:22,690 --> 00:45:21,320

billion years old today and those are

1242

00:45:28,630 --> 00:45:22,700

the points and this is where they fall

1243

00:45:30,550 --> 00:45:28,640

in that image so these the data we got

1244

00:45:31,780 --> 00:45:30,560

so we got six of these duck diagrams

1245

00:45:33,280 --> 00:45:31,790

like I said these contracted diaries

1246

00:45:35,140 --> 00:45:33,290

with my wife calls on duck diagrams and

1247

00:45:36,910 --> 00:45:35,150

the first one we got was here and now

1248

00:45:38,410 --> 00:45:36,920

here's full disclosure I'm an observer I

1249

00:45:40,330 --> 00:45:38,420

have a team of folks on here some work

1250

00:45:42,160 --> 00:45:40,340

on Hubble like me some work on Keck I

1251
00:45:44,020 --> 00:45:42,170
have some theorists on the team and I'm

1252
00:45:45,850 --> 00:45:44,030
used to theorist not to be disparaging a

1253
00:45:47,410 --> 00:45:45,860
theorist coming up with a theory and

1254
00:45:49,900 --> 00:45:47,420
then you go test and you go well let me

1255
00:45:51,850 --> 00:45:49,910
revise that theory so we got these data

1256
00:45:53,590 --> 00:45:51,860
right here and because I work on these

1257
00:45:54,970 --> 00:45:53,600
kind of diagrams a lot I immediately saw

1258
00:45:57,010 --> 00:45:54,980
in my office that this was a very

1259
00:45:57,850 --> 00:45:57,020
ancient population which is not what I

1260
00:45:59,950 --> 00:45:57,860
was expecting

1261
00:46:01,660 --> 00:45:59,960
I wrote this proposal to measure how all

1262
00:46:03,130 --> 00:46:01,670
these stars were and I was sure just

1263
00:46:04,570 --> 00:46:03,140

like every galaxy we've ever measured

1264

00:46:06,820 --> 00:46:04,580

before there would be young stars and

1265

00:46:09,100 --> 00:46:06,830

old stars but instead the stars were all

1266

00:46:10,150 --> 00:46:09,110

just old and I almost fell out of my

1267

00:46:11,290 --> 00:46:10,160

chair and you're looking at these and

1268

00:46:13,240 --> 00:46:11,300

going okay it's a bunch of yellow dots

1269

00:46:14,860 --> 00:46:13,250

but for me it was really surprising

1270

00:46:16,570 --> 00:46:14,870

because I did not expect the theory to

1271

00:46:18,100 --> 00:46:16,580

be true and so I called up Jason

1272

00:46:19,930 --> 00:46:18,110

Tomlinson who made that simulation in

1273

00:46:21,220 --> 00:46:19,940

the beginning of my talk tried him down

1274

00:46:22,630 --> 00:46:21,230

to my office he works one floor up for

1275

00:46:23,650 --> 00:46:22,640

me here in this building and he said

1276

00:46:24,880 --> 00:46:23,660

well yeah that's what's supposed to do

1277

00:46:26,170 --> 00:46:24,890

they're supposed to be old and I said

1278

00:46:27,640 --> 00:46:26,180

yeah but I didn't think that was really

1279

00:46:28,630 --> 00:46:27,650

going to happen I thought there was

1280

00:46:30,160 --> 00:46:28,640

going to be young stars and old stars

1281

00:46:32,230 --> 00:46:30,170

just like every galaxy we've ever looked

1282

00:46:33,930 --> 00:46:32,240

at before so those were the first data

1283

00:46:35,960 --> 00:46:33,940

that executed the program Hercules

1284

00:46:37,880 --> 00:46:35,970

satellite the Milky Way and then

1285

00:46:39,470 --> 00:46:37,890

got the other five galaxies and they're

1286

00:46:40,520 --> 00:46:39,480

all in different positions in each of

1287

00:46:41,599 --> 00:46:40,530

these diagrams here cuz some are closed

1288

00:46:44,150 --> 00:46:41,609

or some are furthest that makes the

1289

00:46:45,230 --> 00:46:44,160

stars brighter and fainter but if you do

1290

00:46:46,880 --> 00:46:45,240

this kind of work you look at each of

1291

00:46:48,140 --> 00:46:46,890

these you say oh my god the stars are

1292

00:46:49,609 --> 00:46:48,150

really ancient every one of these

1293

00:46:50,990 --> 00:46:49,619

galaxies they also look very similar

1294

00:46:53,109 --> 00:46:51,000

these diagrams all look very similar to

1295

00:46:56,000 --> 00:46:53,119

each other so just for a comparison

1296

00:46:57,740 --> 00:46:56,010

without using any theory I'm going to

1297

00:46:59,540 --> 00:46:57,750

take data from another well studied

1298

00:47:00,710 --> 00:46:59,550

object that we use to make comparisons

1299

00:47:03,620 --> 00:47:00,720

the data like I just showed you this is

1300

00:47:05,480 --> 00:47:03,630

m92 NGC 634 one it's one of the most

1301
00:47:06,080 --> 00:47:05,490
well studied ancient objects in the

1302
00:47:08,030 --> 00:47:06,090
universe

1303
00:47:10,339 --> 00:47:08,040
it's a metal-poor star cluster Allan

1304
00:47:12,410 --> 00:47:10,349
Sandage looked at this in the 1950s to

1305
00:47:13,640 --> 00:47:12,420
figure out how stars evolve it's an

1306
00:47:15,589 --> 00:47:13,650
ancient star cluster

1307
00:47:17,089 --> 00:47:15,599
its chemical abundances are such that

1308
00:47:19,370 --> 00:47:17,099
the metals in the atmosphere are less

1309
00:47:21,620 --> 00:47:19,380
than 1% of the abundance in the Sun it's

1310
00:47:24,230 --> 00:47:21,630
a globular cluster this is a half second

1311
00:47:25,460 --> 00:47:24,240
exposure on Hubble Allan Sandage would

1312
00:47:26,720 --> 00:47:25,470
spend nights of the telescope in the

1313
00:47:27,440 --> 00:47:26,730

ground looking at this with Hubble's so

1314

00:47:28,970 --> 00:47:27,450

powerful this is

1315

00:47:30,710 --> 00:47:28,980

oops this is just a half second exposure

1316

00:47:33,440 --> 00:47:30,720

this is the advanced camera for surveys

1317

00:47:35,450 --> 00:47:33,450

it's kind of like your CC the CCD chip

1318

00:47:37,640 --> 00:47:35,460

on here is kind of like your chip on

1319

00:47:39,290 --> 00:47:37,650

your digital camera now there's a crack

1320

00:47:41,329 --> 00:47:39,300

down the middle here splits the chip

1321

00:47:42,950 --> 00:47:41,339

into two halves so that's why you see

1322

00:47:44,900 --> 00:47:42,960

this two sections here but it's a 4k by

1323

00:47:46,940 --> 00:47:44,910

4k image the 16 megapixel camera

1324

00:47:49,810 --> 00:47:46,950

basically on Hubble and all these are

1325

00:47:52,910 --> 00:47:49,820

stars in this globular cluster m92

1326
00:47:55,430 --> 00:47:52,920
this is the climactic diagram from those

1327
00:47:56,960 --> 00:47:55,440
data so this is the luminosity here

1328
00:47:59,390 --> 00:47:56,970
bright stars at the top here's the color

1329
00:48:00,650 --> 00:47:59,400
red stars on the right and again stars

1330
00:48:02,150 --> 00:48:00,660
don't just have random colors and

1331
00:48:04,430 --> 00:48:02,160
brightnesses they trace out this very

1332
00:48:05,960 --> 00:48:04,440
specific pattern that's the lifecycle of

1333
00:48:07,310 --> 00:48:05,970
the star hydrogen burning stars the

1334
00:48:08,390 --> 00:48:07,320
exhaust hydrogen go up here become red

1335
00:48:11,060 --> 00:48:08,400
giants that come over here and burn

1336
00:48:13,130 --> 00:48:11,070
helium and this is the kink right here

1337
00:48:15,500 --> 00:48:13,140
it tells you the age so what I can do is

1338
00:48:17,329 --> 00:48:15,510

I can say all right I'll highlight the

1339

00:48:19,339 --> 00:48:17,339

helium burning stars over here and then

1340

00:48:21,290 --> 00:48:19,349

I'll draw a curve through this and I'll

1341

00:48:22,970 --> 00:48:21,300

just compare that to the data I got on

1342

00:48:24,530 --> 00:48:22,980

those galaxies this is an ancient star

1343

00:48:27,859 --> 00:48:24,540

cluster 13 billion years old that's been

1344

00:48:29,690 --> 00:48:27,869

studied for 60 years so here are the

1345

00:48:32,900 --> 00:48:29,700

data on the new galaxies that we found

1346

00:48:33,980 --> 00:48:32,910

and here's where the m92 data fall when

1347

00:48:35,960 --> 00:48:33,990

you superimpose them at the same

1348

00:48:38,359 --> 00:48:35,970

distance and goes right through the data

1349

00:48:39,500 --> 00:48:38,369

in every case and really this was I know

1350

00:48:41,089 --> 00:48:39,510

how shocking is to you but I was

1351
00:48:42,470 --> 00:48:41,099
flabbergasted when we did this that all

1352
00:48:44,030 --> 00:48:42,480
these galaxies which like I said

1353
00:48:45,560 --> 00:48:44,040
galaxies by definition usually have a

1354
00:48:47,540 --> 00:48:45,570
wide range in age every single one of

1355
00:48:49,190 --> 00:48:47,550
them looks like I'm 92 so not only do

1356
00:48:50,270 --> 00:48:49,200
they all look exactly like each

1357
00:48:52,370 --> 00:48:50,280
there - first order you know it's at

1358
00:48:53,750 --> 00:48:52,380
least by I so this was kind of

1359
00:48:56,030 --> 00:48:53,760
astonishing but it's a pretty good

1360
00:48:57,320 --> 00:48:56,040
support for this theory of what's

1361
00:48:59,120 --> 00:48:57,330
happening to missing satellites we've

1362
00:49:01,700 --> 00:48:59,130
known about these galaxies for decades

1363
00:49:03,650 --> 00:49:01,710

that form a wide range of stars or wide

1364

00:49:05,600 --> 00:49:03,660

range ages but the theory of the missing

1365

00:49:07,370 --> 00:49:05,610

satellites you know why we don't find

1366

00:49:09,140 --> 00:49:07,380

them is that most of them never form

1367

00:49:10,940 --> 00:49:09,150

stars at all and between those two

1368

00:49:12,230 --> 00:49:10,950

categories the ones that been forming

1369

00:49:14,060 --> 00:49:12,240

stars forever the ones that never form

1370

00:49:16,460 --> 00:49:14,070

stars at all should be this transition

1371

00:49:18,020 --> 00:49:16,470

group of galaxies that just formed old

1372

00:49:19,190 --> 00:49:18,030

stars and then we're snuffed out in the

1373

00:49:20,900 --> 00:49:19,200

early universe and that's what this is

1374

00:49:22,910 --> 00:49:20,910

telling us these galaxies form stars

1375

00:49:24,890 --> 00:49:22,920

right around the same time m92 was

1376

00:49:27,950 --> 00:49:24,900

formed and then we're snuffed out when

1377

00:49:29,420 --> 00:49:27,960

the lights came on these are pretty

1378

00:49:31,160 --> 00:49:29,430

boring data about just show them this is

1379

00:49:33,230 --> 00:49:31,170

the Keck data we got so this is number

1380

00:49:35,750 --> 00:49:33,240

of stars versus the chemical composition

1381

00:49:37,670 --> 00:49:35,760

so four stars here this is one percent

1382

00:49:40,010 --> 00:49:37,680

of the subtler composition this is 0.1%

1383

00:49:41,690 --> 00:49:40,020

this is 0.01 percent so these are very

1384

00:49:43,270 --> 00:49:41,700

low metallicity compared to the sun and

1385

00:49:45,710 --> 00:49:43,280

this is number of stars in the galaxy

1386

00:49:47,540 --> 00:49:45,720

compared to what fraction of the solar

1387

00:49:49,610 --> 00:49:47,550

composition there is so most of the

1388

00:49:51,200 --> 00:49:49,620

stars fall between 0.1 percent and 10

1389

00:49:53,150 --> 00:49:51,210

percent of the solar composition so the

1390

00:49:54,620 --> 00:49:53,160

stars are very metal-poor they're very

1391

00:49:56,360 --> 00:49:54,630

few metals so they're born from pristine

1392

00:49:57,590 --> 00:49:56,370

gas in the early universe this is again

1393

00:50:00,380 --> 00:49:57,600

supporting evidence that these are

1394

00:50:01,700 --> 00:50:00,390

pristine ancient galaxies m92 just for

1395

00:50:04,310 --> 00:50:01,710

comparison is right here where the green

1396

00:50:05,900 --> 00:50:04,320

line is so m92 is a little less than 1%

1397

00:50:09,800 --> 00:50:05,910

the composition of the Sun it's also

1398

00:50:12,710 --> 00:50:09,810

ancient and metal-poor so just for

1399

00:50:14,840 --> 00:50:12,720

another way to compare these data these

1400

00:50:16,850 --> 00:50:14,850

are the data from Hercules I'm zooming

1401
00:50:17,990 --> 00:50:16,860
in here now on the clock so the little

1402
00:50:19,670 --> 00:50:18,000
kink right here again this brightness

1403
00:50:21,080 --> 00:50:19,680
versus color and I'm going to take the

1404
00:50:22,610 --> 00:50:21,090
data from all the other galaxies and

1405
00:50:24,380 --> 00:50:22,620
superimpose them on here just to show

1406
00:50:28,250 --> 00:50:24,390
how similar they are so this is Hercules

1407
00:50:29,360 --> 00:50:28,260
in yellow that's Leo four in green and

1408
00:50:30,290 --> 00:50:29,370
as you said well I can't really see it

1409
00:50:34,790 --> 00:50:30,300
that well to us they're right on top of

1410
00:50:37,610 --> 00:50:34,800
each other that's CVN - and purple that

1411
00:50:40,310 --> 00:50:37,620
sort some major one in blue that's

1412
00:50:42,350 --> 00:50:40,320
bootys one in red and that's cone barren

1413
00:50:43,760 --> 00:50:42,360

brown so if you put all these galaxies

1414

00:50:45,500 --> 00:50:43,770

in the same reference frame their data

1415

00:50:47,240 --> 00:50:45,510

fall right on top of each other these

1416

00:50:49,220 --> 00:50:47,250

are six satellite galaxies of the Milky

1417

00:50:51,170 --> 00:50:49,230

Way all at different distances from the

1418

00:50:52,940 --> 00:50:51,180

Milky Way all different parts of the sky

1419

00:50:55,370 --> 00:50:52,950

and they all look exactly the same to

1420

00:50:57,320 --> 00:50:55,380

the eye so that implies some kind of

1421

00:50:58,880 --> 00:50:57,330

global influence effected all of them

1422

00:51:00,440 --> 00:50:58,890

and there's a lot of things going on

1423

00:51:01,940 --> 00:51:00,450

with galaxies form supernovae blow off

1424

00:51:03,080 --> 00:51:01,950

all the gas out of the stars new

1425

00:51:04,940 --> 00:51:03,090

generations of stars are born

1426
00:51:07,040 --> 00:51:04,950
it's a chaotic process but something

1427
00:51:08,690 --> 00:51:07,050
synchronized the star formation in all

1428
00:51:11,000 --> 00:51:08,700
six of these galaxies to a very high

1429
00:51:12,170 --> 00:51:11,010
degree and one possible thing that's

1430
00:51:13,370 --> 00:51:12,180
obvious here after you've heard the

1431
00:51:14,510 --> 00:51:13,380
pitch in the beginning is that it was

1432
00:51:15,860 --> 00:51:14,520
Rihanna's ation in the universe that

1433
00:51:18,470 --> 00:51:15,870
would be a global influence that

1434
00:51:20,300 --> 00:51:18,480
affected all the galaxies this is where

1435
00:51:21,890 --> 00:51:20,310
theory tells us the star should fall if

1436
00:51:23,450 --> 00:51:21,900
all the stars were between 12 and 13

1437
00:51:25,190 --> 00:51:23,460
billion years old they would fall on

1438
00:51:26,960 --> 00:51:25,200

this great curve here which is a good

1439

00:51:28,160 --> 00:51:26,970

match to the data the data spread out a

1440

00:51:29,900 --> 00:51:28,170

little bit more down here because there

1441

00:51:31,310 --> 00:51:29,910

are a little noisier as you go faint but

1442

00:51:35,720 --> 00:51:31,320

this is where the stars would have been

1443

00:51:36,590 --> 00:51:35,730

born right along this curve so just to

1444

00:51:38,690 --> 00:51:36,600

show you now a little more

1445

00:51:42,170 --> 00:51:38,700

quantitatively this is the zoom in now

1446

00:51:43,820 --> 00:51:42,180

on the clock for Hercules and the

1447

00:51:45,020 --> 00:51:43,830

theoretical prediction a random draw on

1448

00:51:46,580 --> 00:51:45,030

the theoretical prediction of where the

1449

00:51:48,260 --> 00:51:46,590

star should fall so one of these panels

1450

00:51:49,820 --> 00:51:48,270

is the data one is the model I won't

1451

00:51:51,320 --> 00:51:49,830

make you guess which one is which but

1452

00:51:53,270 --> 00:51:51,330

you can see the model and the data look

1453

00:51:54,950 --> 00:51:53,280

very similar the green curve is there 92

1454

00:51:58,280 --> 00:51:54,960

again just for comparison so that's

1455

00:52:01,610 --> 00:51:58,290

Hercules ones data ones the model that's

1456

00:52:03,020 --> 00:52:01,620

all six of the galaxies so in one panel

1457

00:52:04,160 --> 00:52:03,030

I'm showing you the theoretical

1458

00:52:05,630 --> 00:52:04,170

prediction for how the Stars should be

1459

00:52:06,950 --> 00:52:05,640

scattered around a diagram like this and

1460

00:52:08,840 --> 00:52:06,960

other ones the real data from Hubble and

1461

00:52:10,340 --> 00:52:08,850

each panel here they look very similar

1462

00:52:12,980 --> 00:52:10,350

right the distribution of stars is very

1463

00:52:14,510 --> 00:52:12,990

similar in each case and so what is in

1464

00:52:17,840 --> 00:52:14,520

each case is the models on the right and

1465

00:52:19,310 --> 00:52:17,850

the data on the left and the theoretical

1466

00:52:20,870 --> 00:52:19,320

prediction for where the stars ripple in

1467

00:52:23,270 --> 00:52:20,880

this diagram matches the data very well

1468

00:52:24,770 --> 00:52:23,280

I can show it this way to the grey

1469

00:52:26,900 --> 00:52:24,780

shading here is where the month the

1470

00:52:28,400 --> 00:52:26,910

theory says the star should fall and the

1471

00:52:30,050 --> 00:52:28,410

other points are where the stars do fall

1472

00:52:32,540 --> 00:52:30,060

and there's excellent agreement in all

1473

00:52:34,130 --> 00:52:32,550

six galaxies so this really tells us

1474

00:52:35,480 --> 00:52:34,140

that these are fossil galaxies now it

1475

00:52:37,160 --> 00:52:35,490

may not be true that the reorganization

1476

00:52:40,190 --> 00:52:37,170

of the universe is what made them old

1477

00:52:41,810 --> 00:52:40,200

but we were testing that theory we said

1478

00:52:43,190 --> 00:52:41,820

if there are ancient fossil galaxies

1479

00:52:44,810 --> 00:52:43,200

these would be excellent candidates for

1480

00:52:45,920 --> 00:52:44,820

being fossil galaxies we looked at them

1481

00:52:47,300 --> 00:52:45,930

closely with Hubble and they do seem

1482

00:52:49,100 --> 00:52:47,310

like they're very pristine and they're

1483

00:52:50,690 --> 00:52:49,110

metallicity and they're very very old

1484

00:52:52,970 --> 00:52:50,700

they're about 13 billion years old the

1485

00:52:54,320 --> 00:52:52,980

average age in each of these fits here

1486

00:52:56,060 --> 00:52:54,330

this is thirteen point three billion

1487

00:52:57,620 --> 00:52:56,070

years old thirteen point six billion

1488

00:52:58,820 --> 00:52:57,630

years old this is thirteen point nine

1489

00:52:59,960 --> 00:52:58,830

billion years old and I know some of

1490

00:53:00,800 --> 00:52:59,970

you're going to go wait a minute Frank a

1491

00:53:02,480 --> 00:53:00,810

little while ago to start my the

1492

00:53:04,250 --> 00:53:02,490

universe is only 13.8 billion years old

1493

00:53:06,290 --> 00:53:04,260

there's about half a billion years of

1494

00:53:08,270 --> 00:53:06,300

uncertainty and these fits do to the

1495

00:53:09,200 --> 00:53:08,280

models so it's consistent with the age

1496

00:53:10,430 --> 00:53:09,210

of the universe it's not like we're

1497

00:53:12,290 --> 00:53:10,440

saying this galaxy is older than the

1498

00:53:13,940 --> 00:53:12,300

universe but within the uncertainties

1499

00:53:14,870 --> 00:53:13,950

these galaxies were all born right after

1500

00:53:16,730 --> 00:53:14,880

the Big Bang

1501

00:53:18,560 --> 00:53:16,740

this one's 13 point 1 billion

1502

00:53:20,770 --> 00:53:18,570

years old 13 point 1 billion years old

1503

00:53:23,090 --> 00:53:20,780

12 point 7 billion years old on average

1504

00:53:25,130 --> 00:53:23,100

so these are the oldest known galaxies

1505

00:53:26,960 --> 00:53:25,140

these 6 use the only galaxies where

1506

00:53:29,540 --> 00:53:26,970

we've measured ages to this accuracy and

1507

00:53:33,410 --> 00:53:29,550

all of them are older than any galaxy

1508

00:53:34,370 --> 00:53:33,420

we've ever measured before this is

1509

00:53:36,530 --> 00:53:34,380

another way of showing the same thing

1510

00:53:39,350 --> 00:53:36,540

this is a fraction of stars born in the

1511

00:53:40,790 --> 00:53:39,360

galaxy versus time on the x axis so what

1512

00:53:42,560 --> 00:53:40,800

happens here so this is looking back in

1513

00:53:45,050 --> 00:53:42,570

time to the early universe 14 billion

1514

00:53:47,300 --> 00:53:45,060

years ago or so and star formation

1515

00:53:49,220 --> 00:53:47,310

starts very quickly 80% of the stars are

1516

00:53:51,350 --> 00:53:49,230

formed in the very first billion years

1517

00:53:52,850 --> 00:53:51,360

and then they kind of tapers off and

1518

00:53:54,530 --> 00:53:52,860

there's the width here is just the

1519

00:53:55,940 --> 00:53:54,540

uncertainty in the model so this would

1520

00:53:58,280 --> 00:53:55,950

be a narrow curve of our models were

1521

00:53:59,600 --> 00:53:58,290

better but so the star creation comes on

1522

00:54:01,640 --> 00:53:59,610

very suddenly and then this little tail

1523

00:54:03,500 --> 00:54:01,650

as realization starts to shut things

1524

00:54:05,030 --> 00:54:03,510

down in these galaxies so this is the

1525

00:54:07,070 --> 00:54:05,040

this is a fit to the data for Hercules

1526

00:54:08,450 --> 00:54:07,080

this is what it looks like for all six

1527

00:54:10,130 --> 00:54:08,460

galaxies the star form and they all look

1528

00:54:11,840 --> 00:54:10,140

very similar star formation comes on

1529

00:54:13,520 --> 00:54:11,850

very rapidly if none of the stars are

1530

00:54:15,290 --> 00:54:13,530

formed right after the Big Bang and then

1531

00:54:16,609 --> 00:54:15,300

there's a little tail going on for a few

1532

00:54:18,170 --> 00:54:16,619

billion years afterwards as it the

1533

00:54:22,599 --> 00:54:18,180

realisation the universe shuts off the

1534

00:54:24,590 --> 00:54:22,609

galaxies and their stars so

1535

00:54:25,730 --> 00:54:24,600

unfortunately for where we live or maybe

1536

00:54:27,349 --> 00:54:25,740

fortunately maybe it wouldn't be such a

1537

00:54:29,030 --> 00:54:27,359

great place to live we live in kind of a

1538

00:54:30,980 --> 00:54:29,040

cosmological backwater there's not a lot

1539

00:54:33,349 --> 00:54:30,990

going on in the local group so this is a

1540

00:54:35,270 --> 00:54:33,359

box here showing us part of the local

1541

00:54:37,070 --> 00:54:35,280

universe 80 million light years on aside

1542

00:54:39,260 --> 00:54:37,080

and the kind of work I'm talking about

1543

00:54:42,050 --> 00:54:39,270

here where you can use Hubble to measure

1544

00:54:43,010 --> 00:54:42,060

ages of stars very very accurately there

1545

00:54:44,870 --> 00:54:43,020

are a lot of ways to measure stellar

1546

00:54:46,670 --> 00:54:44,880

ages that you could do less accurately

1547

00:54:48,050 --> 00:54:46,680

you can do them far away but for doing

1548

00:54:50,000 --> 00:54:48,060

really accurate ages you can only do it

1549

00:54:51,650 --> 00:54:50,010

relatively nearby and Hubble can do this

1550

00:54:53,690 --> 00:54:51,660

kind of work in this yellow sphere right

1551
00:54:54,980 --> 00:54:53,700
here so that's where we can do the kind

1552
00:54:56,840 --> 00:54:54,990
of work I'm talking about right now and

1553
00:54:57,770 --> 00:54:56,850
it's not a really interesting patch of

1554
00:55:00,620 --> 00:54:57,780
the universe where we live unfortunately

1555
00:55:02,210 --> 00:55:00,630
so the symbols here these paperclip

1556
00:55:03,260 --> 00:55:02,220
looking things that I drew here is my

1557
00:55:05,300 --> 00:55:03,270
lame attempt to make a spiral galaxy

1558
00:55:06,650 --> 00:55:05,310
these are giant spiral galaxies the

1559
00:55:08,930 --> 00:55:06,660
Milky Way's right here at the center

1560
00:55:11,180 --> 00:55:08,940
Andromeda is our only other nearby giant

1561
00:55:12,770 --> 00:55:11,190
spiral these big red things are

1562
00:55:14,240 --> 00:55:12,780
elliptical galaxies giant elliptical

1563
00:55:15,500 --> 00:55:14,250

galaxies and the little brown dots are

1564

00:55:17,330 --> 00:55:15,510

dwarf galaxies like I've been talking

1565

00:55:18,859 --> 00:55:17,340

about tonight so we live in kind of a

1566

00:55:20,359 --> 00:55:18,869

boring part of the universe it's out in

1567

00:55:22,310 --> 00:55:20,369

the boonies there's not a lot going on

1568

00:55:24,560 --> 00:55:22,320

here it's the Milky Way Andromeda and a

1569

00:55:27,290 --> 00:55:24,570

few dozens Dwarf galaxies and Hubble can

1570

00:55:29,120 --> 00:55:27,300

measure the ages of these galaxies the

1571

00:55:30,470 --> 00:55:29,130

James Webb Space Telescope is launching

1572

00:55:31,849 --> 00:55:30,480

in 2018

1573

00:55:33,200 --> 00:55:31,859

it could do the kind of work I'm talking

1574

00:55:34,880 --> 00:55:33,210

about tonight and volume three times

1575

00:55:36,319 --> 00:55:34,890

larger so it gets a lot more dwarf

1576
00:55:38,150 --> 00:55:36,329
galaxies who starts to get to the spiral

1577
00:55:39,890 --> 00:55:38,160
galaxy that's not what it was built for

1578
00:55:41,390 --> 00:55:39,900
though it looks in the infrared it's got

1579
00:55:42,920 --> 00:55:41,400
a much bigger mirror it's going to

1580
00:55:44,599 --> 00:55:42,930
measure the ages of galaxies by looking

1581
00:55:46,370 --> 00:55:44,609
directly back in time at high redshift

1582
00:55:48,500 --> 00:55:46,380
so you know if you look very far away

1583
00:55:49,790 --> 00:55:48,510
you're looking in time so James Webb is

1584
00:55:51,620 --> 00:55:49,800
going to look at the most distant

1585
00:55:53,120 --> 00:55:51,630
galaxies and observe them evolving

1586
00:55:53,900 --> 00:55:53,130
directly it's not going to do the kind

1587
00:55:55,670 --> 00:55:53,910
of stuff I'm talking about tonight

1588
00:55:56,750 --> 00:55:55,680

primarily but it will do some of that

1589

00:55:59,660 --> 00:55:56,760

kind of work and it could do it a little

1590

00:56:01,579 --> 00:55:59,670

better than Hubble folks are also

1591

00:56:02,990 --> 00:56:01,589

looking at building much bigger versions

1592

00:56:04,940 --> 00:56:03,000

of Hubble's this is an active thing

1593

00:56:06,109 --> 00:56:04,950

going on right now there's a lot of

1594

00:56:07,760 --> 00:56:06,119

folks looking to see what are the next

1595

00:56:09,380 --> 00:56:07,770

big NASA missions in the next couple

1596

00:56:11,180 --> 00:56:09,390

decades and people are talking about

1597

00:56:12,530 --> 00:56:11,190

building a UV optical telescope like

1598

00:56:15,440 --> 00:56:12,540

Hubble that it would have an 8 meter

1599

00:56:17,990 --> 00:56:15,450

mirror so Hubble's got a two point four

1600

00:56:19,490 --> 00:56:18,000

meter mirror people are looking at an 8

1601
00:56:21,680 --> 00:56:19,500
meter mirror that would get out of our

1602
00:56:23,150 --> 00:56:21,690
little you know middle of nowhere patch

1603
00:56:25,310 --> 00:56:23,160
of the universe you could start doing

1604
00:56:26,810 --> 00:56:25,320
this kind of work in spiral galaxies out

1605
00:56:28,250 --> 00:56:26,820
in the nearest towns you can actually

1606
00:56:30,560 --> 00:56:28,260
pick up an elliptical galaxy and lots of

1607
00:56:32,060 --> 00:56:30,570
other types of galaxies there are folks

1608
00:56:33,560 --> 00:56:32,070
who are really ambitious who are talking

1609
00:56:35,480 --> 00:56:33,570
about building a 16 meter version or

1610
00:56:36,980 --> 00:56:35,490
Hubble and this is really something that

1611
00:56:38,569 --> 00:56:36,990
people are looking at right now the

1612
00:56:40,520 --> 00:56:38,579
primary motivation for this is to look

1613
00:56:42,020 --> 00:56:40,530

for life around other stars so this is

1614

00:56:43,550 --> 00:56:42,030

the kind of telescope you need if you

1615

00:56:45,470 --> 00:56:43,560

want to be able to detect life directly

1616

00:56:46,550 --> 00:56:45,480

on planets orbiting other stars and if

1617

00:56:47,630 --> 00:56:46,560

you're going to build such a telescope

1618

00:56:49,190 --> 00:56:47,640

people can use your further stuff too

1619

00:56:50,180 --> 00:56:49,200

and people like me out the light looking

1620

00:56:51,650 --> 00:56:50,190

for life around other stars it's

1621

00:56:53,599 --> 00:56:51,660

obviously very exciting I measure the

1622

00:56:55,430 --> 00:56:53,609

ages of stars you could do what I'm

1623

00:56:56,630 --> 00:56:55,440

talking about tonight in this volume of

1624

00:56:58,579 --> 00:56:56,640

the universe and that would be a true

1625

00:57:00,290 --> 00:56:58,589

census of the local universe you get

1626
00:57:02,030 --> 00:57:00,300
lots of giant elliptical galaxies these

1627
00:57:03,470 --> 00:57:02,040
red things you get tons of spiral

1628
00:57:05,240 --> 00:57:03,480
galaxies many more hundreds of dwarf

1629
00:57:07,190 --> 00:57:05,250
galaxies you could really get a sense of

1630
00:57:08,660 --> 00:57:07,200
how the universe has formed it stars in

1631
00:57:10,220 --> 00:57:08,670
the nearby University of that kind of

1632
00:57:11,480 --> 00:57:10,230
telescope I probably would not get a

1633
00:57:12,559 --> 00:57:11,490
gigantic fraction of the time most the

1634
00:57:14,240 --> 00:57:12,569
time it will be looking for life front

1635
00:57:16,880 --> 00:57:14,250
other stars but you could get some time

1636
00:57:18,589 --> 00:57:16,890
doing this type of work so this is the

1637
00:57:19,420 --> 00:57:18,599
Hubble Space Telescope and low-earth

1638
00:57:21,470 --> 00:57:19,430

orbit

1639

00:57:23,599 --> 00:57:21,480

most of our carbon torment tonight comes

1640

00:57:25,520 --> 00:57:23,609

from Hubble also comes from Keck I

1641

00:57:27,140 --> 00:57:25,530

worked previously up until a few months

1642

00:57:29,450 --> 00:57:27,150

ago on the James Webb Space Telescope

1643

00:57:30,589 --> 00:57:29,460

for the last eight years so I'll just

1644

00:57:32,450 --> 00:57:30,599

give you a little update on that this is

1645

00:57:34,190 --> 00:57:32,460

James Webb it has unlike a two point

1646

00:57:36,230 --> 00:57:34,200

four meter mirror it has a six and a

1647

00:57:38,270 --> 00:57:36,240

half meter mirror coated in gold it's a

1648

00:57:39,859 --> 00:57:38,280

beryllium mirror and then just to give

1649

00:57:41,990 --> 00:57:39,869

you a sense of scale this is the light

1650

00:57:43,460 --> 00:57:42,000

shield this is the Sun shield it's about

1651
00:57:45,109 --> 00:57:43,470
the size of a tennis court

1652
00:57:47,359 --> 00:57:45,119
made of a material similar to like candy

1653
00:57:48,890 --> 00:57:47,369
wrappers it's got five layers here keeps

1654
00:57:50,690 --> 00:57:48,900
the instruments in the telescope in the

1655
00:57:54,130 --> 00:57:50,700
shade while it's orbiting out around the

1656
00:57:56,660 --> 00:57:54,140
Sun we're launching that in October 2018

1657
00:57:58,220 --> 00:57:56,670
these are the main science goals of

1658
00:57:59,810 --> 00:57:58,230
James Webb so it's going to look at the

1659
00:58:01,190 --> 00:57:59,820
first galaxies in the universe so again

1660
00:58:02,480 --> 00:58:01,200
it will be measuring the evolution of

1661
00:58:03,920 --> 00:58:02,490
galaxies but in a very different way

1662
00:58:06,080 --> 00:58:03,930
it's going to look directly back in time

1663
00:58:07,760 --> 00:58:06,090

of the most distant galaxies it's going

1664

00:58:09,770 --> 00:58:07,770

to watch over that cosmic time how

1665

00:58:11,330 --> 00:58:09,780

galaxies evolve because it's looking in

1666

00:58:13,940 --> 00:58:11,340

the infrared it can peer through dust

1667

00:58:15,560 --> 00:58:13,950

and gas to see stars and Galant planets

1668

00:58:17,420 --> 00:58:15,570

being born and it's gonna be able to

1669

00:58:20,650 --> 00:58:17,430

look for the origin of life so these are

1670

00:58:23,660 --> 00:58:20,660

the main science themes of James Webb

1671

00:58:25,700 --> 00:58:23,670

just for comparison Hubble is in

1672

00:58:26,930 --> 00:58:25,710

low-earth orbit you know on this scale

1673

00:58:28,190 --> 00:58:26,940

you wouldn't be able to see how far away

1674

00:58:29,990 --> 00:58:28,200

from Earth it is it'd be orbiting right

1675

00:58:32,089 --> 00:58:30,000

there James Webb is going to go out here

1676
00:58:33,530 --> 00:58:32,099
to a point we called Lagrange two it's

1677
00:58:37,640 --> 00:58:33,540
four times further away than the moon

1678
00:58:38,810 --> 00:58:37,650
one and a half kilometers away and then

1679
00:58:43,220 --> 00:58:38,820
just here's a comparison of the

1680
00:58:45,620 --> 00:58:43,230
telescope sizes here's a person 1.75

1681
00:58:47,470 --> 00:58:45,630
meters tall here's Hubble's meter 2.4

1682
00:58:52,160 --> 00:58:47,480
meters tall and here's James Webb

1683
00:58:54,560 --> 00:58:52,170
six-and-a-half meters tall in 18

1684
00:58:56,270 --> 00:58:54,570
segments that's ground testing down a

1685
00:58:57,829 --> 00:58:56,280
NASA of some of the mirror segments

1686
00:58:58,910 --> 00:58:57,839
again coated in gold people freaked out

1687
00:59:00,620 --> 00:58:58,920
a little bit you say the mirror is made

1688
00:59:02,690 --> 00:59:00,630

of gold oh my god that's it's wasting so

1689

00:59:04,400 --> 00:59:02,700

much money the whole mirror has about

1690

00:59:05,839 --> 00:59:04,410

this much gold on the coating of it okay

1691

00:59:10,339 --> 00:59:05,849

so just for comparison so it's a very

1692

00:59:12,200 --> 00:59:10,349

thin layer on the surface here are the

1693

00:59:13,730 --> 00:59:12,210

instruments so we were testing the

1694

00:59:15,500 --> 00:59:13,740

instruments individually at different

1695

00:59:16,760 --> 00:59:15,510

locations around the world up until a

1696

00:59:18,140 --> 00:59:16,770

few years ago and then we started

1697

00:59:19,520 --> 00:59:18,150

integrating them into the integrated

1698

00:59:21,410 --> 00:59:19,530

science instrument module that got

1699

00:59:23,510 --> 00:59:21,420

tested last year Goddard so it's near

1700

00:59:25,099 --> 00:59:23,520

cam which is a near infrared camera Miri

1701

00:59:27,500 --> 00:59:25,109

which is a mid infrared instrument also

1702

00:59:29,480 --> 00:59:27,510

camera and a spectrograph near spec and

1703

00:59:32,300 --> 00:59:29,490

your infrared spectrograph and near us

1704

00:59:33,950 --> 00:59:32,310

also a near infrared camera hence

1705

00:59:38,120 --> 00:59:33,960

spectrograph specifically designed for

1706

00:59:39,710 --> 00:59:38,130

exoplanet searches and here's the test

1707

00:59:41,150 --> 00:59:39,720

chamber at Goddard where we were just

1708

00:59:44,950 --> 00:59:41,160

testing we wrapped up testing of the

1709

00:59:47,599 --> 00:59:44,960

instruments this last year in February

1710

00:59:48,980 --> 00:59:47,609

this is the chamber that will be used to

1711

00:59:51,680 --> 00:59:48,990

test the instruments and the mirror

1712

00:59:53,030 --> 00:59:51,690

together next year in April this is the

1713

00:59:54,589 --> 00:59:53,040

same chamber that was used for the

1714

00:59:56,180 --> 00:59:54,599

Apollo Lunar Module

1715

00:59:56,839 --> 00:59:56,190

I walked around inside this a few years

1716

00:59:57,890 --> 00:59:56,849

ago before they

1717

00:59:59,299 --> 00:59:57,900

started cleaning it out and for the

1718

01:00:00,710 --> 00:59:59,309

testing I have to say it's crazy

1719

01:00:02,329 --> 01:00:00,720

impressive and those are people standing

1720

01:00:03,799 --> 01:00:02,339

here so you walk around inside the

1721

01:00:05,569 --> 01:00:03,809

scaffolding it's the same chamber those

1722

01:00:07,009 --> 01:00:05,579

used to test the Apollo missions and

1723

01:00:10,099 --> 01:00:07,019

we'll it's at Johnson Space Center will

1724

01:00:11,539 --> 01:00:10,109

be starting testing there next year and

1725

01:00:12,710 --> 01:00:11,549

that's what it look like so James Webb

1726

01:00:14,690 --> 01:00:12,720

will be what we call the cup up

1727

01:00:16,160 --> 01:00:14,700

configuration so the mirror is facing up

1728

01:00:17,839 --> 01:00:16,170

the instruments are sitting here facing

1729

01:00:19,339 --> 01:00:17,849

down and we'll do some simulations of

1730

01:00:22,940 --> 01:00:19,349

the conditions in space to test it

1731

01:00:24,979 --> 01:00:22,950

before we launch it so just to summarize

1732

01:00:26,960 --> 01:00:24,989

the ultra faint dwarf galaxies are

1733

01:00:28,789 --> 01:00:26,970

extremely metal-poor some of the most

1734

01:00:30,410 --> 01:00:28,799

metal-poor stars in the universe that we

1735

01:00:31,640 --> 01:00:30,420

know about are found in these ultra

1736

01:00:33,049 --> 01:00:31,650

faint dwarf galaxies and their chemical

1737

01:00:34,640 --> 01:00:33,059

abundances and most of the stars are a

1738

01:00:36,769 --> 01:00:34,650

tenth of a percent to one percent of

1739

01:00:38,049 --> 01:00:36,779

those we found in the Sun the ultra

1740

01:00:40,880 --> 01:00:38,059

faint dwarf galaxies are ancient

1741

01:00:42,349 --> 01:00:40,890

three-quarters of the stars formed their

1742

01:00:44,210 --> 01:00:42,359

star three-quarters of the stars were

1743

01:00:46,400 --> 01:00:44,220

formed more than 13 billion years ago

1744

01:00:48,769 --> 01:00:46,410

so these galaxies are truly ancient

1745

01:00:50,210 --> 01:00:48,779

there are known as far as we can tell

1746

01:00:51,559 --> 01:00:50,220

intermediate stars are nothing really

1747

01:00:53,479 --> 01:00:51,569

younger than 10 billion years old on

1748

01:00:54,799 --> 01:00:53,489

these stars and that's very distinct

1749

01:00:56,150 --> 01:00:54,809

from pretty much not only the classical

1750

01:00:57,769 --> 01:00:56,160

dwarf galaxies every other galaxies that

1751
01:01:00,859 --> 01:00:57,779
ever been studied most galaxies have a

1752
01:01:02,150 --> 01:01:00,869
young stars and old stars star formation

1753
01:01:03,589 --> 01:01:02,160
appears to be synchronised in these

1754
01:01:04,999 --> 01:01:03,599
objects even though there's six

1755
01:01:06,859 --> 01:01:05,009
different galaxies spread out on the sky

1756
01:01:07,849 --> 01:01:06,869
they all have pretty much the same star

1757
01:01:09,049 --> 01:01:07,859
formation history it's like a guillotine

1758
01:01:10,219 --> 01:01:09,059
came along and shut off the star

1759
01:01:12,019 --> 01:01:10,229
information in all these at the same

1760
01:01:13,339 --> 01:01:12,029
time and that's what you would expect if

1761
01:01:14,779 --> 01:01:13,349
they were all snuffed out by the

1762
01:01:16,640 --> 01:01:14,789
reorganization of the universe shortly

1763
01:01:18,440 --> 01:01:16,650

after the Big Bang and this is

1764

01:01:19,999 --> 01:01:18,450

consistent with pollutions that are

1765

01:01:22,099 --> 01:01:20,009

opposed to the missing satellite problem

1766

01:01:23,690 --> 01:01:22,109

most of the missing satellites are there

1767

01:01:25,819 --> 01:01:23,700

but they just have fewer know stars so

1768

01:01:28,130 --> 01:01:25,829

we can't see them thanks and I'll show

1769

01:01:29,150 --> 01:01:28,140

this video of the j2 ST deployment in

1770

01:02:05,749 --> 01:01:29,160

two years while I answer questions

1771

01:02:10,630 --> 01:02:07,569

so dark matters just matter that's not

1772

01:02:14,059 --> 01:02:10,640

luminous so I mean dark matter is it

1773

01:02:15,529 --> 01:02:14,069

right but people are trying to figure

1774

01:02:16,910 --> 01:02:15,539

out what dark matter is so we don't

1775

01:02:18,559 --> 01:02:16,920

really have a good handle on what dark

1776

01:02:19,910 --> 01:02:18,569

matter is people are searching for there

1777

01:02:21,859 --> 01:02:19,920

and we know it's there from its

1778

01:02:23,359 --> 01:02:21,869

gravitational effects but you can't

1779

01:02:32,959 --> 01:02:23,369

observe it directly you just see it's in

1780

01:02:34,130 --> 01:02:32,969

dirt you know well in these galaxies

1781

01:02:35,719 --> 01:02:34,140

they're dark but we call it dark matter

1782

01:02:37,249 --> 01:02:35,729

dominated so the ones I showed you

1783

01:02:38,959 --> 01:02:37,259

tonight there's very little like so

1784

01:02:40,219 --> 01:02:38,969

there's only a few stars and then you

1785

01:02:41,779 --> 01:02:40,229

know there's dark matter there because

1786

01:02:42,829 --> 01:02:41,789

of the orbits of those stars but then

1787

01:02:44,120 --> 01:02:42,839

there are other clumps of dark matter

1788

01:02:46,219 --> 01:02:44,130

out there where there's no stars in them

1789

01:02:53,209 --> 01:02:46,229

at all we just infer their presence from

1790

01:02:55,670 --> 01:02:53,219

from the gravitational pull the clumping

1791

01:02:56,569 --> 01:02:55,680

looks very similar in theory to that

1792

01:02:57,769 --> 01:02:56,579

simulation I showed in the beginning

1793

01:02:59,630 --> 01:02:57,779

with all the hundreds of little blue

1794

01:03:00,680 --> 01:02:59,640

points around the Milky Way but people

1795

01:03:03,890 --> 01:03:00,690

have been searching for dark matter

1796

01:03:05,420 --> 01:03:03,900

pretty strenuous ly and you know not

1797

01:03:07,009 --> 01:03:05,430

finding a lot of it so that's the

1798

01:03:08,930 --> 01:03:07,019

theoretical prediction of how it clumps

1799

01:03:10,069 --> 01:03:08,940

you know but how it actually clumps we

1800

01:03:20,259 --> 01:03:10,079

don't have a good handle on yet because

1801
01:03:24,439 --> 01:03:23,029
yeah B since we can't observe the clumps

1802
01:03:25,579 --> 01:03:24,449
that have no stars we really can't

1803
01:03:27,079 --> 01:03:25,589
observe those directly so what I'm

1804
01:03:29,479 --> 01:03:27,089
looking at here are the ones that just

1805
01:03:31,910 --> 01:03:29,489
formed a few stars and that's that gives

1806
01:03:33,049 --> 01:03:31,920
us credence to the theory that why the

1807
01:03:34,729 --> 01:03:33,059
missing silence are there would be great

1808
01:03:36,400 --> 01:03:34,739
if we actually observe those hundreds of

1809
01:03:42,290 --> 01:03:36,410
clumps that we don't have any stars in

1810
01:03:46,680 --> 01:03:45,120
so the oldest stars in those galaxies go

1811
01:03:48,210 --> 01:03:46,690
back to the Big Bang within the error

1812
01:03:49,770 --> 01:03:48,220
bars so back to the thirteen half

1813
01:03:51,030 --> 01:03:49,780

billion years old or so so that was the

1814

01:03:52,470 --> 01:03:51,040

image that's on the David Bowie album

1815

01:03:54,120 --> 01:03:52,480

that was the goal of that program was to

1816

01:03:56,340 --> 01:03:54,130

measure the range of Ages in Andromeda

1817

01:03:58,050 --> 01:03:56,350

out and it's halo stars and so we found

1818

01:03:59,280 --> 01:03:58,060

stars over 13 1/2 million years old we

1819

01:04:00,780 --> 01:03:59,290

found stars there were just a billion

1820

01:04:03,420 --> 01:04:00,790

years old know everything in between and

1821

01:04:04,620 --> 01:04:03,430

that's the case for the Milky Way that's

1822

01:04:06,060 --> 01:04:04,630

the case for Andromeda that's the case

1823

01:04:07,590 --> 01:04:06,070

for the satellite galaxies that we've

1824

01:04:09,630 --> 01:04:07,600

known about it's these Ultra faint

1825

01:04:11,310 --> 01:04:09,640

dwarfs that only have ancient stars

1826
01:04:12,660 --> 01:04:11,320
every other galaxy we've looked at as

1827
01:04:14,940 --> 01:04:12,670
young stars only young for an astronomer

1828
01:04:17,280 --> 01:04:14,950
you know it's definitely less than 10

1829
01:04:23,460 --> 01:04:17,290
billion years old and old stars as

1830
01:04:25,350 --> 01:04:23,470
well is that the structure the Milky Way

1831
01:04:28,290 --> 01:04:25,360
believed to have formed around ten

1832
01:04:31,320 --> 01:04:28,300
billion years ago the structure of the

1833
01:04:34,140 --> 01:04:31,330
disk of the galaxy right so some stars

1834
01:04:41,040 --> 01:04:34,150
are as well as the universe but the

1835
01:04:42,840 --> 01:04:41,050
structure itself is believed to be about

1836
01:04:44,610 --> 01:04:42,850
ten billion years old and we can see

1837
01:04:45,900 --> 01:04:44,620
that by looking at higher retro so if

1838
01:04:47,130 --> 01:04:45,910

you look at varied in the very distant

1839

01:04:48,780 --> 01:04:47,140

universe which is looking back in time

1840

01:04:50,130 --> 01:04:48,790

you can see mostly Universal smaller

1841

01:04:52,050 --> 01:04:50,140

galaxies and then they start clumping

1842

01:05:03,300 --> 01:04:52,060

together and forming more massive

1843

01:05:06,320 --> 01:05:03,310

galaxies as they merge so yeah well yeah

1844

01:05:25,110 --> 01:05:06,330

I mean there's one technical reason so

1845

01:05:26,760 --> 01:05:25,120

I'm yeah yeah right here yeah yeah I

1846

01:05:28,950 --> 01:05:26,770

mean is it Commission's commissioning on

1847

01:05:34,650 --> 01:05:28,960

James Webb last six months so it's a six

1848

01:05:36,090 --> 01:05:34,660

month process steps I mean hundreds and

1849

01:05:38,150 --> 01:05:36,100

hundreds of steps right oh so there's a

1850

01:05:44,190 --> 01:05:38,160

lot of steps different things unfurling

1851

01:05:46,440 --> 01:05:44,200

the folks yeah so it'll commit it'll

1852

01:05:48,420 --> 01:05:46,450

it'll be deploying on its way to the

1853

01:05:49,680 --> 01:05:48,430

Lagrangian right so and then we'll be

1854

01:05:50,730 --> 01:05:49,690

able monitoring it the whole time and

1855

01:05:51,830 --> 01:05:50,740

there's some things you don't want to do

1856

01:05:53,030 --> 01:05:51,840

until you tell

1857

01:05:55,310 --> 01:05:53,040

hope is cooled significantly it's

1858

01:05:57,230 --> 01:05:55,320

cooling off on the way there there's a

1859

01:05:58,460 --> 01:05:57,240

careful orchestration of events there as

1860

01:05:59,750 --> 01:05:58,470

well so you don't have like Isis

1861

01:06:01,310 --> 01:05:59,760

accumulating on the instruments and

1862

01:06:03,020 --> 01:06:01,320

their optics and so forth so it's a very

1863

01:06:04,760 --> 01:06:03,030

careful choreographic series of events

1864

01:06:06,020 --> 01:06:04,770

as it goes out to the crunch - and then

1865

01:06:09,260 --> 01:06:06,030

after the first six months is over we

1866

01:06:29,299 --> 01:06:09,270

start doing science that's the plan all

1867

01:06:33,870 --> 01:06:32,069

yeah so we use it because this that's a

1868

01:06:35,849 --> 01:06:33,880

very good explanation so the James Webb

1869

01:06:37,439 --> 01:06:35,859

Space Telescope works primarily in the

1870

01:06:39,509 --> 01:06:37,449

infrared at wavelengths longer than our

1871

01:06:41,219 --> 01:06:39,519

eyes work and a very good substance to

1872

01:06:44,159 --> 01:06:41,229

work with for reflectivity at those

1873

01:06:46,079 --> 01:06:44,169

wavelengths is gold right it's crazy

1874

01:06:55,039 --> 01:06:46,089

other week we in back sure okay wait

1875

01:06:59,759 --> 01:06:58,019

sure so the lights come on so when the

1876

01:07:01,439 --> 01:06:59,769

very first stars in galaxies form you

1877

01:07:03,479 --> 01:07:01,449

have these massive stars and universe

1878

01:07:05,219 --> 01:07:03,489

gets flooded with ultraviolet light so

1879

01:07:06,689 --> 01:07:05,229

it's very very energetic like x-ray

1880

01:07:08,249 --> 01:07:06,699

light as well even higher energy light

1881

01:07:09,390 --> 01:07:08,259

and what it goes it goes sweeping

1882

01:07:11,880 --> 01:07:09,400

through the universe and all this

1883

01:07:13,499 --> 01:07:11,890

neutral gas gets energized and rely on

1884

01:07:16,019 --> 01:07:13,509

eyes so basically the electrons get

1885

01:07:17,549 --> 01:07:16,029

stripped off the atoms and so that's a

1886

01:07:19,769 --> 01:07:17,559

very energetic process when the universe

1887

01:07:21,630 --> 01:07:19,779

very earlier on is much much hotter than

1888

01:07:22,799 --> 01:07:21,640

it is today today the temperature the

1889

01:07:25,469 --> 01:07:22,809

universe the Cosmic Microwave Background

1890

01:07:27,539 --> 01:07:25,479

is 2.7 Kelvin above you know so it's

1891

01:07:28,890 --> 01:07:27,549

three degrees above absolute zero back

1892

01:07:30,630 --> 01:07:28,900

in the early universe is much much

1893

01:07:31,949 --> 01:07:30,640

hotter and so what happens is this

1894

01:07:33,870 --> 01:07:31,959

energy goes sweeping through the

1895

01:07:34,949 --> 01:07:33,880

universe you have these clumps of dark

1896

01:07:36,239 --> 01:07:34,959

matter which are like little

1897

01:07:37,859 --> 01:07:36,249

gravitational wells

1898

01:07:39,509 --> 01:07:37,869

they have gas sitting there in the dark

1899

01:07:41,849 --> 01:07:39,519

with the dark matter and then this

1900

01:07:43,709 --> 01:07:41,859

energy comes sweeping through and sweeps

1901

01:07:45,870 --> 01:07:43,719

the gas out of those clumps of dark

1902

01:07:47,309 --> 01:07:45,880

matter it doesn't do that for the really

1903

01:07:48,569 --> 01:07:47,319

big clumps of dark matter so the really

1904

01:07:50,549 --> 01:07:48,579

big clumps of dark matter they don't

1905

01:07:52,499 --> 01:07:50,559

lose all their gas and also because they

1906

01:07:54,059 --> 01:07:52,509

have more gravity they react Yuma late

1907

01:07:56,130 --> 01:07:54,069

that ground quick gas and sweep it back

1908

01:07:57,890 --> 01:07:56,140

up but these small clumps of dark matter

1909

01:08:00,509 --> 01:07:57,900

the ones that don't really form stars

1910

01:08:02,849 --> 01:08:00,519

the gas is swept up and never comes back

1911

01:08:03,959 --> 01:08:02,859

and so they don't form stars and it's

1912

01:08:06,839 --> 01:08:03,969

just a clump of dark matter they've been

1913

01:08:09,209 --> 01:08:06,849

stripped of their gas so have it right

1914

01:08:31,390 --> 01:08:09,219

over here to the right you in the red

1915

01:08:37,450 --> 01:08:35,620

I find it yeah maybe you could repeat

1916

01:08:39,190 --> 01:08:37,460

one more time I'm actually not asking

1917

01:08:41,349 --> 01:08:39,200

why do we get the globular structures

1918

01:08:51,970 --> 01:08:41,359

and some some galaxies and the disk

1919

01:08:54,520 --> 01:08:51,980

structures and other galaxies so the

1920

01:08:56,079 --> 01:08:54,530

dark matters is driving the large-scale

1921

01:08:57,190 --> 01:08:56,089

structure of the universe if like I said

1922

01:08:59,170 --> 01:08:57,200

it's kind of like the scaffolding that

1923

01:09:01,090 --> 01:08:59,180

all the gas and matter in the universe

1924

01:09:03,190 --> 01:09:01,100

accretes along it and then much more

1925

01:09:05,349 --> 01:09:03,200

complex things happen on small scales

1926

01:09:07,450 --> 01:09:05,359

like like the Andromeda galaxy or the

1927

01:09:09,010 --> 01:09:07,460

Milky Way basically you have things

1928

01:09:10,780 --> 01:09:09,020

they're spinning and then they start to

1929

01:09:12,430 --> 01:09:10,790

collapse perpendicular to the direction

1930

01:09:14,079 --> 01:09:12,440

of spinning it makes a disc there's

1931

01:09:15,550 --> 01:09:14,089

still a swarm of stars kind of like a

1932

01:09:17,410 --> 01:09:15,560

bee swarm around that that's called the

1933

01:09:19,750 --> 01:09:17,420

halo so it's a very very complex

1934

01:09:21,550 --> 01:09:19,760

hydrodynamic oppresses I mean they don't

1935

01:09:23,380 --> 01:09:21,560

have a simulation new on my computer but

1936

01:09:24,820 --> 01:09:23,390

basically you have a lot of interactions

1937

01:09:26,740 --> 01:09:24,830

between the matter on the small scales

1938

01:09:28,570 --> 01:09:26,750

of a galaxy I'm galaxy is small for our

1939

01:09:30,430 --> 01:09:28,580

purposes here on the large scale of the

1940

01:09:32,230 --> 01:09:30,440

universe you have these filamentary

1941

01:09:34,090 --> 01:09:32,240

structure these filaments of dark matter

1942

01:09:35,530 --> 01:09:34,100

where everything all the matter kind of

1943

01:09:36,820 --> 01:09:35,540

collapses along those filaments and

1944

01:09:39,490 --> 01:09:36,830

we're a couple filaments come together

1945

01:09:40,780 --> 01:09:39,500

you have a galaxy form there so okay

1946

01:09:43,450 --> 01:09:40,790

Tom we've got a question from online

1947

01:09:45,340 --> 01:09:43,460

sure our ancient stars metal-poor

1948

01:09:48,099 --> 01:09:45,350

because there hasn't been a lot of star

1949

01:09:50,140 --> 01:09:48,109

recycling yet yes well ancients start if

1950

01:09:51,730 --> 01:09:50,150

you're if a star is ancient if it was

1951

01:09:54,700 --> 01:09:51,740

born in the early universe it won't have

1952

01:09:56,350 --> 01:09:54,710

many metals period then if stars are

1953

01:09:58,090 --> 01:09:56,360

born more recently they could be born

1954

01:09:59,620 --> 01:09:58,100

from pristine gas if they just happen to

1955

01:10:01,240 --> 01:09:59,630

be in a lucky patch of the universe but

1956

01:10:02,740 --> 01:10:01,250

more often than not because they've been

1957

01:10:04,720 --> 01:10:02,750

multiple generations of stars those

1958

01:10:06,220 --> 01:10:04,730

stars have pulled the oldest the stars

1959

01:10:08,020 --> 01:10:06,230

that have already blown up in supernovae

1960

01:10:09,460 --> 01:10:08,030

they've polluted the gas and then new

1961

01:10:20,800 --> 01:10:09,470

generations of stars are born they have

1962

01:10:24,530 --> 01:10:23,270

yeah I don't have opinion on it cuz I'm

1963

01:10:25,820 --> 01:10:24,540

not a theorist rep but people are still

1964

01:10:27,890 --> 01:10:25,830

arguing about it until we can actually

1965

01:10:29,419 --> 01:10:27,900

you know measure it more directly

1966

01:10:36,649 --> 01:10:29,429

there's not oh there's a lot of theories

1967

01:10:39,800 --> 01:10:36,659

out there right so yeah right here so

1968

01:10:41,689 --> 01:10:39,810

dark matters around 20-25 percent dark

1969

01:10:42,740 --> 01:10:41,699

energies around seventy percent or

1970

01:10:43,910 --> 01:10:42,750

something like that and then there's

1971

01:10:45,979 --> 01:10:43,920

just a few percent is baryonic matter

1972

01:11:01,750 --> 01:10:45,989

like you know we're made out of in what

1973

01:11:05,600 --> 01:11:03,950

because most of the matter in the

1974

01:11:15,350 --> 01:11:05,610

universe is dark so they're the biggest

1975

01:11:17,240 --> 01:11:15,360

source of gravity in the universe so not

1976

01:11:18,830 --> 01:11:17,250

that we know of in fact dark matter

1977

01:11:20,209 --> 01:11:18,840

itself doesn't we don't really even know

1978

01:11:21,830 --> 01:11:20,219

how much it interacts with normal matter

1979

01:11:23,570 --> 01:11:21,840

in fact I mean you have it we see the

1980

01:11:25,370 --> 01:11:23,580

effects of its gravity you can see the

1981

01:11:27,109 --> 01:11:25,380

motions of stars in the Milky Way are

1982

01:11:29,270 --> 01:11:27,119

moving in a way that implies there's a

1983

01:11:30,740 --> 01:11:29,280

lot more mass there than the mass of the

1984

01:11:31,970 --> 01:11:30,750

stars we can see so we know the dark

1985

01:11:34,100 --> 01:11:31,980

matter is there we know it has a

1986

01:11:35,240 --> 01:11:34,110

gravitational effect on things but other

1987

01:11:36,320 --> 01:11:35,250

than that we don't know a lot about it

1988

01:11:37,640 --> 01:11:36,330

we don't know how much it interacts with

1989

01:11:39,919 --> 01:11:37,650

itself how much it interact with other

1990

01:11:41,750 --> 01:11:39,929

matter yeah I figure to think about is

1991

01:11:44,450 --> 01:11:41,760

about eighty-five percent of the mass of

1992

01:11:46,939 --> 01:11:44,460

the gravity in the universe is dark

1993

01:11:59,709 --> 01:11:46,949

matter okay only ten to fifteen percent

1994

01:12:03,100 --> 01:12:01,390

just us it's pretty accessible and

1995

01:12:06,459 --> 01:12:03,110

stable so this is a good place to put it

1996

01:12:08,770 --> 01:12:06,469

out there we put other we oh okay sorry

1997

01:12:11,399 --> 01:12:08,780

yeah so the Lagrangian was chosen she

1998

01:12:14,620 --> 01:12:11,409

the the question was why was the

1999

01:12:16,000 --> 01:12:14,630

Lagrangian for JWST s orbit we actually

2000

01:12:17,890 --> 01:12:16,010

put a lot of satellites out there

2001

01:12:19,660 --> 01:12:17,900

because it's a relatively stable point

2002

01:12:21,250 --> 01:12:19,670

it doesn't take a lot of fuel to keep a

2003

01:12:23,140 --> 01:12:21,260

satellite in orbit around that LaGrant

2004

01:12:24,790 --> 01:12:23,150

and it's fairly accessible compared to

2005

01:12:26,200 --> 01:12:24,800

some Dettol L'Orange points which are on

2006

01:12:41,830 --> 01:12:26,210

the other side of the Sun and so forth

2007

01:12:44,290 --> 01:12:41,840

oh yeah hmm Wow there we go into space

2008

01:12:46,090 --> 01:12:44,300

they don't go swept away and forever I'm

2009

01:12:48,010 --> 01:12:46,100

saying that the gas in a local sense

2010

01:12:49,990 --> 01:12:48,020

becomes so hot that the protons

2011

01:12:51,160 --> 01:12:50,000

electrons separate but it's not like

2012

01:12:52,149 --> 01:12:51,170

they're going to different parts of the

2013

01:12:58,030 --> 01:12:52,159

universe they're all local they're

2014

01:12:59,140 --> 01:12:58,040

together and get oh well okay it's a

2015

01:13:02,680 --> 01:12:59,150

couple different things going on in

2016

01:13:04,300 --> 01:13:02,690

there so the gas gets very energized by

2017

01:13:06,970 --> 01:13:04,310

the Stars coming on so it becomes

2018

01:13:08,620 --> 01:13:06,980

ionized and then also it basically boils

2019

01:13:10,720 --> 01:13:08,630

out of the gravitational wells of these

2020

01:13:12,399 --> 01:13:10,730

Dark Matter clumps so the escape

2021

01:13:14,350 --> 01:13:12,409

velocity basically becomes such that it

2022

01:13:16,479 --> 01:13:14,360

escapes these Dark Matter clumps if the

2023

01:13:17,620 --> 01:13:16,489

Dark Matter clump is large enough the

2024

01:13:19,060 --> 01:13:17,630

gas will fall back into the

2025

01:13:21,340 --> 01:13:19,070

gravitational well and continue forming

2026

01:13:23,169 --> 01:13:21,350

stars which is what most galaxies do but

2027

01:13:24,399 --> 01:13:23,179

if it's not the gas just goes on into

2028

01:13:26,020 --> 01:13:24,409

the intergalactic medium between the

2029

01:13:27,520 --> 01:13:26,030

galaxies so there is a lot of gas out

2030

01:13:28,930 --> 01:13:27,530

there I mean one of the press releases

2031

01:13:31,120 --> 01:13:28,940

Frank talked about people even look for

2032

01:13:32,470 --> 01:13:31,130

galaxies by looking for neutral gas and

2033

01:13:41,220 --> 01:13:32,480

so forth so there's gas between the

2034

01:13:44,859 --> 01:13:43,660

it does it's no longer in those dark

2035

01:13:59,350 --> 01:13:44,869

matter clumps it gets swept out in

2036

01:14:01,209 --> 01:13:59,360

between the clumps yeah yeah I have no

2037

01:14:03,160 --> 01:14:01,219

idea off the top of my head I mean some

2038

01:14:04,750 --> 01:14:03,170

of these things some of these things you

2039

01:14:05,680 --> 01:14:04,760

know there's an economy of scale that

2040

01:14:06,970 --> 01:14:05,690

you know that people are trying to

2041

01:14:08,379 --> 01:14:06,980

leverage when they look at these future

2042

01:14:09,729 --> 01:14:08,389

missions but it would be very expensive

2043

01:14:11,589 --> 01:14:09,739

I'm not saying it would be

2044

01:14:12,970 --> 01:14:11,599

technologically trivial either we would

2045

01:14:14,080 --> 01:14:12,980

have to work very hard on it as well

2046

01:14:16,300 --> 01:14:14,090

it's not it's not like it would be a

2047

01:14:18,220 --> 01:14:16,310

piece of cake but uh but it's within the

2048

01:14:20,050 --> 01:14:18,230

grasp of today's technology you know if

2049

01:14:22,770 --> 01:14:20,060

if the money was there but it would be a

2050

01:14:26,589 --> 01:14:22,780

lot more expensive than James Webb Rahal

2051

01:14:30,250 --> 01:14:26,599

8 billion okay another question from

2052

01:14:32,560 --> 01:14:30,260

online would a 16 meter mirror telescope

2053

01:14:34,780 --> 01:14:32,570

be able to directly image low mass

2054

01:14:36,430 --> 01:14:34,790

worlds such as Earth or Mars

2055

01:14:37,870 --> 01:14:36,440

yeah that's the goal I mean depends on

2056

01:14:40,330 --> 01:14:37,880

how well separated they are from their

2057

01:14:43,120 --> 01:14:40,340

host star but if they were separated

2058

01:14:45,129 --> 01:14:43,130

enough then does that be the goal to see

2059

01:14:53,140 --> 01:14:45,139

you know habitable worlds with such a

2060

01:14:54,609 --> 01:14:53,150

telescope to directly image them yeah as

2061

01:14:55,839 --> 01:14:54,619

far as we know we don't think I mean

2062

01:14:57,280 --> 01:14:55,849

darknet we again we don't know how much

2063

01:14:58,870 --> 01:14:57,290

dark matter interacts with normal matter

2064

01:15:00,040 --> 01:14:58,880

and energy and so forth so it has a

2065

01:15:01,750 --> 01:15:00,050

gravitational effect other than that I

2066

01:15:03,160 --> 01:15:01,760

don't know a lot about dark matter you

2067

01:15:05,080 --> 01:15:03,170

know there's a lot of theories about it

2068

01:15:06,070 --> 01:15:05,090

but no mostly the realization when you

2069

01:15:08,770 --> 01:15:06,080

talk about randomization you talk about

2070

01:15:16,479 --> 01:15:08,780

the baryonic matter this gentleman over

2071

01:15:20,180 --> 01:15:18,589

so the question is how do black holes

2072

01:15:21,770 --> 01:15:20,190

interact with dark matter black holes

2073

01:15:23,629 --> 01:15:21,780

are a form of dark matter we don't think

2074

01:15:25,250 --> 01:15:23,639

they make up a large part of the budget

2075

01:15:26,899 --> 01:15:25,260

of dark matter but they interact

2076

01:15:29,720 --> 01:15:26,909

gravitationally with dark matter as well

2077

01:15:31,129 --> 01:15:29,730

so you know dark matter can interact

2078

01:15:32,479 --> 01:15:31,139

with a black hole gravitationally other

2079

01:15:34,879 --> 01:15:32,489

than that we don't know how dark matter

2080

01:15:36,200 --> 01:15:34,889

interacts with ordinary matter yeah we

2081

01:15:38,089 --> 01:15:36,210

actually had a discussion about dark

2082

01:15:39,620 --> 01:15:38,099

matter online during your talk okay

2083

01:15:41,540 --> 01:15:39,630

people wanting to know well what is dark

2084

01:15:53,200 --> 01:15:41,550

matter I said it if I knew that I'd be

2085

01:15:53,210 --> 01:16:04,680

yep

2086

01:16:09,669 --> 01:16:07,060

well I mean I could use another analogy

2087

01:16:11,260 --> 01:16:09,679

but to me the dark matter is traced

2088

01:16:13,750 --> 01:16:11,270

throughout the universe in these

2089

01:16:16,270 --> 01:16:13,760

filaments and then the thin layer of gas

2090

01:16:17,379 --> 01:16:16,280

and the leftover matter that the kind of

2091

01:16:19,240 --> 01:16:17,389

matter of mater kind of falls

2092

01:16:20,770 --> 01:16:19,250

gravitationally on top of that and where

2093

01:16:23,169 --> 01:16:20,780

it collapses together due to gravity it

2094

01:16:24,549 --> 01:16:23,179

starts forming stars so to me it's the

2095

01:16:25,720 --> 01:16:24,559

structure upon which everything else is

2096

01:16:27,100 --> 01:16:25,730

built when you see the large scale

2097

01:16:29,020 --> 01:16:27,110

structure in the universe it's defined

2098

01:16:30,459 --> 01:16:29,030

by dark matter the same way that the

2099

01:16:32,140 --> 01:16:30,469

scaffolding of a building defines the

2100

01:17:00,040 --> 01:16:32,150

structure of a building but I mean there

2101
01:17:01,709 --> 01:17:00,050
might be better analogies try and

2102
01:17:04,330 --> 01:17:01,719
summarize that question for the yeah so

2103
01:17:05,950 --> 01:17:04,340
for the online folks how confident we

2104
01:17:08,709 --> 01:17:05,960
are in the algorithms that allow us to

2105
01:17:10,299 --> 01:17:08,719
reduce the data basically so pretty

2106
01:17:11,740 --> 01:17:10,309
confident because we came at this a

2107
01:17:14,109 --> 01:17:11,750
couple different ways as I showed in the

2108
01:17:16,419 --> 01:17:14,119
talk we have comparison populations that

2109
01:17:18,040 --> 01:17:16,429
are very very well studied so we use

2110
01:17:19,510 --> 01:17:18,050
this camera there's a very very sense of

2111
01:17:21,399 --> 01:17:19,520
camera Hubble we measure the brightness

2112
01:17:23,649 --> 01:17:21,409
is in the colors of the stars and then

2113
01:17:25,060 --> 01:17:23,659

we use the same exact camryn filters to

2114

01:17:26,470 --> 01:17:25,070

measure a well-studied object and that's

2115

01:17:28,689 --> 01:17:26,480

our controls in this case I showed them

2116

01:17:30,640 --> 01:17:28,699

92 we've actually used it for loads of

2117

01:17:32,620 --> 01:17:30,650

Studies on Hubble but I'm going to do is

2118

01:17:34,209 --> 01:17:32,630

the best comparison here so you can do

2119

01:17:35,470 --> 01:17:34,219

an apples-to-apples comparison where a

2120

01:17:36,490 --> 01:17:35,480

lot of the systematics you might be

2121

01:17:37,660 --> 01:17:36,500

worried about just dropped by the

2122

01:17:39,609 --> 01:17:37,670

wayside because you're doing the same

2123

01:17:41,530 --> 01:17:39,619

exact thing with both our 92 and these

2124

01:17:42,729 --> 01:17:41,540

galaxies and then we also come at it

2125

01:17:45,189 --> 01:17:42,739

from a different angle we take the

2126
01:17:46,959 --> 01:17:45,199
theory of how stars evolved that pattern

2127
01:17:49,270 --> 01:17:46,969
they trace out in the diagram and we

2128
01:17:50,680 --> 01:17:49,280
calibrate those theoretical models to

2129
01:17:51,790 --> 01:17:50,690
the data that we've taken with this

2130
01:17:53,109 --> 01:17:51,800
camera over and over and over again so

2131
01:17:54,160 --> 01:17:53,119
that's another way of doing it so now

2132
01:17:55,810 --> 01:17:54,170
we're pretty confident and then

2133
01:17:58,030 --> 01:17:55,820
measuring the stars the signal noise for

2134
01:17:59,410 --> 01:17:58,040
to get this accuracy in the ages we got

2135
01:18:01,180 --> 01:17:59,420
two solenoids of 100 since you mentioned

2136
01:18:02,919 --> 01:18:01,190
signal noise so the signal noise ratio

2137
01:18:04,930 --> 01:18:02,929
is 100 so it's very very you know what

2138
01:18:07,109 --> 01:18:04,940

percent photometry and let me just say

2139

01:18:10,000 --> 01:18:07,119

the folks in this building are brilliant

2140

01:18:12,760 --> 01:18:10,010

I'm not an observer ok you guys are

2141

01:18:14,330 --> 01:18:12,770

absolutely brilliant at characterizing

2142

01:18:16,330 --> 01:18:14,340

all of the artifacts

2143

01:18:19,850 --> 01:18:16,340

could be possible in Hubble images okay

2144

01:18:21,440 --> 01:18:19,860

they have I mean they've had 25 years to

2145

01:18:23,630 --> 01:18:21,450

work at this and really understand all

2146

01:18:25,640 --> 01:18:23,640

the stuff and they do amazing stuff at

2147

01:18:28,070 --> 01:18:25,650

being able to really pull out what

2148

01:18:29,870 --> 01:18:28,080

signal and what's noise out of these out

2149

01:18:31,280 --> 01:18:29,880

of the datasets and a lot of the sources

2150

01:18:32,810 --> 01:18:31,290

of systematic error like for example

2151

01:18:35,330 --> 01:18:32,820

this object right here that I'm moving

2152

01:18:40,430 --> 01:18:35,340

to well I probably blew past it just now

2153

01:18:42,020 --> 01:18:40,440

but uh m92 m92 is a very crowded star

2154

01:18:44,540 --> 01:18:42,030

field so it gets a little noisier in the

2155

01:18:46,940 --> 01:18:44,550

data well I'll show you this these are

2156

01:18:48,800 --> 01:18:46,950

very this is a very sparse star field so

2157

01:18:51,590 --> 01:18:48,810

it's pretty easy to measure the here me

2158

01:18:54,020 --> 01:18:51,600

show you again here that's a very sparse

2159

01:18:55,460 --> 01:18:54,030

image and if i zoom in on it here it's

2160

01:18:56,750 --> 01:18:55,470

pretty easy to measure the brightness of

2161

01:18:58,250 --> 01:18:56,760

this star the brightness of this star

2162

01:18:59,540 --> 01:18:58,260

and so forth because they're not

2163

01:19:00,980 --> 01:18:59,550

stepping on top of each other you know

2164

01:19:03,110 --> 01:19:00,990

it's just a nice way so well isolated

2165

01:19:04,430 --> 01:19:03,120

star so really this is we tried to make

2166

01:19:05,960 --> 01:19:04,440

this measurement a turkey shoot we did

2167

01:19:08,210 --> 01:19:05,970

very long exposures left the shutter

2168

01:19:09,440 --> 01:19:08,220

open for 16 orbits really get accurate

2169

01:19:10,790 --> 01:19:09,450

measurements of each of these stars and

2170

01:19:13,010 --> 01:19:10,800

there they're not crowding on top of

2171

01:19:14,450 --> 01:19:13,020

each other or anything so I'm like m92

2172

01:19:23,450 --> 01:19:14,460

it's a little harder because the stars

2173

01:19:25,070 --> 01:19:23,460

are crowding yeah gravity itself so self

2174

01:19:26,770 --> 01:19:25,080

gravity it's just it has a gravitational

2175

01:19:36,200 --> 01:19:26,780

influence on the rest of the dark matter

2176

01:19:40,850 --> 01:19:36,210

so it just collapses on itself Albert

2177

01:19:52,100 --> 01:19:40,860

Einstein to care all right any last

2178

01:19:54,050 --> 01:19:52,110

questions back corner up there I mean it

2179

01:19:56,090 --> 01:19:54,060

could happen if Elon Musk wants to you

2180

01:19:57,860 --> 01:19:56,100

know say must wants to say hey I want

2181

01:19:59,240 --> 01:19:57,870

you to launch a satellite on the SpaceX

2182

01:20:01,670 --> 01:19:59,250

for you guys or whatever you know it's

2183

01:20:02,660 --> 01:20:01,680

possible right now the discussions that

2184

01:20:04,160 --> 01:20:02,670

you know people are talking about

2185

01:20:05,270 --> 01:20:04,170

they're all talking about NASA launches

2186

01:20:06,470 --> 01:20:05,280

but you know it could happen in

2187

01:20:12,980 --> 01:20:06,480

partnership with private industry who

2188

01:20:14,000 --> 01:20:12,990

knows it's possible yeah so what which

2189

01:20:15,860 --> 01:20:14,010

many like to see the two newest

2190

01:20:21,470 --> 01:20:15,870

degeneracy videos or the deployment

2191

01:20:23,120 --> 01:20:21,480

video sure yeah there's a better one

2192

01:20:25,010 --> 01:20:23,130

available on the web now since I put

2193

01:20:26,900 --> 01:20:25,020

that one in the slide that is a little

2194

01:20:28,880 --> 01:20:26,910

more exciting this one is almost like

2195

01:20:30,050 --> 01:20:28,890

you know scale equals one time it almost

2196

01:20:34,820 --> 01:20:30,060

happens you have to it almost takes like

2197

01:20:36,260 --> 01:20:34,830

six months to watch it but uh we both is

2198

01:20:37,820 --> 01:20:36,270

this is why I don't put transitions in

2199

01:20:43,880 --> 01:20:37,830

my slides most of the time because I

2200

01:20:46,300 --> 01:20:43,890

hate waiting for those okay well well

2201
01:20:50,600 --> 01:20:46,310
while you play the video one more time

2202
01:20:52,550 --> 01:20:50,610
here's a question from online is it

2203
01:20:54,500 --> 01:20:52,560
possible that there could be planets

2204
01:20:56,270 --> 01:20:54,510
orbiting the stars in these small

2205
01:20:58,340 --> 01:20:56,280
galaxies these galaxies were formed

2206
01:21:01,400 --> 01:20:58,350
thirteen billion years ago they're low

2207
01:21:03,370 --> 01:21:01,410
metallicity the problem are you are we

2208
01:21:05,360 --> 01:21:03,380
going to find planets around them so

2209
01:21:08,150 --> 01:21:05,370
astronomers when they look for planets

2210
01:21:09,530 --> 01:21:08,160
around stars they you know planets are

2211
01:21:10,850 --> 01:21:09,540
very abundant and we're finding out that

2212
01:21:12,830 --> 01:21:10,860
they're that we find them around stars

2213
01:21:15,650 --> 01:21:12,840

all over the place on nearby stars but

2214

01:21:17,840 --> 01:21:15,660

the as Frank was just saying these stars

2215

01:21:19,760 --> 01:21:17,850

were born in clouds of gas that were

2216

01:21:22,160 --> 01:21:19,770

very pristine not a lot of material for

2217

01:21:23,510 --> 01:21:22,170

building planets so there's not a lot of

2218

01:21:25,520 --> 01:21:23,520

likelihood here that there would be

2219

01:21:27,590 --> 01:21:25,530

planets around the stars in these ultra

2220

01:21:29,920 --> 01:21:27,600

faint dwarf galaxies the analogy I can

2221

01:21:32,240 --> 01:21:29,930

make is that Hubble did a very very

2222

01:21:33,800 --> 01:21:32,250

thorough search for planets in a

2223

01:21:36,620 --> 01:21:33,810

globular cluster I guess it was around

2224

01:21:38,060 --> 01:21:36,630

15 years ago now 47 talk which is not

2225

01:21:39,950 --> 01:21:38,070

even as metal-poor as these ultra faint

2226

01:21:41,600 --> 01:21:39,960

dwarf galaxies it's a little bit it's a

2227

01:21:43,520 --> 01:21:41,610

little more metallicity than 10% solar

2228

01:21:45,290 --> 01:21:43,530

so it's not like 1% or a thousandth of

2229

01:21:47,230 --> 01:21:45,300

solar like these and they didn't find

2230

01:21:48,670 --> 01:21:47,240

any planets around

2231

01:21:50,200 --> 01:21:48,680

so really if you want to look for

2232

01:21:51,850 --> 01:21:50,210

planets you look for stars that are

2233

01:21:53,350 --> 01:21:51,860

closer and metallicity to the Sun

2234

01:21:55,150 --> 01:21:53,360

because those are more likely to be born

2235

01:21:56,440 --> 01:21:55,160

from material with a lot of enriched gas

2236

01:21:58,330 --> 01:21:56,450

and so forth around where you have the

2237

01:21:59,680 --> 01:21:58,340

building blocks of planets as well so

2238

01:22:01,240 --> 01:21:59,690

there's probably not a lot of planets in

2239

01:22:04,000 --> 01:22:01,250

these galaxies and these ultra faint

2240

01:22:05,740 --> 01:22:04,010

door galaxies okay well thank you all

2241

01:22:08,380 --> 01:22:05,750

for coming tonight if you have any last

2242

01:22:11,320 --> 01:22:08,390

questions come up and see if we can chat

2243

01:22:14,040 --> 01:22:11,330

next month um bill Blair will be talking

2244

01:22:16,480 --> 01:22:14,050

about Stella populations in Messier III

2245

01:22:18,190 --> 01:22:16,490

remember that next month you must

2246

01:22:21,310 --> 01:22:18,200

approach from the south not from the

2247

01:22:28,130 --> 01:22:21,320

north and let us give Tom another warm

2248

01:22:45,560 --> 01:22:43,220

I went when I got out of graduate school