

PUBLIC LECTURE SERIES

# The Milky Way vs. Andromeda: When Galaxies Collide

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Featuring Guest Speaker:  
Laura Prichard

1  
00:00:00,000 --> 00:00:03,830  
when galaxies collide

2  
00:00:06,909 --> 00:00:05,510  
i'm dr frank summers of the space

3  
00:00:09,990 --> 00:00:06,919  
telescope science

4  
00:00:12,470 --> 00:00:10,000  
institute and i would like to thank my

5  
00:00:13,430 --> 00:00:12,480  
wonderful tech team thomas marufu and

6  
00:00:16,710 --> 00:00:13,440  
grant justice

7  
00:00:17,750 --> 00:00:16,720  
who are taking this meeting and sending

8  
00:00:20,710 --> 00:00:17,760  
it out

9  
00:00:22,150 --> 00:00:20,720  
over youtube for you to watch i note

10  
00:00:25,910 --> 00:00:22,160  
that we will be online

11  
00:00:29,349 --> 00:00:25,920  
only until further notice

12  
00:00:31,109 --> 00:00:29,359  
our upcoming talks include in march

13  
00:00:33,190 --> 00:00:31,119

the hubble space telescope from

14

00:00:34,150 --> 00:00:33,200

cosmological conflict to alien

15

00:00:36,470 --> 00:00:34,160

atmospheres

16

00:00:38,229 --> 00:00:36,480

this is tom brown the head of the hubble

17

00:00:40,549 --> 00:00:38,239

program here at sdsci

18

00:00:41,910 --> 00:00:40,559

and he's going to give you a wonderful

19

00:00:43,910 --> 00:00:41,920

wonderful overview

20

00:00:45,029 --> 00:00:43,920

of what hubble has done over the last 30

21

00:00:48,150 --> 00:00:45,039

years

22

00:00:49,990 --> 00:00:48,160

on april 6th uh christopher wanzak an

23

00:00:51,990 --> 00:00:50,000

author will be here to talk about one of

24

00:00:55,590 --> 00:00:52,000

his books space fares

25

00:00:58,790 --> 00:00:55,600

how humans will settle the moon mars

26

00:01:01,590 --> 00:00:58,800

and beyond in may we have

27

00:01:03,189 --> 00:01:01,600

a really special treat for you we have

28

00:01:05,670 --> 00:01:03,199

the consonant collective

29

00:01:07,350 --> 00:01:05,680

and the bergamot quartet of the peabody

30

00:01:09,990 --> 00:01:07,360

institute here in baltimore

31

00:01:11,350 --> 00:01:10,000

this is one of the premier music

32

00:01:13,510 --> 00:01:11,360

conservatories

33

00:01:15,109 --> 00:01:13,520

and they will be presenting finding the

34

00:01:17,270 --> 00:01:15,119

music of the spheres

35

00:01:18,630 --> 00:01:17,280

hearing stars it will not be just

36

00:01:21,429 --> 00:01:18,640

lecture it will

37

00:01:23,270 --> 00:01:21,439

also be a musical performance you're not

38

00:01:25,910 --> 00:01:23,280

going to want to miss that one

39

00:01:26,789 --> 00:01:25,920

and if you want to find out keep up with

40

00:01:31,670 --> 00:01:26,799

all these things

41

00:01:34,710 --> 00:01:31,680

you go to [www.stsci.edu](http://www.stsci.edu)

42

00:01:35,830 --> 00:01:34,720

public hyphen lectures you'll find this

43

00:01:38,390 --> 00:01:35,840

webpage

44

00:01:39,990 --> 00:01:38,400

and on the left you can see you'll find

45

00:01:43,190 --> 00:01:40,000

links to our webcast

46

00:01:44,230 --> 00:01:43,200

both on youtube and on the stsci webcast

47

00:01:46,310 --> 00:01:44,240

archive

48

00:01:47,510 --> 00:01:46,320

as well as you can sign up for the

49

00:01:49,109 --> 00:01:47,520

lectures announcements

50

00:01:51,510 --> 00:01:49,119

by entering your email address and

51  
00:01:53,510 --> 00:01:51,520  
hitting the subscribe button

52  
00:01:55,429 --> 00:01:53,520  
of course you can find out information

53  
00:01:57,030 --> 00:01:55,439  
about the upcoming lectures

54  
00:01:59,030 --> 00:01:57,040  
and if you click on one of those

55  
00:01:59,830 --> 00:01:59,040  
lectures you will get the complete

56  
00:02:02,630 --> 00:01:59,840  
details

57  
00:02:04,310 --> 00:02:02,640  
including the abstract of the talk and

58  
00:02:07,429 --> 00:02:04,320  
after it has been presented

59  
00:02:07,990 --> 00:02:07,439  
links to the sdsci webcast as well as

60  
00:02:11,270 --> 00:02:08,000  
the

61  
00:02:14,869 --> 00:02:13,030  
if you'd like to sign up for our email i

62  
00:02:16,790 --> 00:02:14,879  
showed you how to sign up at the website

63  
00:02:17,910 --> 00:02:16,800

but you also might you know instead of

64

00:02:20,830 --> 00:02:17,920

using the email

65

00:02:22,070 --> 00:02:20,840

subscribe to our youtube channel

66

00:02:25,110 --> 00:02:22,080

youtube.com

67

00:02:25,990 --> 00:02:25,120

all one word hubble space telescope this

68

00:02:28,070 --> 00:02:26,000

is where we post

69

00:02:29,990 --> 00:02:28,080

all of our videos as well as our live

70

00:02:32,390 --> 00:02:30,000

events and if you subscribe

71

00:02:34,229 --> 00:02:32,400

you will get notices of those new videos

72

00:02:35,589 --> 00:02:34,239

as well as reminders of these live

73

00:02:37,270 --> 00:02:35,599

events

74

00:02:39,110 --> 00:02:37,280

finally if you have comments or

75

00:02:40,910 --> 00:02:39,120

questions you can send them to

76

00:02:43,910 --> 00:02:40,920

publiclecture

77

00:02:46,150 --> 00:02:43,920

stsci.edu

78

00:02:47,910 --> 00:02:46,160

we also have social media channels for

79

00:02:50,470 --> 00:02:47,920

both the hubble space telescope

80

00:02:52,470 --> 00:02:50,480

the james webb space telescope and for

81

00:02:55,670 --> 00:02:52,480

the space telescope science institute

82

00:02:58,710 --> 00:02:55,680

on facebook twitter youtube and

83

00:02:59,750 --> 00:02:58,720

instagram i myself do a tiny bit of

84

00:03:02,830 --> 00:02:59,760

social media

85

00:03:06,149 --> 00:03:02,840

on facebook and twitter as dr frank

86

00:03:09,270 --> 00:03:08,309

and now the news from the universe for

87

00:03:13,350 --> 00:03:09,280

february

88

00:03:18,070 --> 00:03:15,990

the first story tonight it was a dark

89

00:03:21,350 --> 00:03:18,080

and stormy night

90

00:03:22,149 --> 00:03:21,360

on neptune now for those of my

91

00:03:24,070 --> 00:03:22,159

generation

92

00:03:26,630 --> 00:03:24,080

the phrase it was a dark and stormy

93

00:03:28,630 --> 00:03:26,640

night is not associated with a novel at

94

00:03:31,110 --> 00:03:28,640

which it was the very first line

95

00:03:32,229 --> 00:03:31,120

but it's really associated with snoopy

96

00:03:34,869 --> 00:03:32,239

and peanuts

97

00:03:36,470 --> 00:03:34,879

because this is what snoopy uses as his

98

00:03:38,390 --> 00:03:36,480

first line of his novel

99

00:03:40,229 --> 00:03:38,400

that he's writing and that's the only

100

00:03:42,550 --> 00:03:40,239

way anybody in my generation

101  
00:03:44,229 --> 00:03:42,560  
actually knew of it i'm told there was a

102  
00:03:45,750 --> 00:03:44,239  
book that actually included this as the

103  
00:03:48,789 --> 00:03:45,760  
first line

104  
00:03:52,070 --> 00:03:48,799  
and in terms of storms we can get some

105  
00:03:55,429 --> 00:03:52,080  
really stormy nights here on earth this

106  
00:03:58,149 --> 00:03:55,439  
is hurricane isabel and hurricane isabel

107  
00:03:58,710 --> 00:03:58,159  
came through baltimore about 15 years

108  
00:04:02,229 --> 00:03:58,720  
ago

109  
00:04:04,869 --> 00:04:02,239  
and it was quite the stormy night there

110  
00:04:05,350 --> 00:04:04,879  
but if you follow astronomy you know

111  
00:04:08,789 --> 00:04:05,360  
that

112  
00:04:11,750 --> 00:04:08,799  
stormy

113  
00:04:12,550 --> 00:04:11,760

because you want big storms you go to

114

00:04:19,430 --> 00:04:12,560

jupiter

115

00:04:23,189 --> 00:04:19,440

big oval up here that's a storm

116

00:04:25,749 --> 00:04:23,199

that's as large as our entire planet

117

00:04:26,390 --> 00:04:25,759

and so you have this big orange storm

118

00:04:28,390 --> 00:04:26,400

here

119

00:04:29,510 --> 00:04:28,400

and they've actually had observations of

120

00:04:31,909 --> 00:04:29,520

the great red spot

121

00:04:33,590 --> 00:04:31,919

for a couple hundred years so it's not

122

00:04:36,469 --> 00:04:33,600

just a dark and stormy night

123

00:04:37,590 --> 00:04:36,479

it's a dark and stormy centuries on

124

00:04:39,270 --> 00:04:37,600

jupiter

125

00:04:41,590 --> 00:04:39,280

and you can see that these also these

126

00:04:42,150 --> 00:04:41,600

white ovals are also storms in jupiter

127

00:04:44,790 --> 00:04:42,160

you get

128

00:04:45,670 --> 00:04:44,800

red orange ones and red ones and white

129

00:04:49,830 --> 00:04:45,680

ones

130

00:04:53,590 --> 00:04:49,840

but neptune neptune actually has storms

131

00:04:56,950 --> 00:04:53,600

that are dark yes this is what's called

132

00:05:00,950 --> 00:04:56,960

the great dark spot on neptune

133

00:05:04,070 --> 00:05:00,960

right it was observed by voyager in 1989

134

00:05:06,710 --> 00:05:04,080

when the only um the only space mission

135

00:05:08,790 --> 00:05:06,720

that has flown past the planet neptune

136

00:05:09,990 --> 00:05:08,800

and so we saw that there is a

137

00:05:13,430 --> 00:05:10,000

possibility of having these

138

00:05:16,230 --> 00:05:13,440

giant dark storms on neptune

139

00:05:17,749 --> 00:05:16,240

unfortunately it's not as long lived as

140

00:05:21,110 --> 00:05:17,759

the great red spot

141

00:05:23,590 --> 00:05:21,120

because when hubble looked in 1994

142

00:05:26,070 --> 00:05:23,600

and this is images of both hemispheres

143

00:05:29,189 --> 00:05:26,080

of neptune in 1994 from hubble

144

00:05:32,710 --> 00:05:29,199

the great dark spot was gone so

145

00:05:35,909 --> 00:05:32,720

these dark storms on neptune form

146

00:05:37,830 --> 00:05:35,919

and obviously disappear hubble is the

147

00:05:38,870 --> 00:05:37,840

only telescope that has the keen

148

00:05:41,790 --> 00:05:38,880

resolution

149

00:05:43,909 --> 00:05:41,800

to be able to follow these storms and in

150

00:05:47,110 --> 00:05:43,919

2016 for example

151  
00:05:48,950 --> 00:05:47,120  
we saw this dark storm on neptune in its

152  
00:05:51,189 --> 00:05:48,960  
southern hemisphere

153  
00:05:52,390 --> 00:05:51,199  
and the idea is from computer

154  
00:05:53,990 --> 00:05:52,400  
simulations

155  
00:05:55,830 --> 00:05:54,000  
that these storms will form at

156  
00:05:59,189 --> 00:05:55,840  
mid-latitudes and

157  
00:06:00,950 --> 00:05:59,199  
as they migrate toward the equator

158  
00:06:02,150 --> 00:06:00,960  
they will dissipate because they're sort

159  
00:06:03,430 --> 00:06:02,160  
of supported by something called the

160  
00:06:04,870 --> 00:06:03,440  
coriolis force

161  
00:06:06,870 --> 00:06:04,880  
you don't really need to understand that

162  
00:06:08,390 --> 00:06:06,880  
just know that the coriolis force goes

163  
00:06:11,830 --> 00:06:08,400

away as you get

164

00:06:14,550 --> 00:06:11,840

to the equator so that they might

165

00:06:14,870 --> 00:06:14,560

dissipate as they get to the equator

166

00:06:17,590 --> 00:06:14,880

well

167

00:06:18,950 --> 00:06:17,600

hubble has covered four dark storms

168

00:06:21,110 --> 00:06:18,960

since it's been watching

169

00:06:23,830 --> 00:06:21,120

and the most recent one here it is

170

00:06:26,629 --> 00:06:23,840

observed in january 2020

171

00:06:27,749 --> 00:06:26,639

and you can see the large uh dark spot

172

00:06:29,909 --> 00:06:27,759

here

173

00:06:31,510 --> 00:06:29,919

and on the right hand side you can see a

174

00:06:34,309 --> 00:06:31,520

smaller dark spot

175

00:06:36,309 --> 00:06:34,319

now the large the large dark storm was

176

00:06:38,070 --> 00:06:36,319

discovered in 2018

177

00:06:39,749 --> 00:06:38,080

and they followed it as it started to

178

00:06:43,590 --> 00:06:39,759

move towards the equator

179

00:06:45,990 --> 00:06:43,600

and presumably would then dissipate away

180

00:06:46,950 --> 00:06:46,000

but in january 2020 when they looked

181

00:06:50,230 --> 00:06:46,960

they found

182

00:06:52,790 --> 00:06:50,240

not only was there a second dark spot

183

00:06:53,749 --> 00:06:52,800

but also that the storm had reverse

184

00:06:55,350 --> 00:06:53,759

direction

185

00:06:57,830 --> 00:06:55,360

and was now heading away from the

186

00:06:59,270 --> 00:06:57,840

equator this is something that they had

187

00:07:02,309 --> 00:06:59,280

never seen

188

00:07:03,990 --> 00:07:02,319

so the question is well first of all why

189

00:07:06,230 --> 00:07:04,000

did it reverse direction

190

00:07:08,629 --> 00:07:06,240

and second of all is this second dark

191

00:07:10,390 --> 00:07:08,639

storm related to the first

192

00:07:12,710 --> 00:07:10,400

i will tell you that we don't know the

193

00:07:14,710 --> 00:07:12,720

answer but there is an intriguing

194

00:07:16,950 --> 00:07:14,720

hypothesis

195

00:07:18,629 --> 00:07:16,960

computer simulations show that these

196

00:07:20,870 --> 00:07:18,639

dark storms should actually

197

00:07:22,710 --> 00:07:20,880

break up every now and then and split

198

00:07:26,070 --> 00:07:22,720

into multiple storms

199

00:07:26,710 --> 00:07:26,080

so this could be evidence that this

200

00:07:30,230 --> 00:07:26,720

storm was

201  
00:07:30,950 --> 00:07:30,240  
migrating towards the equator started to

202  
00:07:33,749 --> 00:07:30,960  
break up

203  
00:07:35,909 --> 00:07:33,759  
spawned off that smaller storm and

204  
00:07:38,710 --> 00:07:35,919  
started to reverse direction

205  
00:07:39,830 --> 00:07:38,720  
we can't prove that hypothesis but they

206  
00:07:42,790 --> 00:07:39,840  
will be studying it

207  
00:07:44,710 --> 00:07:42,800  
continuously right as i said hubble is

208  
00:07:45,909 --> 00:07:44,720  
the only telescope that can resolve

209  
00:07:49,510 --> 00:07:45,919  
these storms and

210  
00:07:50,309 --> 00:07:49,520  
follow them so over the 30 years hubble

211  
00:07:52,550 --> 00:07:50,319  
has seen

212  
00:07:54,309 --> 00:07:52,560  
four dark storms so we really don't have

213  
00:07:55,510 --> 00:07:54,319

a tremendous amount of information to

214

00:07:57,990 --> 00:07:55,520

work on

215

00:07:59,589 --> 00:07:58,000

but every time we see one and every new

216

00:08:02,230 --> 00:07:59,599

data point we get

217

00:08:03,670 --> 00:08:02,240

tells us more and more about uncovering

218

00:08:08,150 --> 00:08:03,680

those dark storms

219

00:08:16,309 --> 00:08:12,469

our second story it's an episode of csi

220

00:08:16,869 --> 00:08:16,319

smc now when i talk about csi i'm

221

00:08:18,869 --> 00:08:16,879

talking about

222

00:08:20,950 --> 00:08:18,879

crime scene investigation this is a

223

00:08:22,390 --> 00:08:20,960

series of television shows i've actually

224

00:08:23,350 --> 00:08:22,400

been several television shows they take

225

00:08:27,670 --> 00:08:23,360

place in

226

00:08:31,909 --> 00:08:27,680

las vegas and miami and in new york

227

00:08:34,469 --> 00:08:31,919

well this episode of csi takes place in

228

00:08:36,870 --> 00:08:34,479

the small magellanic cloud which we

229

00:08:40,149 --> 00:08:36,880

often refer to as the smc

230

00:08:42,070 --> 00:08:40,159

right it is a dwarf galaxy it's a

231

00:08:43,750 --> 00:08:42,080

satellite galaxy of the milky way the

232

00:08:44,949 --> 00:08:43,760

small magellanic cloud and the large

233

00:08:48,230 --> 00:08:44,959

magellanic cloud

234

00:08:51,110 --> 00:08:48,240

that orbits around our milky way galaxy

235

00:08:52,230 --> 00:08:51,120

and the crime scene here is located in

236

00:08:55,829 --> 00:08:52,240

the outskirts

237

00:08:56,710 --> 00:08:55,839

of the snc all right our crime scene is

238

00:09:04,790 --> 00:08:56,720

called

239

00:09:06,790 --> 00:09:04,800

supernova remnant 1e0102.2 hyphen 7219

240

00:09:07,990 --> 00:09:06,800

which is quite the mouthful so we're

241

00:09:10,790 --> 00:09:08,000

just going to call it

242

00:09:11,990 --> 00:09:10,800

supernova remnant e0102 that's what

243

00:09:15,350 --> 00:09:12,000

astronomers call it

244

00:09:16,310 --> 00:09:15,360

for sure all right and x-rays at the

245

00:09:18,790 --> 00:09:16,320

crime scene

246

00:09:20,150 --> 00:09:18,800

revealed that it is the explosive death

247

00:09:23,590 --> 00:09:20,160

of a star

248

00:09:25,590 --> 00:09:23,600

a supernova remnant and the remains of

249

00:09:28,870 --> 00:09:25,600

the star were splattered across

250

00:09:30,550 --> 00:09:28,880

interstellar space so was it stellar

251  
00:09:33,910 --> 00:09:30,560  
suicide

252  
00:09:35,590 --> 00:09:33,920  
or was it murder

253  
00:09:37,590 --> 00:09:35,600  
all right all right it wasn't murder

254  
00:09:40,470 --> 00:09:37,600  
okay it was suicide okay

255  
00:09:41,590 --> 00:09:40,480  
supernova explosions are when a star

256  
00:09:43,750 --> 00:09:41,600  
blows itself

257  
00:09:45,670 --> 00:09:43,760  
apart so we actually understand the

258  
00:09:47,350 --> 00:09:45,680  
process of a supernova explosion there's

259  
00:09:49,829 --> 00:09:47,360  
no mystery there

260  
00:09:51,030 --> 00:09:49,839  
but there are other questions that

261  
00:09:54,470 --> 00:09:51,040  
remain

262  
00:09:57,269 --> 00:09:54,480  
where and when did the exposure occur

263  
00:09:59,190 --> 00:09:57,279

and can we locate and identify the

264

00:10:02,630 --> 00:09:59,200

stellar corpse

265

00:10:05,990 --> 00:10:02,640

to do that they called in a specialist

266

00:10:07,910 --> 00:10:06,000

named hubble all right hubble

267

00:10:09,630 --> 00:10:07,920

is known for its high resolution

268

00:10:12,710 --> 00:10:09,640

measurements that provide

269

00:10:15,670 --> 00:10:12,720

invaluable forensic evidence

270

00:10:18,069 --> 00:10:15,680

so this this observation right here is

271

00:10:22,870 --> 00:10:18,079

from 2003.

272

00:10:25,110 --> 00:10:22,880

hubble also observed it in 2016.

273

00:10:26,790 --> 00:10:25,120

and if you look back into the archive

274

00:10:27,750 --> 00:10:26,800

hubble actually has observations

275

00:10:31,750 --> 00:10:27,760

spanning about

276

00:10:33,910 --> 00:10:31,760

20 years of the supernova remnant

277

00:10:35,190 --> 00:10:33,920

and this supernova remnant is expanding

278

00:10:38,949 --> 00:10:35,200

and it's an explosion

279

00:10:42,310 --> 00:10:38,959

at millions of miles an hour so

280

00:10:45,590 --> 00:10:42,320

looking very carefully they can

281

00:10:48,069 --> 00:10:45,600

look to see what's happening

282

00:10:48,710 --> 00:10:48,079

and this is a little movie here we're

283

00:10:50,870 --> 00:10:48,720

going to go

284

00:10:52,630 --> 00:10:50,880

into black and white so we can turn it

285

00:10:54,550 --> 00:10:52,640

and we're going to bounce back and forth

286

00:10:55,590 --> 00:10:54,560

between epochs and you can see a tiny

287

00:10:58,949 --> 00:10:55,600

little bit of motion

288

00:11:01,670 --> 00:10:58,959

okay it's tiny motion but let's zoom in

289

00:11:03,750 --> 00:11:01,680

and you can see these gas clouds fleeing

290

00:11:07,990 --> 00:11:03,760

the scene of the crime

291

00:11:11,430 --> 00:11:08,000

in particular they traced 45 knots of

292

00:11:15,110 --> 00:11:11,440

ionized oxygen across 19

293

00:11:19,190 --> 00:11:15,120

years to determine the 3d structure

294

00:11:23,030 --> 00:11:19,200

of this expanding nebula the results

295

00:11:25,509 --> 00:11:23,040

oops the results are that they

296

00:11:27,590 --> 00:11:25,519

have a common center of expansion they

297

00:11:30,310 --> 00:11:27,600

can trace these knots motion

298

00:11:31,590 --> 00:11:30,320

in 3d back to a common center of

299

00:11:34,470 --> 00:11:31,600

expansion

300

00:11:35,750 --> 00:11:34,480

and knowing how fast they're moving they

301

00:11:38,389 --> 00:11:35,760

can figure out how long

302

00:11:39,670 --> 00:11:38,399

it took and they can pin down the time

303

00:11:44,550 --> 00:11:39,680

of the explosion

304

00:11:47,670 --> 00:11:44,560

at about 1700 years ago as seen on earth

305

00:11:48,150 --> 00:11:47,680

however there's still a problem if you

306

00:11:51,990 --> 00:11:48,160

look

307

00:11:55,990 --> 00:11:52,000

carefully at the location it's empty

308

00:11:59,670 --> 00:11:56,000

right a supernova should leave behind

309

00:12:03,350 --> 00:11:59,680

a neutron star or a black hole and these

310

00:12:06,389 --> 00:12:03,360

should shine in x-rays

311

00:12:08,069 --> 00:12:06,399

but a previously identified x-ray source

312

00:12:10,230 --> 00:12:08,079

that's near this

313

00:12:12,069 --> 00:12:10,240

isn't quite close enough it's a little

314

00:12:15,670 --> 00:12:12,079

bit too far away

315

00:12:17,750 --> 00:12:15,680

in order for the um the uh

316

00:12:19,430 --> 00:12:17,760

neutron star or black hole to get a kick

317

00:12:21,509 --> 00:12:19,440

and move out that far

318

00:12:23,430 --> 00:12:21,519

it would have to move at a velocity

319

00:12:24,069 --> 00:12:23,440

that's just too high for supernova

320

00:12:26,150 --> 00:12:24,079

explosions

321

00:12:28,389 --> 00:12:26,160

because it's only got 1700 years to move

322

00:12:30,870 --> 00:12:28,399

it and they say you know this doesn't

323

00:12:33,269 --> 00:12:30,880

fit with the modus operandi of a

324

00:12:36,550 --> 00:12:33,279

supernova explosion

325

00:12:39,829 --> 00:12:36,560

so while we can't end this episode

326

00:12:42,949 --> 00:12:39,839

with a triumphant dano

327

00:12:46,069 --> 00:12:42,959

we can say stay tuned

328

00:12:48,550 --> 00:12:46,079

for the next explosive episode as our

329

00:12:51,269 --> 00:12:48,560

intrepid astronomical detectives

330

00:12:55,990 --> 00:12:51,279

hunt down the stellar corpse of this

331

00:13:01,110 --> 00:12:58,870

and now we go to our featured speaker

332

00:13:04,150 --> 00:13:01,120

for today

333

00:13:07,030 --> 00:13:04,160

our speaker today is laura pritchard

334

00:13:08,629 --> 00:13:07,040

she is a post-doc at the space telescope

335

00:13:09,910 --> 00:13:08,639

science institute she's been there for

336

00:13:13,990 --> 00:13:09,920

three years

337

00:13:16,069 --> 00:13:14,000

and she came to us courtesy of the uk

338

00:13:17,670 --> 00:13:16,079

she did her graduate work at the

339

00:13:19,350 --> 00:13:17,680

university of oxford

340

00:13:21,269 --> 00:13:19,360

and her undergraduate work at the

341

00:13:24,230 --> 00:13:21,279

university of leeds

342

00:13:26,629 --> 00:13:24,240

and while at the university of belize

343

00:13:29,110 --> 00:13:26,639

she was on an exchange program

344

00:13:30,389 --> 00:13:29,120

where she actually worked with raja guru

345

00:13:33,670 --> 00:13:30,399

hatha kurta

346

00:13:36,230 --> 00:13:33,680

who is the speaker from la

347

00:13:36,870 --> 00:13:36,240

but two from two weeks ago so she got to

348

00:13:38,550 --> 00:13:36,880

go to

349

00:13:41,030 --> 00:13:38,560

unite uh the university of california

350

00:13:43,670 --> 00:13:41,040

santa cruz and worked there with raja

351  
00:13:46,069 --> 00:13:43,680  
and during that she was extremely lucky

352  
00:13:49,030 --> 00:13:46,079  
raja took her to hawaii to observe

353  
00:13:50,629 --> 00:13:49,040  
uh on keck so she's had quite the

354  
00:13:52,710 --> 00:13:50,639  
experience around it

355  
00:13:54,790 --> 00:13:52,720  
um and i asked her you know what has she

356  
00:13:56,550 --> 00:13:54,800  
been doing in the pandemic and she says

357  
00:13:57,990 --> 00:13:56,560  
well she's been cooking a lot that she

358  
00:14:00,550 --> 00:13:58,000  
really likes to cook and

359  
00:14:02,150 --> 00:14:00,560  
um it's been uh one of her passions and

360  
00:14:04,949 --> 00:14:02,160  
she'd be able to practice a lot

361  
00:14:05,829 --> 00:14:04,959  
and she's also very passionate about

362  
00:14:08,949 --> 00:14:05,839  
hiking

363  
00:14:09,750 --> 00:14:08,959

so i suggested to her she'd get out to

364

00:14:11,670 --> 00:14:09,760

some of the

365

00:14:13,269 --> 00:14:11,680

national parks here in the us because

366

00:14:14,629 --> 00:14:13,279

honestly there are some of the greatest

367

00:14:16,629 --> 00:14:14,639

hiking spots

368

00:14:18,389 --> 00:14:16,639

but tonight she will tell you about the

369

00:14:20,150 --> 00:14:18,399

milky way versus andromeda

370

00:14:22,550 --> 00:14:20,160

when galaxies collide ladies and

371

00:14:24,629 --> 00:14:22,560

gentlemen dr laura pritchard

372

00:14:26,310 --> 00:14:24,639

hi everyone thank you so much frank and

373

00:14:29,110 --> 00:14:26,320

to the other organizers

374

00:14:31,189 --> 00:14:29,120

it's a real honor to be giving a space

375

00:14:34,470 --> 00:14:31,199

telescope public lecture

376

00:14:36,230 --> 00:14:34,480

so thank you all for tuning in

377

00:14:38,470 --> 00:14:36,240

one of the main reasons i wanted to give

378

00:14:39,590 --> 00:14:38,480

this talk is for my family back in the

379

00:14:41,189 --> 00:14:39,600

uk

380

00:14:43,110 --> 00:14:41,199

so they've never actually seen me give a

381

00:14:44,790 --> 00:14:43,120

talk on astronomy and as this one is

382

00:14:46,230 --> 00:14:44,800

live streamed it felt like the perfect

383

00:14:47,829 --> 00:14:46,240

opportunity

384

00:14:50,150 --> 00:14:47,839

and as i haven't seen them in over a

385

00:14:51,350 --> 00:14:50,160

year i figured why not now

386

00:14:53,590 --> 00:14:51,360

so i'm very looking forward to getting

387

00:14:55,590 --> 00:14:53,600

my vaccine and hopefully being reunited

388

00:14:58,150 --> 00:14:55,600

with them soon

389

00:14:59,750 --> 00:14:58,160

so i work at the space telescope science

390

00:15:02,389 --> 00:14:59,760

institute and this is based in the

391

00:15:03,990 --> 00:15:02,399

wonderful city of baltimore in maryland

392

00:15:05,670 --> 00:15:04,000

and if you're regulars at this talk

393

00:15:08,069 --> 00:15:05,680

series you're probably very familiar

394

00:15:11,430 --> 00:15:08,079

with space telescope and its work

395

00:15:13,509 --> 00:15:11,440

but some of you may also not be so this

396

00:15:15,430 --> 00:15:13,519

is one of the main reasons i live and

397

00:15:15,910 --> 00:15:15,440

work in baltimore this is the hubble

398

00:15:18,150 --> 00:15:15,920

space

399

00:15:19,110 --> 00:15:18,160

telescope and hubble's science

400

00:15:21,110 --> 00:15:19,120

operations

401  
00:15:23,030 --> 00:15:21,120  
are based here at the space telescope

402  
00:15:25,269 --> 00:15:23,040  
science institute

403  
00:15:26,470 --> 00:15:25,279  
so anytime you see a gorgeous picture of

404  
00:15:29,350 --> 00:15:26,480  
space it's almost

405  
00:15:29,910 --> 00:15:29,360  
always from hubble and the main reason

406  
00:15:32,389 --> 00:15:29,920  
for that

407  
00:15:33,350 --> 00:15:32,399  
is that hubble is above the earth's

408  
00:15:35,189 --> 00:15:33,360  
atmosphere

409  
00:15:37,430 --> 00:15:35,199  
so it doesn't have to look through

410  
00:15:38,870 --> 00:15:37,440  
clouds it doesn't have to look through

411  
00:15:40,230 --> 00:15:38,880  
pollution haze

412  
00:15:41,910 --> 00:15:40,240  
and it doesn't have to look through

413  
00:15:43,590 --> 00:15:41,920

turbulence in the earth's atmosphere

414

00:15:45,829 --> 00:15:43,600

this is the same turbulence that you

415

00:15:47,749 --> 00:15:45,839

experience if you're on a plane

416

00:15:49,350 --> 00:15:47,759

so it's these kind of bubbles in the

417

00:15:52,150 --> 00:15:49,360

atmosphere that actually cause

418

00:15:54,710 --> 00:15:52,160

stars to twinkle so if you go above the

419

00:15:57,749 --> 00:15:54,720

earth's atmosphere where hubble is

420

00:15:59,829 --> 00:15:57,759

then you're able to see um

421

00:16:02,069 --> 00:15:59,839

the night sky in a very crisp way and

422

00:16:03,189 --> 00:16:02,079

these stars appear as very steady beams

423

00:16:05,590 --> 00:16:03,199

of light

424

00:16:07,110 --> 00:16:05,600

so hubble is nowhere near baltimore or

425

00:16:10,870 --> 00:16:07,120

any other city as you can see

426

00:16:15,350 --> 00:16:10,880

it's 340 miles above the earth's surface

427

00:16:18,470 --> 00:16:15,360

and it orbits earth every 95 minutes

428

00:16:19,189 --> 00:16:18,480

so one side note here is that thanks to

429

00:16:21,590 --> 00:16:19,199

hubble

430

00:16:23,189 --> 00:16:21,600

images of space look so incredible now

431

00:16:24,069 --> 00:16:23,199

that it can be quite hard to tell the

432

00:16:26,230 --> 00:16:24,079

difference between

433

00:16:27,670 --> 00:16:26,240

an amazing picture from hubble and an

434

00:16:32,710 --> 00:16:27,680

artist's impression

435

00:16:35,749 --> 00:16:32,720

so the reason i say that is because um

436

00:16:37,910 --> 00:16:35,759

basically now that images look so good

437

00:16:40,310 --> 00:16:37,920

when we start to talk about scales of

438

00:16:42,790 --> 00:16:40,320

space it can get confusing

439

00:16:43,509 --> 00:16:42,800

because you may wonder well if that's so

440

00:16:45,030 --> 00:16:43,519

far away

441

00:16:46,870 --> 00:16:45,040

how are we able to get such a good

442

00:16:48,389 --> 00:16:46,880

picture of it when in fact it's just a

443

00:16:51,110 --> 00:16:48,399

beautiful fake image

444

00:16:52,550 --> 00:16:51,120

so in this talk anytime there is an

445

00:16:53,110 --> 00:16:52,560

artist's impression of something in

446

00:16:56,230 --> 00:16:53,120

space

447

00:17:00,710 --> 00:16:56,240

i've just made a small note of that

448

00:17:03,189 --> 00:17:00,720

so i study galaxy evolution

449

00:17:04,069 --> 00:17:03,199

and i use the hubble space telescope to

450

00:17:05,990 --> 00:17:04,079

do this and

451  
00:17:07,350 --> 00:17:06,000  
other telus and other telescopes on the

452  
00:17:09,750 --> 00:17:07,360  
ground for this

453  
00:17:11,110 --> 00:17:09,760  
so in this talk i'm going to go into a

454  
00:17:14,150 --> 00:17:11,120  
little bit of the history

455  
00:17:15,750 --> 00:17:14,160  
of how galaxies were discovered i'm then

456  
00:17:17,270 --> 00:17:15,760  
going to talk about the different types

457  
00:17:19,669 --> 00:17:17,280  
of galaxies we see

458  
00:17:21,590 --> 00:17:19,679  
and how those are formed and then i'm

459  
00:17:24,549 --> 00:17:21,600  
going to go into what will happen

460  
00:17:27,750 --> 00:17:24,559  
to our galaxy the milky way and what

461  
00:17:31,029 --> 00:17:27,760  
that will mean for us here on earth

462  
00:17:33,430 --> 00:17:31,039  
laura hi um do you have youtube

463  
00:17:35,190 --> 00:17:33,440

you may be wondering why this isn't so

464

00:17:37,430 --> 00:17:35,200

obviously seen

465

00:17:38,390 --> 00:17:37,440

on a night say for example if you live

466

00:17:40,070 --> 00:17:38,400

in baltimore

467

00:17:41,990 --> 00:17:40,080

well one of the main issues that

468

00:17:42,950 --> 00:17:42,000

prevents us from being able to observe

469

00:17:46,150 --> 00:17:42,960

the night sky

470

00:17:48,710 --> 00:17:46,160

is light so this could be light from

471

00:17:50,470 --> 00:17:48,720

lamps or buildings or it could also be

472

00:17:53,350 --> 00:17:50,480

light from the moon

473

00:17:54,310 --> 00:17:53,360

so in order to get the best glimpse of

474

00:17:56,150 --> 00:17:54,320

the night sky

475

00:17:58,549 --> 00:17:56,160

you need to step away from artificial

476  
00:17:59,270 --> 00:17:58,559  
light on a clear night when the moon

477  
00:18:01,909 --> 00:17:59,280  
isn't up

478  
00:18:02,870 --> 00:18:01,919  
and let your eyes adjust for about 15

479  
00:18:04,710 --> 00:18:02,880  
minutes

480  
00:18:06,230 --> 00:18:04,720  
and on those very clear nights you may

481  
00:18:08,310 --> 00:18:06,240  
be able to catch a glimpse of that

482  
00:18:10,870 --> 00:18:08,320  
gorgeous band of the milky way running

483  
00:18:13,029 --> 00:18:10,880  
across the night sky

484  
00:18:15,430 --> 00:18:13,039  
so here is a clearer picture of the

485  
00:18:20,230 --> 00:18:15,440  
milky way galaxy

486  
00:18:23,350 --> 00:18:20,240  
so our galaxy is a spiral disc

487  
00:18:25,270 --> 00:18:23,360  
and we are in that disc so when we

488  
00:18:26,390 --> 00:18:25,280

look out at the rest of our galaxy we

489

00:18:28,549 --> 00:18:26,400

really only see this

490

00:18:29,510 --> 00:18:28,559

thin band of light it's like looking at

491

00:18:32,710 --> 00:18:29,520

a dinner plate

492

00:18:34,310 --> 00:18:32,720

edge on for example our galaxy is made

493

00:18:36,470 --> 00:18:34,320

up of dust and those those

494

00:18:37,750 --> 00:18:36,480

dark lanes running through the middle

495

00:18:40,789 --> 00:18:37,760

made up of stars

496

00:18:42,230 --> 00:18:40,799

and gas and those are all held together

497

00:18:44,950 --> 00:18:42,240

by gravity gravity

498

00:18:45,430 --> 00:18:44,960

is the same force that keeps us on earth

499

00:18:49,110 --> 00:18:45,440

and

500

00:18:51,190 --> 00:18:49,120

the same force that keeps us

501  
00:18:52,789 --> 00:18:51,200  
in orbit around the sun and the moon in

502  
00:18:55,990 --> 00:18:52,799  
orbit around us

503  
00:18:56,390 --> 00:18:56,000  
so this large collection makes up our

504  
00:18:59,669 --> 00:18:56,400  
home

505  
00:19:00,070 --> 00:18:59,679  
the milky way so the stars that you can

506  
00:19:02,230 --> 00:19:00,080  
see

507  
00:19:04,789 --> 00:19:02,240  
above and below the plane of the galaxy

508  
00:19:08,150 --> 00:19:04,799  
here those are actually very close to us

509  
00:19:09,430 --> 00:19:08,160  
in the plane of the galaxy and this glow

510  
00:19:10,310 --> 00:19:09,440  
of light that you can see in the

511  
00:19:12,630 --> 00:19:10,320  
background

512  
00:19:14,150 --> 00:19:12,640  
are actually all of the hundreds of

513  
00:19:15,990 --> 00:19:14,160

billions of stars

514

00:19:17,430 --> 00:19:16,000

that make up our galaxy they're just so

515

00:19:19,190 --> 00:19:17,440

far away that they really kind of look

516

00:19:20,549 --> 00:19:19,200

like a fine mist in the background

517

00:19:22,789 --> 00:19:20,559

glowing

518

00:19:23,990 --> 00:19:22,799

you may also spot those kind of red

519

00:19:26,549 --> 00:19:24,000

patches there

520

00:19:27,750 --> 00:19:26,559

those are actually heated clouds of

521

00:19:29,270 --> 00:19:27,760

hydrogen gas

522

00:19:31,270 --> 00:19:29,280

so that's some of the visible gas that

523

00:19:33,510 --> 00:19:31,280

you can see and you may spot

524

00:19:34,549 --> 00:19:33,520

a couple of other interesting objects

525

00:19:36,390 --> 00:19:34,559

and these are the

526

00:19:38,150 --> 00:19:36,400

two bluish blobs down to the bottom

527

00:19:38,549 --> 00:19:38,160

right hand corner and frank has already

528

00:19:40,470 --> 00:19:38,559

actually

529

00:19:42,549 --> 00:19:40,480

introduced one of them so these are the

530

00:19:44,549 --> 00:19:42,559

magellanic clouds

531

00:19:45,750 --> 00:19:44,559

and you may wonder why you haven't seen

532

00:19:46,870 --> 00:19:45,760

these if you live in the northern

533

00:19:48,710 --> 00:19:46,880

hemisphere

534

00:19:49,909 --> 00:19:48,720

these are only visible from the southern

535

00:19:53,190 --> 00:19:49,919

hemisphere

536

00:19:54,950 --> 00:19:53,200

so you'd have to head to australia or

537

00:19:57,190 --> 00:19:54,960

south america or southern africa to

538

00:19:59,510 --> 00:19:57,200

catch a glimpse of the magellanic clouds

539

00:20:00,710 --> 00:19:59,520

and as frank mentioned these are whole

540

00:20:03,750 --> 00:20:00,720

galaxies

541

00:20:05,510 --> 00:20:03,760

that orbit our own galaxy the milky way

542

00:20:07,270 --> 00:20:05,520

and they're spiraling in and will one

543

00:20:10,549 --> 00:20:07,280

day be fully merged

544

00:20:15,590 --> 00:20:13,350

so our understanding of the milky way

545

00:20:18,070 --> 00:20:15,600

galaxies and the universe as a whole

546

00:20:19,430 --> 00:20:18,080

has come a long way in the last few

547

00:20:21,750 --> 00:20:19,440

hundred years

548

00:20:23,830 --> 00:20:21,760

and even huge leaps have been made

549

00:20:26,870 --> 00:20:23,840

within the last century

550

00:20:28,549 --> 00:20:26,880

so in the mid to late 1700s the

551  
00:20:29,990 --> 00:20:28,559  
herschel's william herschel and his

552  
00:20:33,350 --> 00:20:30,000  
sister caroline

553  
00:20:35,430 --> 00:20:33,360  
made a huge effort to survey the heavens

554  
00:20:36,950 --> 00:20:35,440  
they made vast leaps forward in

555  
00:20:39,590 --> 00:20:36,960  
telescope design

556  
00:20:41,350 --> 00:20:39,600  
starting from newton's original design

557  
00:20:42,230 --> 00:20:41,360  
and then they also recorded everything

558  
00:20:43,990 --> 00:20:42,240  
they could see

559  
00:20:45,430 --> 00:20:44,000  
over the course of their lives and this

560  
00:20:48,470 --> 00:20:45,440  
work was continued

561  
00:20:50,310 --> 00:20:48,480  
by william's son john caroline really

562  
00:20:52,149 --> 00:20:50,320  
helped in this effort to develop

563  
00:20:55,430 --> 00:20:52,159

the modern mathematical approach that we

564

00:20:59,669 --> 00:20:57,830

and what they noticed in the sky was

565

00:21:02,310 --> 00:20:59,679

that alongside the point-like

566

00:21:02,950 --> 00:21:02,320

stars they also found lots of things

567

00:21:05,830 --> 00:21:02,960

they called

568

00:21:06,390 --> 00:21:05,840

nebulae this is a latin word that means

569

00:21:09,110 --> 00:21:06,400

mist

570

00:21:10,789 --> 00:21:09,120

and it's basically anything that they uh

571

00:21:13,029 --> 00:21:10,799

anything that was not point like

572

00:21:14,310 --> 00:21:13,039

anything that was fuzzy or irregularly

573

00:21:17,430 --> 00:21:14,320

shaped

574

00:21:18,950 --> 00:21:17,440

they called these nebulae and there was

575

00:21:21,110 --> 00:21:18,960

a great debate at the time

576  
00:21:23,029 --> 00:21:21,120  
over the nature of what these nebulae

577  
00:21:24,470 --> 00:21:23,039  
were and here's some of their original

578  
00:21:27,909 --> 00:21:24,480  
sketches of the things that they were

579  
00:21:30,870 --> 00:21:27,919  
observing through their telescope

580  
00:21:31,750 --> 00:21:30,880  
so a huge step towards our understanding

581  
00:21:34,710 --> 00:21:31,760  
of what these

582  
00:21:36,950 --> 00:21:34,720  
nebulae actually were came from the vast

583  
00:21:38,310 --> 00:21:36,960  
intellectual leaps of both thomas wright

584  
00:21:41,830 --> 00:21:38,320  
in 1750

585  
00:21:44,070 --> 00:21:41,840  
and emmanuel kant in 1755.

586  
00:21:45,510 --> 00:21:44,080  
so the herschel's wright and kant were

587  
00:21:48,390 --> 00:21:45,520  
actually all contemporaries

588  
00:21:50,310 --> 00:21:48,400

working around the same time so thomas

589

00:21:53,430 --> 00:21:50,320

wright was a british philosopher

590

00:21:56,470 --> 00:21:53,440

and he first proposed that we

591

00:21:58,950 --> 00:21:56,480

are in a massive disk of stars

592

00:22:00,070 --> 00:21:58,960

and that that band of light that you see

593

00:22:02,470 --> 00:22:00,080

in the night sky

594

00:22:03,350 --> 00:22:02,480

is an optical illusion like we were

595

00:22:05,669 --> 00:22:03,360

describing with

596

00:22:06,870 --> 00:22:05,679

the thin plane and we are in that disc

597

00:22:09,510 --> 00:22:06,880

there

598

00:22:10,870 --> 00:22:09,520

he then also proposed that the nebulae

599

00:22:13,510 --> 00:22:10,880

herschel's nebulae

600

00:22:14,390 --> 00:22:13,520

were the same type of thing as our

601  
00:22:17,510 --> 00:22:14,400  
galaxy

602  
00:22:20,070 --> 00:22:17,520  
but on a whole uh different plane

603  
00:22:21,590 --> 00:22:20,080  
so they were termed island universes

604  
00:22:23,590 --> 00:22:21,600  
because at the time it was thought that

605  
00:22:25,029 --> 00:22:23,600  
our milky way really was the whole

606  
00:22:27,110 --> 00:22:25,039  
universe

607  
00:22:29,270 --> 00:22:27,120  
and so wright proposed that there were

608  
00:22:32,549 --> 00:22:29,280  
whole other universes

609  
00:22:35,669 --> 00:22:32,559  
or you know universes these are galaxies

610  
00:22:37,029 --> 00:22:35,679  
in these other planes and immanuel kant

611  
00:22:37,909 --> 00:22:37,039  
fully acknowledging wright's

612  
00:22:39,830 --> 00:22:37,919  
breakthrough

613  
00:22:41,870 --> 00:22:39,840

continued this work and developed this

614

00:22:43,430 --> 00:22:41,880

theory and he published his results in

615

00:22:45,669 --> 00:22:43,440

1755.

616

00:22:47,830 --> 00:22:45,679

now this breakthrough is often solely

617

00:22:50,470 --> 00:22:47,840

attributed to emmanuel kant

618

00:22:51,990 --> 00:22:50,480

um and there's no denying he was also a

619

00:22:53,590 --> 00:22:52,000

brilliant philosopher as well he was a

620

00:22:56,710 --> 00:22:53,600

german philosopher

621

00:22:58,789 --> 00:22:56,720

um so these island universes were the

622

00:23:01,110 --> 00:22:58,799

topic of much debate

623

00:23:03,029 --> 00:23:01,120

so there's the theory does that mean

624

00:23:05,669 --> 00:23:03,039

that the case was closed

625

00:23:07,270 --> 00:23:05,679

hardly if at all basically these

626  
00:23:07,990 --> 00:23:07,280  
theories when they came out at the time

627  
00:23:11,029 --> 00:23:08,000  
were widely

628  
00:23:13,590 --> 00:23:11,039  
criticized and discredited

629  
00:23:15,590 --> 00:23:13,600  
how can you actually prove this theory

630  
00:23:18,710 --> 00:23:15,600  
if you can't measure the distance

631  
00:23:20,830 --> 00:23:18,720  
to the nebulae so

632  
00:23:22,149 --> 00:23:20,840  
this debate was not solved for another

633  
00:23:25,590 --> 00:23:22,159  
169

634  
00:23:29,310 --> 00:23:25,600  
years but a key breakthrough

635  
00:23:33,110 --> 00:23:29,320  
for really resolving this debate came

636  
00:23:36,789 --> 00:23:33,120  
153 years later in 1908

637  
00:23:40,230 --> 00:23:36,799  
by the work of henrietta leave it

638  
00:23:42,310 --> 00:23:40,240

now to explain um

639

00:23:44,230 --> 00:23:42,320

swan leave it's genius i'm using the

640

00:23:46,149 --> 00:23:44,240

example of a lighthouse

641

00:23:47,830 --> 00:23:46,159

and this lighthouse is a reference to a

642

00:23:49,990 --> 00:23:47,840

trip that i made to nantucket in the

643

00:23:53,909 --> 00:23:50,000

summer of 2019 where i gave a similar

644

00:23:56,149 --> 00:23:53,919

talk so um

645

00:23:57,830 --> 00:23:56,159

my trip to nantucket was to visit the

646

00:24:00,149 --> 00:23:57,840

mariah mitchell observatory

647

00:24:01,510 --> 00:24:00,159

as an affiliated astronomer and if

648

00:24:03,110 --> 00:24:01,520

you've never heard of mariah mitchell

649

00:24:04,549 --> 00:24:03,120

before i would highly recommend

650

00:24:07,029 --> 00:24:04,559

going to read up about her she was a

651  
00:24:10,390 --> 00:24:07,039  
fascinating woman born in 1818

652  
00:24:11,909 --> 00:24:10,400  
around the time that william herschel um

653  
00:24:14,950 --> 00:24:11,919  
around the end of william herschel's

654  
00:24:18,310 --> 00:24:14,960  
career she was the first professional

655  
00:24:20,390 --> 00:24:18,320  
women astronomer in america and this was

656  
00:24:21,269 --> 00:24:20,400  
at a time when even having an education

657  
00:24:23,990 --> 00:24:21,279  
as a woman

658  
00:24:26,310 --> 00:24:24,000  
was a rare thing she was also a vocal

659  
00:24:27,110 --> 00:24:26,320  
opponent to slavery and segregation and

660  
00:24:29,269 --> 00:24:27,120  
she admitted

661  
00:24:30,789 --> 00:24:29,279  
non-white students to her school at a

662  
00:24:33,110 --> 00:24:30,799  
time when

663  
00:24:35,590 --> 00:24:33,120

many schools were still segregated and

664

00:24:37,669 --> 00:24:35,600

she also hosted prominent abolitionists

665

00:24:40,470 --> 00:24:37,679

and civil rights activists

666

00:24:42,070 --> 00:24:40,480

who had escaped slavery on nantucket

667

00:24:43,190 --> 00:24:42,080

these were frederick douglass who was

668

00:24:45,669 --> 00:24:43,200

born here in

669

00:24:47,430 --> 00:24:45,679

in maryland and has ties to baltimore

670

00:24:49,669 --> 00:24:47,440

and also sojourner truth

671

00:24:50,549 --> 00:24:49,679

so an interesting slice of history there

672

00:24:53,430 --> 00:24:50,559

so i um

673

00:24:54,710 --> 00:24:53,440

but back to swan leave it and her

674

00:24:57,909 --> 00:24:54,720

breakthrough

675

00:24:59,350 --> 00:24:57,919

so here you can see that this lighthouse

676  
00:25:02,390 --> 00:24:59,360  
is flashing

677  
00:25:03,830 --> 00:25:02,400  
so imagine you're on a ship at night you

678  
00:25:06,470 --> 00:25:03,840  
know that you must be approaching

679  
00:25:08,070 --> 00:25:06,480  
land soon and you see this bright

680  
00:25:09,830 --> 00:25:08,080  
fashion flashing light

681  
00:25:11,350 --> 00:25:09,840  
so you know that that's a lighthouse by

682  
00:25:12,870 --> 00:25:11,360  
the way that it's flashing

683  
00:25:14,789 --> 00:25:12,880  
so you know that you must be close to

684  
00:25:17,830 --> 00:25:14,799  
land

685  
00:25:18,950 --> 00:25:17,840  
now picture that instead you just see a

686  
00:25:21,750 --> 00:25:18,960  
very faint

687  
00:25:22,870 --> 00:25:21,760  
flashing light on the horizon well you

688  
00:25:24,470 --> 00:25:22,880

know that that's still

689

00:25:25,990 --> 00:25:24,480

a lighthouse by the way that it's

690

00:25:29,110 --> 00:25:26,000

flashing but because it's so

691

00:25:31,510 --> 00:25:29,120

faint you know that it must be far away

692

00:25:32,630 --> 00:25:31,520

the key bit of information here is that

693

00:25:34,710 --> 00:25:32,640

i know how big

694

00:25:36,070 --> 00:25:34,720

a lighthouse should be if i was standing

695

00:25:38,230 --> 00:25:36,080

right next to it

696

00:25:40,070 --> 00:25:38,240

therefore if it looks very faint then i

697

00:25:40,870 --> 00:25:40,080

can just determine that it's very far

698

00:25:43,350 --> 00:25:40,880

away

699

00:25:46,149 --> 00:25:43,360

we do this automatically all the time if

700

00:25:49,029 --> 00:25:46,159

we recognize something or someone

701  
00:25:49,350 --> 00:25:49,039  
far away just by how big they appear to

702  
00:25:51,510 --> 00:25:49,360  
be

703  
00:25:53,590 --> 00:25:51,520  
our brain automatically calculates how

704  
00:25:55,990 --> 00:25:53,600  
close they are

705  
00:25:57,110 --> 00:25:56,000  
so unsurprisingly lighthouses are

706  
00:26:00,230 --> 00:25:57,120  
relatively

707  
00:26:01,430 --> 00:26:00,240  
scarce in space but instead henrietta

708  
00:26:04,710 --> 00:26:01,440  
swan leavitt

709  
00:26:06,710 --> 00:26:04,720  
used a similar principle in order to

710  
00:26:08,950 --> 00:26:06,720  
determine distances

711  
00:26:10,710 --> 00:26:08,960  
during her work as a human computer at

712  
00:26:13,590 --> 00:26:10,720  
the harvard observatory

713  
00:26:14,390 --> 00:26:13,600

she found a relation for this special

714

00:26:17,510 --> 00:26:14,400

type

715

00:26:20,310 --> 00:26:17,520

of variable star she'd found

716

00:26:21,029 --> 00:26:20,320

that by measuring the regularity of the

717

00:26:24,149 --> 00:26:21,039

flashes

718

00:26:27,190 --> 00:26:24,159

much like a lighthouse you could know

719

00:26:29,909 --> 00:26:27,200

how big that star was supposed to be

720

00:26:31,590 --> 00:26:29,919

so if you saw that the star was flashing

721

00:26:31,990 --> 00:26:31,600

you could measure how bright it should

722

00:26:34,230 --> 00:26:32,000

be

723

00:26:36,710 --> 00:26:34,240

so if it looked very faint then you

724

00:26:38,950 --> 00:26:36,720

could tell that it was really far away

725

00:26:40,549 --> 00:26:38,960

and this was her genius discovery in

726

00:26:42,149 --> 00:26:40,559

1908.

727

00:26:45,110 --> 00:26:42,159

in astronomy this is what we call a

728

00:26:46,950 --> 00:26:45,120

standard candle this is a bright source

729

00:26:49,110 --> 00:26:46,960

and we know how bright it should be

730

00:26:52,549 --> 00:26:49,120

therefore we can use that information

731

00:26:55,110 --> 00:26:52,559

to determine distance

732

00:26:58,470 --> 00:26:55,120

so this great debate of the nature of

733

00:27:00,789 --> 00:26:58,480

nebulae was revived in 1920 between two

734

00:27:02,310 --> 00:27:00,799

prominent astronomers at the time curtis

735

00:27:04,710 --> 00:27:02,320

and shapley

736

00:27:05,510 --> 00:27:04,720

and this debate was resolved by edwin

737

00:27:09,269 --> 00:27:05,520

hubble

738

00:27:12,070 --> 00:27:09,279

in 1924 a full 169

739

00:27:13,750 --> 00:27:12,080  
years after writing kant's original

740

00:27:16,390 --> 00:27:13,760  
theory

741

00:27:18,230 --> 00:27:16,400  
this is less than 100 years ago and it's

742

00:27:21,669 --> 00:27:18,240  
amazing to think that even during

743

00:27:24,230 --> 00:27:21,679  
world war one humans did not understand

744

00:27:25,830 --> 00:27:24,240  
the full extent of the universe

745

00:27:27,669 --> 00:27:25,840  
they thought that the milky way was

746

00:27:29,830 --> 00:27:27,679  
really all that there was

747

00:27:33,669 --> 00:27:29,840  
and they couldn't possibly imagine that

748

00:27:37,430 --> 00:27:33,679  
it was vaster than our wildest dreams

749

00:27:39,430 --> 00:27:37,440  
so hubble there's no doubt

750

00:27:41,510 --> 00:27:39,440  
um discovered some of the most amazing

751  
00:27:42,710 --> 00:27:41,520  
secrets that unlocked our understanding

752  
00:27:44,789 --> 00:27:42,720  
of the universe

753  
00:27:46,230 --> 00:27:44,799  
but by many accounts he was not the

754  
00:27:48,310 --> 00:27:46,240  
sharpest astronomer

755  
00:27:49,269 --> 00:27:48,320  
he arrived at the right place at the

756  
00:27:50,950 --> 00:27:49,279  
right time

757  
00:27:53,110 --> 00:27:50,960  
and he put in the work to get the

758  
00:27:54,789 --> 00:27:53,120  
discoveries

759  
00:27:56,789 --> 00:27:54,799  
hubble arrived to mount wilson

760  
00:27:59,510 --> 00:27:56,799  
observatory in california

761  
00:28:01,269 --> 00:27:59,520  
in 1919 and this coincided with the

762  
00:28:01,990 --> 00:28:01,279  
completion of the 100-inch hooker

763  
00:28:03,750 --> 00:28:02,000

telescope

764

00:28:05,430 --> 00:28:03,760

which at the time was the world's

765

00:28:08,470 --> 00:28:05,440

largest

766

00:28:11,830 --> 00:28:08,480

hubble measured was studying the

767

00:28:12,630 --> 00:28:11,840

um great andromeda nebula this is a very

768

00:28:14,630 --> 00:28:12,640

diffuse

769

00:28:15,990 --> 00:28:14,640

fuzzy blob on the sky and it's

770

00:28:18,230 --> 00:28:16,000

incredibly faint so you really

771

00:28:19,750 --> 00:28:18,240

need to go to very good observing

772

00:28:21,510 --> 00:28:19,760

conditions to be able to see this

773

00:28:24,549 --> 00:28:21,520

clearly

774

00:28:25,430 --> 00:28:24,559

and what he was studying in detail um as

775

00:28:27,669 --> 00:28:25,440

he was studying

776

00:28:29,669 --> 00:28:27,679

this galaxy in detail and some of you

777

00:28:32,950 --> 00:28:29,679

may know where this is going

778

00:28:36,070 --> 00:28:32,960

he discovered some of swan leavitt's

779

00:28:39,350 --> 00:28:36,080

variable stars but they were incredibly

780

00:28:42,710 --> 00:28:39,360

faint using the relation

781

00:28:44,470 --> 00:28:42,720

that she found in 1908 hubble was able

782

00:28:46,149 --> 00:28:44,480

to measure the distance to the great

783

00:28:51,669 --> 00:28:46,159

andromeda nebula

784

00:28:55,510 --> 00:28:51,679

of 1.5 million light years

785

00:28:57,029 --> 00:28:55,520

so we know this now as the andromeda

786

00:28:59,669 --> 00:28:57,039

galaxy

787

00:29:00,870 --> 00:28:59,679

this was far beyond the reaches of our

788

00:29:03,669 --> 00:29:00,880

milky way

789

00:29:04,789 --> 00:29:03,679

and it placed it firmly outside to an

790

00:29:06,870 --> 00:29:04,799

island of its own

791

00:29:09,029 --> 00:29:06,880

really confirming writing cancer

792

00:29:12,310 --> 00:29:09,039

theories of these island universes that

793

00:29:13,669 --> 00:29:12,320

we now understand as galaxies

794

00:29:16,950 --> 00:29:13,679

but you'll notice here that it's

795

00:29:18,950 --> 00:29:16,960

actually 2.5 million light years away

796

00:29:20,310 --> 00:29:18,960

um based on the newer information that

797

00:29:21,669 --> 00:29:20,320

we have today and the improved

798

00:29:23,430 --> 00:29:21,679

measurements

799

00:29:25,350 --> 00:29:23,440

and this in astronomy is what we call a

800

00:29:26,230 --> 00:29:25,360

pretty good guess it's around the right

801  
00:29:29,590 --> 00:29:26,240  
level

802  
00:29:31,430 --> 00:29:29,600  
um and it was enough to prove this

803  
00:29:34,630 --> 00:29:31,440  
theory that there were these island

804  
00:29:36,630 --> 00:29:34,640  
universes these galaxies so

805  
00:29:37,669 --> 00:29:36,640  
this number is so large that it can

806  
00:29:39,110 --> 00:29:37,679  
often be quite

807  
00:29:41,029 --> 00:29:39,120  
hard to wrap your head around what these

808  
00:29:43,669 --> 00:29:41,039  
numbers really mean in astronomy

809  
00:29:45,590 --> 00:29:43,679  
but i will try and break down what this

810  
00:29:48,389 --> 00:29:45,600  
value really means

811  
00:29:49,190 --> 00:29:48,399  
so the light that we see from andromeda

812  
00:29:53,269 --> 00:29:49,200  
on earth

813  
00:29:53,990 --> 00:29:53,279

is 2.5 million years old it's taken that

814

00:29:57,909 --> 00:29:54,000

long to travel

815

00:30:00,950 --> 00:29:57,919

to us light travels incredibly fast

816

00:30:03,669 --> 00:30:00,960

so fast in fact that on earth it appears

817

00:30:04,549 --> 00:30:03,679

nearly instantaneous but it actually has

818

00:30:08,149 --> 00:30:04,559

a maximum

819

00:30:11,430 --> 00:30:08,159

fixed speed and that's 186

820

00:30:14,549 --> 00:30:11,440

000 miles per second

821

00:30:17,909 --> 00:30:14,559

in a year light can travel

822

00:30:21,110 --> 00:30:17,919

6 trillion miles

823

00:30:24,549 --> 00:30:21,120

that is 6 million million miles and then

824

00:30:26,549 --> 00:30:24,559

andromeda is 2.5 million of those away

825

00:30:27,750 --> 00:30:26,559

so that is a ridiculously large number

826

00:30:30,230 --> 00:30:27,760

and it is really hard to

827

00:30:31,430 --> 00:30:30,240

wrap your head around but even that is

828

00:30:35,510 --> 00:30:31,440

incredibly

829

00:30:37,909 --> 00:30:35,520

close on the scales of the universe

830

00:30:38,950 --> 00:30:37,919

so when hubble was working on this he

831

00:30:41,350 --> 00:30:38,960

was receiving

832

00:30:44,149 --> 00:30:41,360

a lot of backlash for his work and this

833

00:30:47,350 --> 00:30:44,159

was amidst that great debate

834

00:30:49,510 --> 00:30:47,360

so usually astronomers publish their

835

00:30:51,909 --> 00:30:49,520

findings in peer-reviewed articles

836

00:30:53,669 --> 00:30:51,919

present their work to the community and

837

00:30:55,110 --> 00:30:53,679

then that is when the general public

838

00:30:56,470 --> 00:30:55,120

would actually be able to hear about

839

00:30:59,669 --> 00:30:56,480

that information

840

00:31:02,310 --> 00:30:59,679

in the press in part because of the

841

00:31:03,990 --> 00:31:02,320

backlash that hubble was receiving

842

00:31:07,350 --> 00:31:04,000

he went straight to the new york times

843

00:31:09,509 --> 00:31:07,360

with his discovery in november of 1924

844

00:31:11,029 --> 00:31:09,519

he then presented his results to the

845

00:31:12,470 --> 00:31:11,039

astronomical to the american

846

00:31:14,870 --> 00:31:12,480

astronomical society

847

00:31:18,470 --> 00:31:14,880

and the astronomical community on new

848

00:31:22,070 --> 00:31:18,480

year's day in 1925.

849

00:31:25,750 --> 00:31:22,080

so that wasn't all hubble did

850

00:31:28,389 --> 00:31:25,760

he kept measuring distances to galaxies

851  
00:31:30,230 --> 00:31:28,399  
using using that same method using swan

852  
00:31:32,149 --> 00:31:30,240  
leavitt's pulsating stars

853  
00:31:33,990 --> 00:31:32,159  
he could measure the distance to more

854  
00:31:37,029 --> 00:31:34,000  
distant galaxies

855  
00:31:39,269 --> 00:31:37,039  
he then also measured their velocities

856  
00:31:40,630 --> 00:31:39,279  
so this is just speed and also their

857  
00:31:42,789 --> 00:31:40,640  
direction

858  
00:31:44,310 --> 00:31:42,799  
we can use light from galaxies to

859  
00:31:46,470 --> 00:31:44,320  
measure their velocity

860  
00:31:48,789 --> 00:31:46,480  
and measure if they're moving towards or

861  
00:31:52,070 --> 00:31:48,799  
away from us

862  
00:31:54,149 --> 00:31:52,080  
so when galaxies give off light

863  
00:31:56,470 --> 00:31:54,159

when that light arrives at earth that's

864

00:31:58,310 --> 00:31:56,480

when we can see that galaxy

865

00:31:59,590 --> 00:31:58,320

and we can capture that light either by

866

00:32:01,750 --> 00:31:59,600

taking an image

867

00:32:04,149 --> 00:32:01,760

like the ones that hubble takes or you

868

00:32:06,070 --> 00:32:04,159

can take something called a spectrum

869

00:32:07,830 --> 00:32:06,080

and this section of spectrum i'm sure

870

00:32:09,590 --> 00:32:07,840

i'm showing this graphic here is just a

871

00:32:11,509 --> 00:32:09,600

very small section of spectrum it's the

872

00:32:14,230 --> 00:32:11,519

rainbow this is the visible spectrum of

873

00:32:16,149 --> 00:32:14,240

light that we that humans can see

874

00:32:17,430 --> 00:32:16,159

different chemical elements have

875

00:32:19,430 --> 00:32:17,440

different features

876

00:32:21,029 --> 00:32:19,440

in a spectrum and so i'm just showing

877

00:32:22,789 --> 00:32:21,039

one example of a feature there which is

878

00:32:25,430 --> 00:32:22,799

just that dark line that you can see in

879

00:32:28,630 --> 00:32:25,440

the top panel

880

00:32:31,590 --> 00:32:28,640

i know where that feature should be

881

00:32:33,269 --> 00:32:31,600

so if a galaxy is moving away from us

882

00:32:34,230 --> 00:32:33,279

that light that we receive from the

883

00:32:37,430 --> 00:32:34,240

galaxy

884

00:32:39,509 --> 00:32:37,440

is actually stretched a little bit

885

00:32:41,430 --> 00:32:39,519

and we know where the features should be

886

00:32:43,190 --> 00:32:41,440

that's that dashed white line

887

00:32:45,430 --> 00:32:43,200

but then we measure where that feature

888

00:32:46,630 --> 00:32:45,440

actually lands and that's that dark line

889

00:32:49,590 --> 00:32:46,640

in the bottom panel

890

00:32:51,750 --> 00:32:49,600

and that that shift will tell us the

891

00:32:54,070 --> 00:32:51,760

speed of the galaxy

892

00:32:55,110 --> 00:32:54,080

now if the if that feature is shifted

893

00:32:57,190 --> 00:32:55,120

towards the red

894

00:32:59,029 --> 00:32:57,200

end of the spectrum this is what we call

895

00:33:00,389 --> 00:32:59,039

a redshift and this means that the

896

00:33:04,870 --> 00:33:00,399

galaxy is moving

897

00:33:07,350 --> 00:33:04,880

away from us so what hubble found

898

00:33:08,230 --> 00:33:07,360

was that far beyond our local

899

00:33:11,509 --> 00:33:08,240

neighborhood

900

00:33:14,549 --> 00:33:11,519

to more distant galaxies the further

901  
00:33:17,909 --> 00:33:14,559  
a galaxy was was away from us

902  
00:33:19,669 --> 00:33:17,919  
the faster it was moving

903  
00:33:21,750 --> 00:33:19,679  
now that is kind of confusing when you

904  
00:33:22,230 --> 00:33:21,760  
think about it because a lot of hubble's

905  
00:33:23,990 --> 00:33:22,240  
work

906  
00:33:25,269 --> 00:33:24,000  
was showing that there's nothing special

907  
00:33:28,789 --> 00:33:25,279  
about us

908  
00:33:30,470 --> 00:33:28,799  
our galaxy and earth so then

909  
00:33:31,990 --> 00:33:30,480  
if there's nothing special about us and

910  
00:33:33,909 --> 00:33:32,000  
our location

911  
00:33:36,830 --> 00:33:33,919  
why then is everything moving away from

912  
00:33:38,470 --> 00:33:36,840  
us how does it know to travel away from

913  
00:33:41,430 --> 00:33:38,480

us

914

00:33:42,630 --> 00:33:41,440

and turns out there is nothing special

915

00:33:44,710 --> 00:33:42,640

about our location

916

00:33:45,990 --> 00:33:44,720

this is actually a simple geometric

917

00:33:48,470 --> 00:33:46,000

effect

918

00:33:50,710 --> 00:33:48,480

so here i'm showing a regular grid of

919

00:33:53,430 --> 00:33:50,720

galaxies on the left so imagine you have

920

00:33:55,110 --> 00:33:53,440

this array of galaxies evenly spaced

921

00:33:57,029 --> 00:33:55,120

and this galaxy in the middle here we'll

922

00:33:59,990 --> 00:33:57,039

call the milky way

923

00:34:01,909 --> 00:34:00,000

now imagine you expand that grid by a

924

00:34:02,870 --> 00:34:01,919

small amount and those are the orange

925

00:34:06,789 --> 00:34:02,880

lines that you see

926  
00:34:08,790 --> 00:34:06,799  
on the right hand side those galaxies

927  
00:34:11,030 --> 00:34:08,800  
on the orange lines are still evenly

928  
00:34:13,669 --> 00:34:11,040  
spaced and our milky way

929  
00:34:15,510 --> 00:34:13,679  
galaxy right in the middle is stayed

930  
00:34:18,310 --> 00:34:15,520  
stayed pert

931  
00:34:19,430 --> 00:34:18,320  
but what you can see is that galaxies

932  
00:34:21,750 --> 00:34:19,440  
are small distance

933  
00:34:22,710 --> 00:34:21,760  
away from that central galaxy have moved

934  
00:34:25,990 --> 00:34:22,720  
a little bit

935  
00:34:28,389 --> 00:34:26,000  
have moved even more

936  
00:34:30,149 --> 00:34:28,399  
and galaxies towards the edge have moved

937  
00:34:32,389 --> 00:34:30,159  
even further

938  
00:34:33,190 --> 00:34:32,399

so what hubble discovered was that

939

00:34:35,829 --> 00:34:33,200

galaxies

940

00:34:36,230 --> 00:34:35,839

are flying away from us and our milky

941

00:34:41,190 --> 00:34:36,240

way

942

00:34:44,230 --> 00:34:41,200

other galaxies

943

00:34:47,190 --> 00:34:44,240

we have now arrived at another

944

00:34:48,389 --> 00:34:47,200

major breakthrough in astronomy what

945

00:34:53,030 --> 00:34:48,399

hubble found

946

00:34:55,669 --> 00:34:53,040

was that the universe was expanding

947

00:34:56,950 --> 00:34:55,679

and if the universe is expanding then it

948

00:35:00,069 --> 00:34:56,960

must be expanding

949

00:35:03,510 --> 00:35:00,079

from something turns out if you

950

00:35:07,030 --> 00:35:03,520

rewind the motion of all of the galaxies

951  
00:35:10,470 --> 00:35:07,040  
back by 13.8 billion years

952  
00:35:11,270 --> 00:35:10,480  
you get to a point an instant after time

953  
00:35:14,470 --> 00:35:11,280  
began

954  
00:35:15,430 --> 00:35:14,480  
where everything that we know in the

955  
00:35:18,550 --> 00:35:15,440  
universe

956  
00:35:21,030 --> 00:35:18,560  
was at a single point this

957  
00:35:23,829 --> 00:35:21,040  
is the big bang theory and it was

958  
00:35:25,750 --> 00:35:23,839  
proposed in 1927

959  
00:35:27,109 --> 00:35:25,760  
and that was kind of built on previous

960  
00:35:28,550 --> 00:35:27,119  
work

961  
00:35:30,550 --> 00:35:28,560  
and it was confirmed with hubble's

962  
00:35:33,270 --> 00:35:30,560  
findings and the hubble and hubble's law

963  
00:35:36,150 --> 00:35:33,280

in 1929

964

00:35:36,950 --> 00:35:36,160

okay so i'm now going to attempt to

965

00:35:39,670 --> 00:35:36,960

answer

966

00:35:41,349 --> 00:35:39,680

three big questions that i get all the

967

00:35:45,030 --> 00:35:41,359

time in astronomy

968

00:35:47,270 --> 00:35:45,040

from non-astronomers but in order to

969

00:35:48,150 --> 00:35:47,280

really accept the answers that i'm about

970

00:35:50,950 --> 00:35:48,160

to give

971

00:35:52,069 --> 00:35:50,960

you need to first really understand the

972

00:35:55,910 --> 00:35:52,079

limitations

973

00:35:56,870 --> 00:35:55,920

of the human brain we humans live on a

974

00:35:59,750 --> 00:35:56,880

tiny planet

975

00:36:01,589 --> 00:35:59,760

and at human size scales therefore we

976  
00:36:04,230 --> 00:36:01,599  
will never be able to fully

977  
00:36:04,950 --> 00:36:04,240  
experience all of the physics within the

978  
00:36:08,069 --> 00:36:04,960  
universe

979  
00:36:10,069 --> 00:36:08,079  
first hand and we humans like neat

980  
00:36:11,670 --> 00:36:10,079  
answers we like things that we can

981  
00:36:13,589 --> 00:36:11,680  
explain

982  
00:36:15,589 --> 00:36:13,599  
that are satisfying that makes sense to

983  
00:36:18,550 --> 00:36:15,599  
us in the world around us

984  
00:36:20,230 --> 00:36:18,560  
but in science and in astronomy the data

985  
00:36:20,870 --> 00:36:20,240  
don't always give you the answers that

986  
00:36:23,109 --> 00:36:20,880  
you want

987  
00:36:24,470 --> 00:36:23,119  
and you have to be able to accept those

988  
00:36:26,230 --> 00:36:24,480

answers

989

00:36:27,510 --> 00:36:26,240

so as we go into these following

990

00:36:29,750 --> 00:36:27,520

explanations

991

00:36:31,190 --> 00:36:29,760

first accept the limitations of the

992

00:36:33,589 --> 00:36:31,200

human brain

993

00:36:36,470 --> 00:36:33,599

so the first question i get asked often

994

00:36:39,990 --> 00:36:36,480

is if the universe is expanding

995

00:36:41,829 --> 00:36:40,000

what is it expanding into

996

00:36:44,470 --> 00:36:41,839

and i think this is actually the wrong

997

00:36:48,230 --> 00:36:44,480

way to think about this question

998

00:36:50,950 --> 00:36:48,240

our universe has four dimensions it has

999

00:36:52,710 --> 00:36:50,960

three spatial dimensions we live in a

1000

00:36:55,030 --> 00:36:52,720

three-dimensional universe

1001  
00:36:55,990 --> 00:36:55,040  
so to get to any single event within our

1002  
00:36:57,589 --> 00:36:56,000  
universe

1003  
00:36:59,589 --> 00:36:57,599  
you need to have three spatial

1004  
00:37:01,270 --> 00:36:59,599  
coordinates that could be longitude

1005  
00:37:04,710 --> 00:37:01,280  
latitude and altitude

1006  
00:37:05,910 --> 00:37:04,720  
it could be x y z you need three spatial

1007  
00:37:08,150 --> 00:37:05,920  
coordinates

1008  
00:37:09,510 --> 00:37:08,160  
and then i also need to know when an

1009  
00:37:11,030 --> 00:37:09,520  
event occurred

1010  
00:37:14,550 --> 00:37:11,040  
therefore i need to know the time that

1011  
00:37:17,109 --> 00:37:14,560  
it happened that's our fourth dimension

1012  
00:37:17,990 --> 00:37:17,119  
those dimensions are a property of our

1013  
00:37:21,510 --> 00:37:18,000

universe

1014

00:37:25,109 --> 00:37:21,520

also

1015

00:37:25,990 --> 00:37:25,119

making its own space so to think of

1016

00:37:29,270 --> 00:37:26,000

something as

1017

00:37:31,270 --> 00:37:29,280

outside of the universe doesn't actually

1018

00:37:33,990 --> 00:37:31,280

make sense because it's only within the

1019

00:37:36,790 --> 00:37:34,000

universe that space is a thing

1020

00:37:37,430 --> 00:37:36,800

so instead i like to think of it more as

1021

00:37:41,270 --> 00:37:37,440

rapid

1022

00:37:44,710 --> 00:37:41,280

construction it is creating its space

1023

00:37:47,910 --> 00:37:44,720

and as it does everything within it can

1024

00:37:48,710 --> 00:37:47,920

spread out a bit more okay second

1025

00:37:51,510 --> 00:37:48,720

question

1026  
00:37:53,589 --> 00:37:51,520  
equally unsatisfying answer the next

1027  
00:37:56,950 --> 00:37:53,599  
question i get asked a lot of the time

1028  
00:37:58,390 --> 00:37:56,960  
is well if the universe started 13.8

1029  
00:38:00,950 --> 00:37:58,400  
billion years ago

1030  
00:38:02,310 --> 00:38:00,960  
what was there before so you'll remember

1031  
00:38:03,030 --> 00:38:02,320  
that the fourth dimension of the

1032  
00:38:06,630 --> 00:38:03,040  
universe

1033  
00:38:09,829 --> 00:38:06,640  
is time without time

1034  
00:38:12,630 --> 00:38:09,839  
there is no concept of before

1035  
00:38:13,910 --> 00:38:12,640  
so if you rewind the universe right back

1036  
00:38:15,670 --> 00:38:13,920  
to the beginning

1037  
00:38:17,190 --> 00:38:15,680  
there was just the beginning if you

1038  
00:38:20,230 --> 00:38:17,200

remove the timeline

1039

00:38:22,150 --> 00:38:20,240

then you remove any notion of before as

1040

00:38:24,950 --> 00:38:22,160

we understand it in our limited

1041

00:38:26,950 --> 00:38:24,960

experiences as humans

1042

00:38:29,109 --> 00:38:26,960

and the third question i often get is

1043

00:38:32,870 --> 00:38:29,119

why why the big bang

1044

00:38:35,270 --> 00:38:32,880

why us and my answer to that is

1045

00:38:36,790 --> 00:38:35,280

that's not actually my job at that point

1046

00:38:40,390 --> 00:38:36,800

i would point you towards

1047

00:38:44,150 --> 00:38:40,400

world religions spirituality philosophy

1048

00:38:44,790 --> 00:38:44,160

and also just acceptance we may never

1049

00:38:46,470 --> 00:38:44,800

know

1050

00:38:48,390 --> 00:38:46,480

and i'm gonna throw it out there we will

1051  
00:38:51,109 --> 00:38:48,400  
never know

1052  
00:38:52,150 --> 00:38:51,119  
why we're here but does it really matter

1053  
00:38:53,990 --> 00:38:52,160  
we exist

1054  
00:38:55,589 --> 00:38:54,000  
and maybe we can just accept that

1055  
00:38:58,310 --> 00:38:55,599  
reality and be happy

1056  
00:38:59,190 --> 00:38:58,320  
but i guess i will leave that up to you

1057  
00:39:01,270 --> 00:38:59,200  
okay

1058  
00:39:03,030 --> 00:39:01,280  
so stepping back a little bit from the

1059  
00:39:04,870 --> 00:39:03,040  
more philosophical journey

1060  
00:39:07,109 --> 00:39:04,880  
that galaxies can take us on as i know

1061  
00:39:10,630 --> 00:39:07,119  
it can be a bit of a mind boggle

1062  
00:39:14,310 --> 00:39:10,640  
um and let's step back into our local

1063  
00:39:16,310 --> 00:39:14,320

environment within the universe so here

1064

00:39:18,390 --> 00:39:16,320

i'm going to show you a video which is

1065

00:39:18,870 --> 00:39:18,400

made up of all real data which i really

1066

00:39:21,750 --> 00:39:18,880

like

1067

00:39:22,950 --> 00:39:21,760

um it will be a simulated fly through of

1068

00:39:25,109 --> 00:39:22,960

our local neighborhood

1069

00:39:27,589 --> 00:39:25,119

in the galaxy and then it will it will

1070

00:39:29,589 --> 00:39:27,599

also show you get you situated

1071

00:39:31,510 --> 00:39:29,599

what's surrounding our galaxy and what's

1072

00:39:34,630 --> 00:39:31,520

nearby

1073

00:39:35,990 --> 00:39:34,640

so here we're starting looking at the um

1074

00:39:37,510 --> 00:39:36,000

plane of the milky way and we're

1075

00:39:38,390 --> 00:39:37,520

traveling towards the orion

1076

00:39:39,990 --> 00:39:38,400

constellation

1077

00:39:41,349 --> 00:39:40,000

and you'll notice that the stars within

1078

00:39:43,109 --> 00:39:41,359

orion are actually all different

1079

00:39:43,990 --> 00:39:43,119

distances so that's just a projection

1080

00:39:45,750 --> 00:39:44,000

effect

1081

00:39:47,990 --> 00:39:45,760

and we're traveling here towards the

1082

00:39:50,150 --> 00:39:48,000

orion nebula this is a nursery where

1083

00:39:51,589 --> 00:39:50,160

stars are born

1084

00:39:53,910 --> 00:39:51,599

and you can see that there's another

1085

00:39:56,310 --> 00:39:53,920

nebula in the background

1086

00:39:56,950 --> 00:39:56,320

so these and that has a dense column of

1087

00:39:59,109 --> 00:39:56,960

gas in

1088

00:40:00,950 --> 00:39:59,119

and that's called the horsehead nebula

1089

00:40:05,030 --> 00:40:00,960

so these dense columns of gas

1090

00:40:07,510 --> 00:40:05,040

form stars and we're traveling towards

1091

00:40:09,589 --> 00:40:07,520

a third nebula now this is also a

1092

00:40:10,870 --> 00:40:09,599

nursery for stars but it's a bit more

1093

00:40:13,990 --> 00:40:10,880

evolved this is the

1094

00:40:15,270 --> 00:40:14,000

rosette nebula and all of its stars have

1095

00:40:17,349 --> 00:40:15,280

since blown away

1096

00:40:18,790 --> 00:40:17,359

all the gas and dust and it creates this

1097

00:40:22,150 --> 00:40:18,800

gorgeous hollowing out so

1098

00:40:24,390 --> 00:40:22,160

kind of like a flower effect and then we

1099

00:40:27,030 --> 00:40:24,400

are traveling on to a fourth nebula

1100

00:40:28,309 --> 00:40:27,040

but this is different this like the one

1101

00:40:30,630 --> 00:40:28,319

that frank introduced

1102

00:40:31,589 --> 00:40:30,640

in the beginning is actually the site of

1103

00:40:34,150 --> 00:40:31,599

a supernova

1104

00:40:36,309 --> 00:40:34,160

this is the crab nebula and this

1105

00:40:38,069 --> 00:40:36,319

supernova went off a thousand years ago

1106

00:40:40,870 --> 00:40:38,079

and if you look very closely you can see

1107

00:40:42,870 --> 00:40:40,880

the flashing remnant of the dead star

1108

00:40:44,470 --> 00:40:42,880

so no mystery there we can see that

1109

00:40:47,109 --> 00:40:44,480

pulsar

1110

00:40:47,670 --> 00:40:47,119

so here we are lifting up out of the

1111

00:40:50,390 --> 00:40:47,680

plane

1112

00:40:51,990 --> 00:40:50,400

of the milky way and we will never

1113

00:40:53,910 --> 00:40:52,000

actually make it this far

1114

00:40:56,150 --> 00:40:53,920

in order to take a picture like this so

1115

00:40:57,670 --> 00:40:56,160

you'll see that this galaxy actually

1116

00:40:59,670 --> 00:40:57,680

turns into

1117

00:41:01,270 --> 00:40:59,680

a spiral galaxy this isn't actually our

1118

00:41:03,750 --> 00:41:01,280

milky way but it's what we think

1119

00:41:04,309 --> 00:41:03,760

the galaxy might look a bit like and

1120

00:41:06,630 --> 00:41:04,319

you'll see

1121

00:41:07,750 --> 00:41:06,640

the magellanic clouds again that we saw

1122

00:41:09,910 --> 00:41:07,760

earlier

1123

00:41:12,150 --> 00:41:09,920

and we now zoom out to the local

1124

00:41:13,190 --> 00:41:12,160

environment of our galaxy so we're going

1125

00:41:15,910 --> 00:41:13,200

to spin around

1126

00:41:17,990 --> 00:41:15,920

and you will see our massive neighbor

1127

00:41:20,150 --> 00:41:18,000

the andromeda galaxy

1128

00:41:21,430 --> 00:41:20,160

and our smaller neighbor the triangulum

1129

00:41:24,150 --> 00:41:21,440

galaxy

1130

00:41:24,550 --> 00:41:24,160

and we're going to pass through the um

1131

00:41:26,550 --> 00:41:24,560

disc

1132

00:41:28,710 --> 00:41:26,560

of the triangulum galaxy through one

1133

00:41:31,349 --> 00:41:28,720

another star forming region

1134

00:41:32,470 --> 00:41:31,359

and we know that the andromeda galaxy is

1135

00:41:35,750 --> 00:41:32,480

2.5

1136

00:41:37,750 --> 00:41:35,760

million light years from earth so you'll

1137

00:41:38,870 --> 00:41:37,760

notice there are many points of light in

1138

00:41:42,309 --> 00:41:38,880

the background

1139

00:41:43,829 --> 00:41:42,319

each of these is a whole galaxy

1140

00:41:45,430 --> 00:41:43,839

but you'll notice that these aren't

1141

00:41:48,870 --> 00:41:45,440

evenly distributed

1142

00:41:52,069 --> 00:41:48,880

there's a massive clump of of galaxies

1143

00:41:54,470 --> 00:41:52,079

this is the virgo cluster and

1144

00:41:55,829 --> 00:41:54,480

also you can see that there's massive

1145

00:41:57,349 --> 00:41:55,839

areas of the sky with

1146

00:41:59,030 --> 00:41:57,359

really very little in this is what we

1147

00:42:00,710 --> 00:41:59,040

call voids and then you can see these

1148

00:42:02,470 --> 00:42:00,720

kind of strings of galaxies

1149

00:42:04,069 --> 00:42:02,480

feeding into that cluster and these are

1150

00:42:06,150 --> 00:42:04,079

filaments

1151

00:42:07,190 --> 00:42:06,160

so as we now spin around the virgo

1152

00:42:09,270 --> 00:42:07,200

cluster

1153

00:42:11,109 --> 00:42:09,280

you can see that there are different

1154

00:42:14,470 --> 00:42:11,119

types of galaxies that we can

1155

00:42:15,510 --> 00:42:14,480

observe and as we travel through the

1156

00:42:17,829 --> 00:42:15,520

filament

1157

00:42:18,550 --> 00:42:17,839

in towards the center of the cluster you

1158

00:42:20,470 --> 00:42:18,560

can see

1159

00:42:21,990 --> 00:42:20,480

that a lot of the galaxies in that

1160

00:42:24,550 --> 00:42:22,000

filament in the outskirts

1161

00:42:25,910 --> 00:42:24,560

are spiral disc galaxies much like our

1162

00:42:28,150 --> 00:42:25,920

own and andromeda

1163

00:42:29,510 --> 00:42:28,160

but the closer in we get to the center

1164

00:42:31,510 --> 00:42:29,520

of the virgo cluster

1165

00:42:33,190 --> 00:42:31,520

the galaxies actually start to change a

1166

00:42:36,230 --> 00:42:33,200

bit into more of these

1167

00:42:38,630 --> 00:42:36,240

orbs of stars and we finish here

1168

00:42:39,630 --> 00:42:38,640

on the virgo clusters brightest cluster

1169

00:42:44,950 --> 00:42:39,640

galaxy

1170

00:42:49,910 --> 00:42:44,960

m87 and that name may be familiar to you

1171

00:42:52,950 --> 00:42:49,920

so m87 uh back in april 2019

1172

00:42:56,710 --> 00:42:52,960

the supermassive black hole within

1173

00:42:57,190 --> 00:42:56,720

m87 became the first to be directly

1174

00:43:01,510 --> 00:42:57,200

image

1175

00:43:03,829 --> 00:43:01,520

horizon telescope

1176  
00:43:06,390 --> 00:43:03,839  
so supermassive black holes and their

1177  
00:43:08,230 --> 00:43:06,400  
galaxies are a fascinating subject

1178  
00:43:10,470 --> 00:43:08,240  
i won't be going into more detail here

1179  
00:43:13,190 --> 00:43:10,480  
but i highly recommend you check out

1180  
00:43:14,069 --> 00:43:13,200  
my color my colleagues talk dr mitch

1181  
00:43:16,790 --> 00:43:14,079  
rivolsky

1182  
00:43:17,670 --> 00:43:16,800  
he gave a talk in the same series back

1183  
00:43:19,190 --> 00:43:17,680  
in december

1184  
00:43:21,990 --> 00:43:19,200  
and he'll be going into a lot more

1185  
00:43:23,190 --> 00:43:22,000  
detail on on the connection between

1186  
00:43:25,750 --> 00:43:23,200  
galaxies

1187  
00:43:27,670 --> 00:43:25,760  
and their supermassive black holes i'd

1188  
00:43:28,069 --> 00:43:27,680

also like to give another plug for a

1189

00:43:30,550 --> 00:43:28,079

talk

1190

00:43:32,870 --> 00:43:30,560

if you haven't already seen it this was

1191

00:43:36,150 --> 00:43:32,880

a talk by raja gahatakerta

1192

00:43:37,829 --> 00:43:36,160

just a couple of weeks ago and as frank

1193

00:43:39,430 --> 00:43:37,839

mentioned raja was actually a previous

1194

00:43:41,349 --> 00:43:39,440

supervisor for me

1195

00:43:42,550 --> 00:43:41,359

back at the university of california

1196

00:43:44,150 --> 00:43:42,560

santa cruz

1197

00:43:46,550 --> 00:43:44,160

so we worked on a couple of different

1198

00:43:47,270 --> 00:43:46,560

projects one involving stars in the

1199

00:43:49,990 --> 00:43:47,280

milky way

1200

00:43:50,790 --> 00:43:50,000

and another involving stars in andromeda

1201

00:43:53,829 --> 00:43:50,800

and this is really

1202

00:43:55,510 --> 00:43:53,839

raj's expertise so you'll notice given

1203

00:43:57,430 --> 00:43:55,520

the overlap in our interests i'll be

1204

00:44:00,150 --> 00:43:57,440

touching on a couple of similar themes

1205

00:44:01,430 --> 00:44:00,160

to raja but i would definitely recommend

1206

00:44:03,430 --> 00:44:01,440

going to check out raja's

1207

00:44:04,470 --> 00:44:03,440

talk to learn more about our place in

1208

00:44:06,870 --> 00:44:04,480

the cosmos

1209

00:44:08,069 --> 00:44:06,880

black holes gravitational waves and also

1210

00:44:10,550 --> 00:44:08,079

the evolution of the universe

1211

00:44:12,710 --> 00:44:10,560

from those very early stages through to

1212

00:44:15,910 --> 00:44:12,720

where we are today

1213

00:44:18,630 --> 00:44:15,920

so back to classifying galaxies

1214

00:44:19,030 --> 00:44:18,640

so hubble and others spent a lot of time

1215

00:44:20,870 --> 00:44:19,040

looking

1216

00:44:22,950 --> 00:44:20,880

at the different types of galaxies that

1217

00:44:24,790 --> 00:44:22,960

we see in the universe

1218

00:44:25,990 --> 00:44:24,800

and as we saw a little bit in the video

1219

00:44:29,109 --> 00:44:26,000

and that's very clear

1220

00:44:31,030 --> 00:44:29,119

in this image is that you get different

1221

00:44:33,750 --> 00:44:31,040

types of galaxies you get these

1222

00:44:35,109 --> 00:44:33,760

orbs of stars and they tend to be more

1223

00:44:36,950 --> 00:44:35,119

yellow and red

1224

00:44:38,230 --> 00:44:36,960

they're like giant footballs and that

1225

00:44:40,950 --> 00:44:38,240

applies to both us

1226

00:44:41,910 --> 00:44:40,960

and uk football and then in the

1227

00:44:44,710 --> 00:44:41,920

outskirts

1228

00:44:46,150 --> 00:44:44,720

you get to see more spiral galaxies the

1229

00:44:50,150 --> 00:44:46,160

these intricate

1230

00:44:53,349 --> 00:44:50,160

um galaxies like our own milky way

1231

00:44:55,589 --> 00:44:53,359

so i like to think of

1232

00:44:57,589 --> 00:44:55,599

the kind of galaxies towards the center

1233

00:44:57,990 --> 00:44:57,599

of these massive clusters that's kind of

1234

00:45:00,069 --> 00:44:58,000

like

1235

00:45:01,109 --> 00:45:00,079

city living so these are busier

1236

00:45:03,430 --> 00:45:01,119

environments

1237

00:45:04,950 --> 00:45:03,440

they're denser and there tends to be

1238

00:45:07,589 --> 00:45:04,960

more rapid evolution

1239

00:45:09,190 --> 00:45:07,599

compared to the field around dense

1240

00:45:11,589 --> 00:45:09,200

cluster environments

1241

00:45:13,030 --> 00:45:11,599

this is more like country living so

1242

00:45:16,150 --> 00:45:13,040

slower paced

1243

00:45:17,990 --> 00:45:16,160

calmer and slightly slower evolution

1244

00:45:19,910 --> 00:45:18,000

we know that where a human grows up

1245

00:45:22,150 --> 00:45:19,920

affects their evolution

1246

00:45:23,510 --> 00:45:22,160

and the same is true for galaxies where

1247

00:45:26,309 --> 00:45:23,520

a galaxy lives

1248

00:45:27,990 --> 00:45:26,319

i.e how many other galaxies live live

1249

00:45:30,950 --> 00:45:28,000

around it its environment

1250

00:45:31,990 --> 00:45:30,960

affects how you get the different shapes

1251

00:45:35,829 --> 00:45:32,000

and sizes and

1252

00:45:38,630 --> 00:45:35,839

colors so how do you actually

1253

00:45:40,309 --> 00:45:38,640

form these different types of galaxies

1254

00:45:42,470 --> 00:45:40,319

well this is the study of galaxy

1255

00:45:44,790 --> 00:45:42,480

evolution that i work on

1256

00:45:46,790 --> 00:45:44,800

and this is far from solved but we do

1257

00:45:49,750 --> 00:45:46,800

have a few clues

1258

00:45:52,069 --> 00:45:49,760

so first i will go into a couple of very

1259

00:45:54,069 --> 00:45:52,079

simplistic examples of the differences

1260

00:45:55,349 --> 00:45:54,079

between these two types of galaxies that

1261

00:45:57,670 --> 00:45:55,359

we see

1262

00:45:59,109 --> 00:45:57,680

here is a very simplistic model of what

1263

00:46:02,230 --> 00:45:59,119

one of these elliptical

1264

00:46:05,670 --> 00:46:02,240

orbs of stars these elliptical galaxies

1265

00:46:07,910 --> 00:46:05,680

looks like so this is actually a very

1266

00:46:08,950 --> 00:46:07,920

tiny system and you can tell it's small

1267

00:46:12,069 --> 00:46:08,960

because you can actually

1268

00:46:13,349 --> 00:46:12,079

see all of its individual stars now

1269

00:46:15,750 --> 00:46:13,359

broadly speaking

1270

00:46:17,270 --> 00:46:15,760

you can't because of the scales of space

1271

00:46:19,430 --> 00:46:17,280

you can't actually observe

1272

00:46:22,950 --> 00:46:19,440

individual stars in other galaxies

1273

00:46:24,790 --> 00:46:22,960

beyonce the brightest in andromeda

1274

00:46:26,470 --> 00:46:24,800

but this very small system is something

1275

00:46:27,109 --> 00:46:26,480

called a globular cluster and these

1276

00:46:29,670 --> 00:46:27,119

exist

1277

00:46:30,150 --> 00:46:29,680

within spiral galaxies this one is in a

1278

00:46:36,950 --> 00:46:30,160

it

1279

00:46:39,510 --> 00:46:36,960

in such great detail

1280

00:46:41,589 --> 00:46:39,520

but the reason why i pull this example

1281

00:46:43,430 --> 00:46:41,599

up to explain elliptical galaxies is you

1282

00:46:44,069 --> 00:46:43,440

can really clearly see what's happening

1283

00:46:46,790 --> 00:46:44,079

here

1284

00:46:47,670 --> 00:46:46,800

these individual stars are yellow and

1285

00:46:49,910 --> 00:46:47,680

red

1286

00:46:50,870 --> 00:46:49,920

that means they're very small and

1287

00:46:53,589 --> 00:46:50,880

they're old

1288

00:46:54,390 --> 00:46:53,599

and they're cool in astronomy red means

1289

00:46:56,390 --> 00:46:54,400

cool

1290

00:46:57,990 --> 00:46:56,400

so these are long-lived stars they've

1291

00:46:58,470 --> 00:46:58,000

been around for a long time and you can

1292

00:47:00,550 --> 00:46:58,480

see

1293

00:47:01,670 --> 00:47:00,560

there's no dust or gas within this

1294

00:47:04,470 --> 00:47:01,680

system it's

1295

00:47:05,910 --> 00:47:04,480

long since stopped forming stars and

1296

00:47:08,550 --> 00:47:05,920

you're really just left with this kind

1297

00:47:11,589 --> 00:47:08,560

of simple orb of stars

1298

00:47:14,630 --> 00:47:11,599

and here is a very simplistic view

1299

00:47:15,349 --> 00:47:14,640

of what a star from the galaxy a spiral

1300

00:47:17,589 --> 00:47:15,359

galaxy

1301  
00:47:18,630 --> 00:47:17,599  
might look like so this is not actually

1302  
00:47:20,630 --> 00:47:18,640  
a galaxy at all

1303  
00:47:22,150 --> 00:47:20,640  
it's smaller than even the globular

1304  
00:47:23,670 --> 00:47:22,160  
cluster we were looking at this is just

1305  
00:47:26,549 --> 00:47:23,680  
one star forming region

1306  
00:47:27,030 --> 00:47:26,559  
within the magellanic clouds so as you

1307  
00:47:29,270 --> 00:47:27,040  
can see

1308  
00:47:30,150 --> 00:47:29,280  
these are very beautiful they contain

1309  
00:47:34,309 --> 00:47:30,160  
bright

1310  
00:47:37,349 --> 00:47:34,319  
blue stars really massive stars

1311  
00:47:40,710 --> 00:47:37,359  
and in astronomy blue is hot

1312  
00:47:42,309 --> 00:47:40,720  
so these massive stars live fast and die

1313  
00:47:44,069 --> 00:47:42,319

young like james dean

1314

00:47:46,309 --> 00:47:44,079

so they die in millions of years

1315

00:47:48,790 --> 00:47:46,319

compared to the billions of years

1316

00:47:49,750 --> 00:47:48,800

of those smaller redder stars and as a

1317

00:47:52,790 --> 00:47:49,760

result

1318

00:47:53,349 --> 00:47:52,800

they're often so close to this the

1319

00:47:55,829 --> 00:47:53,359

parent

1320

00:47:57,910 --> 00:47:55,839

cloud from which they were formed and

1321

00:47:58,950 --> 00:47:57,920

they've heated up that material that you

1322

00:48:01,349 --> 00:47:58,960

can see

1323

00:48:02,549 --> 00:48:01,359

and that gas and dust starts to glow and

1324

00:48:04,630 --> 00:48:02,559

this is what gives

1325

00:48:08,309 --> 00:48:04,640

these amazing colors and makes these

1326

00:48:11,430 --> 00:48:10,790

so how do we get from these very

1327

00:48:13,270 --> 00:48:11,440

intricate

1328

00:48:14,790 --> 00:48:13,280

spiral galaxies with a lot of these

1329

00:48:16,630 --> 00:48:14,800

star-forming galax

1330

00:48:17,990 --> 00:48:16,640

star-forming regions and bright blue

1331

00:48:20,549 --> 00:48:18,000

stars that's what gives them that kind

1332

00:48:21,349 --> 00:48:20,559

of overall blue appearance to these more

1333

00:48:24,950 --> 00:48:21,359

simplistic

1334

00:48:26,630 --> 00:48:24,960

smooth you know old systems that we see

1335

00:48:28,150 --> 00:48:26,640

well the first thing we have to do is

1336

00:48:30,069 --> 00:48:28,160

remove the dust and gas

1337

00:48:31,430 --> 00:48:30,079

in those systems so they can stop

1338

00:48:34,230 --> 00:48:31,440

forming new stars

1339

00:48:36,069 --> 00:48:34,240

and one way to do this is to throw two

1340

00:48:39,190 --> 00:48:36,079

spirals together

1341

00:48:41,589 --> 00:48:39,200

so when two spiral galaxies collide

1342

00:48:43,430 --> 00:48:41,599

you can get a collision with the gas

1343

00:48:45,510 --> 00:48:43,440

this sparks a lot of rapid star

1344

00:48:46,309 --> 00:48:45,520

formation and you can use up that fuel

1345

00:48:49,510 --> 00:48:46,319

very quickly

1346

00:48:52,230 --> 00:48:49,520

in order to form all new stars but then

1347

00:48:53,990 --> 00:48:52,240

but then that's it and also as two

1348

00:48:56,069 --> 00:48:54,000

galaxies collide they will be

1349

00:48:57,750 --> 00:48:56,079

tearing each other apart and material

1350

00:48:58,390 --> 00:48:57,760

will be flung out into space so you can

1351  
00:49:01,349 --> 00:48:58,400  
expel

1352  
00:49:02,150 --> 00:49:01,359  
a lot of the material as well so here's

1353  
00:49:04,309 --> 00:49:02,160  
a simulation

1354  
00:49:06,950 --> 00:49:04,319  
of just that happening two spiral

1355  
00:49:09,510 --> 00:49:06,960  
galaxies coming together under gravity

1356  
00:49:10,630 --> 00:49:09,520  
tearing each other apart and they fall

1357  
00:49:13,910 --> 00:49:10,640  
together

1358  
00:49:16,390 --> 00:49:13,920  
to form one system but this takes

1359  
00:49:18,069 --> 00:49:16,400  
billions of years which is much longer

1360  
00:49:19,750 --> 00:49:18,079  
than a human lifetime

1361  
00:49:21,670 --> 00:49:19,760  
how do we actually know that this this

1362  
00:49:24,549 --> 00:49:21,680  
process occurs

1363  
00:49:25,190 --> 00:49:24,559

well there's many examples in space um

1364

00:49:27,030 --> 00:49:25,200

and there's

1365

00:49:28,230 --> 00:49:27,040

fairly damning evidence when you piece

1366

00:49:31,270 --> 00:49:28,240

together all of the

1367

00:49:32,870 --> 00:49:31,280

examples that we have here's just four

1368

00:49:34,790 --> 00:49:32,880

classic examples

1369

00:49:37,510 --> 00:49:34,800

so in space we can see that there are

1370

00:49:39,829 --> 00:49:37,520

spiral galaxies very close to each other

1371

00:49:40,950 --> 00:49:39,839

we then see spiral galaxies start to

1372

00:49:43,030 --> 00:49:40,960

interact

1373

00:49:44,470 --> 00:49:43,040

um but we can still very much tell what

1374

00:49:45,030 --> 00:49:44,480

they are but that they're disturbing

1375

00:49:46,390 --> 00:49:45,040

each other

1376  
00:49:47,430 --> 00:49:46,400  
and then you have something like in the

1377  
00:49:49,430 --> 00:49:47,440  
bottom left where they're just

1378  
00:49:51,349 --> 00:49:49,440  
completely tearing each other apart

1379  
00:49:52,470 --> 00:49:51,359  
and you can see these sparks of star

1380  
00:49:54,549 --> 00:49:52,480  
formation

1381  
00:49:56,549 --> 00:49:54,559  
and then we have the image in the bottom

1382  
00:49:58,069 --> 00:49:56,559  
right there where you're starting to see

1383  
00:50:01,030 --> 00:49:58,079  
something a lot like these

1384  
00:50:02,230 --> 00:50:01,040  
old stellar systems so really just those

1385  
00:50:05,270 --> 00:50:02,240  
orb like

1386  
00:50:07,430 --> 00:50:05,280  
yellow red stars but you can still see

1387  
00:50:08,790 --> 00:50:07,440  
that those spiral arms where the blue

1388  
00:50:10,870 --> 00:50:08,800

stars were formed

1389

00:50:13,190 --> 00:50:10,880

you can tell that it was very recently a

1390

00:50:15,349 --> 00:50:13,200

spiral

1391

00:50:16,710 --> 00:50:15,359

so what does this mean for our galaxy

1392

00:50:19,270 --> 00:50:16,720

the milky way

1393

00:50:20,230 --> 00:50:19,280

i told you earlier that the universe is

1394

00:50:24,470 --> 00:50:20,240

expanding

1395

00:50:27,109 --> 00:50:24,480

so why then do galaxies fall together

1396

00:50:28,069 --> 00:50:27,119

so this is just an artist's impression

1397

00:50:29,750 --> 00:50:28,079

of the milky way

1398

00:50:31,910 --> 00:50:29,760

we will never make it this far as we're

1399

00:50:34,950 --> 00:50:31,920

stuck within the disc by gravity

1400

00:50:38,230 --> 00:50:34,960

of of the milky way

1401  
00:50:41,589 --> 00:50:38,240  
um so the forces that hold together

1402  
00:50:44,230 --> 00:50:41,599  
the human body are much

1403  
00:50:46,710 --> 00:50:44,240  
stronger than the pull of the expansion

1404  
00:50:50,390 --> 00:50:46,720  
of the universe so we as humans are

1405  
00:50:52,950 --> 00:50:50,400  
aren't expanding also the earth

1406  
00:50:55,670 --> 00:50:52,960  
stays orbiting the same distance around

1407  
00:50:58,069 --> 00:50:55,680  
the sun because the forces of gravity

1408  
00:50:59,349 --> 00:50:58,079  
on the scale of the solar system are

1409  
00:51:02,710 --> 00:50:59,359  
much stronger

1410  
00:51:03,670 --> 00:51:02,720  
than the pull of the universe at those

1411  
00:51:05,829 --> 00:51:03,680  
scales

1412  
00:51:08,230 --> 00:51:05,839  
and even at larger distances so like we

1413  
00:51:10,150 --> 00:51:08,240

saw those large collections of galaxies

1414

00:51:11,750 --> 00:51:10,160

like in the virgo cluster they're all

1415

00:51:13,910 --> 00:51:11,760

held together by gravity

1416

00:51:15,270 --> 00:51:13,920

and that gravity is stronger than the

1417

00:51:17,270 --> 00:51:15,280

pull of the universe

1418

00:51:18,790 --> 00:51:17,280

on those scales so it's all about

1419

00:51:21,430 --> 00:51:18,800

balancing the scales

1420

00:51:21,990 --> 00:51:21,440

at some point the distances between

1421

00:51:25,270 --> 00:51:22,000

objects

1422

00:51:27,109 --> 00:51:25,280

becomes so large that gravity

1423

00:51:29,589 --> 00:51:27,119

doesn't become the dominant force and

1424

00:51:31,990 --> 00:51:29,599

the pull of the universe that expansion

1425

00:51:32,870 --> 00:51:32,000

can take over as the dominant force and

1426  
00:51:35,510 --> 00:51:32,880  
it's really at those

1427  
00:51:36,870 --> 00:51:35,520  
large distances that you start to see

1428  
00:51:38,950 --> 00:51:36,880  
things flying apart

1429  
00:51:41,430 --> 00:51:38,960  
and this is what hubble measured at

1430  
00:51:43,910 --> 00:51:41,440  
those great distances

1431  
00:51:45,430 --> 00:51:43,920  
but in our local neighborhood however

1432  
00:51:48,150 --> 00:51:45,440  
when you look at our large

1433  
00:51:48,549 --> 00:51:48,160  
neighbor andromeda we can measure that

1434  
00:51:51,990 --> 00:51:48,559  
it is

1435  
00:51:55,349 --> 00:51:52,000  
hurtling towards us at 250

1436  
00:51:58,470 --> 00:51:55,359  
000 miles per hour the pull of gravity

1437  
00:52:00,710 --> 00:51:58,480  
is pulling us towards andromeda and we

1438  
00:52:02,950 --> 00:52:00,720

are on a direct collision course

1439

00:52:05,109 --> 00:52:02,960

that will start to occur in around 4

1440

00:52:08,230 --> 00:52:05,119

billion years time

1441

00:52:10,150 --> 00:52:08,240

so what will this actually look like so

1442

00:52:13,270 --> 00:52:10,160

here's a simulation of that process

1443

00:52:16,630 --> 00:52:13,280

you can see that the milky way is

1444

00:52:19,109 --> 00:52:16,640

spinning here and as we zoom out we see

1445

00:52:20,950 --> 00:52:19,119

our neighbors in the local group we see

1446

00:52:28,150 --> 00:52:20,960

the andromeda galaxy

1447

00:52:32,790 --> 00:52:30,069

so you can see here andromeda is

1448

00:52:35,430 --> 00:52:32,800

hurtling towards the milky way

1449

00:52:36,710 --> 00:52:35,440

but this is on scales of billions of

1450

00:52:39,829 --> 00:52:36,720

years

1451  
00:52:41,510 --> 00:52:39,839  
so as the two galaxies begin to interact

1452  
00:52:43,829 --> 00:52:41,520  
you'll see that they do this dance and

1453  
00:52:46,390 --> 00:52:43,839  
they start tearing each other apart

1454  
00:52:48,150 --> 00:52:46,400  
and they come together to form one

1455  
00:52:50,470 --> 00:52:48,160  
single galaxy

1456  
00:52:51,990 --> 00:52:50,480  
you'll also notice that the color of the

1457  
00:52:54,230 --> 00:52:52,000  
galaxy is changing

1458  
00:52:55,109 --> 00:52:54,240  
so this is using up all that dust and

1459  
00:52:56,950 --> 00:52:55,119  
gas so these

1460  
00:52:58,470 --> 00:52:56,960  
young hot blue stars are stopped

1461  
00:53:00,710 --> 00:52:58,480  
stopping to be formed

1462  
00:53:02,390 --> 00:53:00,720  
and you're left with the light from the

1463  
00:53:04,309 --> 00:53:02,400

red small

1464

00:53:05,670 --> 00:53:04,319

long-lived stars that live for billions

1465

00:53:07,430 --> 00:53:05,680

of years

1466

00:53:09,829 --> 00:53:07,440

and it will just continue to collapse

1467

00:53:13,510 --> 00:53:09,839

down to form a single

1468

00:53:15,750 --> 00:53:13,520

galaxy so what will this amazing process

1469

00:53:16,630 --> 00:53:15,760

actually look like on earth and what

1470

00:53:20,390 --> 00:53:16,640

would it mean

1471

00:53:22,630 --> 00:53:20,400

for us on earth so

1472

00:53:24,549 --> 00:53:22,640

here is the band of the milky way the

1473

00:53:25,750 --> 00:53:24,559

andromeda galaxy and the triangulum

1474

00:53:28,470 --> 00:53:25,760

galaxy

1475

00:53:32,230 --> 00:53:28,480

and you can see that in about 3.75

1476  
00:53:33,670 --> 00:53:32,240  
billion years we are in for a real treat

1477  
00:53:35,829 --> 00:53:33,680  
in four billion years when the two

1478  
00:53:37,349 --> 00:53:35,839  
galaxies begin to interact the sky will

1479  
00:53:40,309 --> 00:53:37,359  
change dramatically

1480  
00:53:42,309 --> 00:53:40,319  
and in six billion years the two will

1481  
00:53:43,190 --> 00:53:42,319  
collapse together to form a single

1482  
00:53:45,030 --> 00:53:43,200  
galaxy

1483  
00:53:47,270 --> 00:53:45,040  
with a very comical name that i love

1484  
00:53:49,349 --> 00:53:47,280  
milk dromeda

1485  
00:53:51,349 --> 00:53:49,359  
so you can see that this process will

1486  
00:53:54,309 --> 00:53:51,359  
look amazing from earth

1487  
00:53:55,910 --> 00:53:54,319  
and it will result in this single galaxy

1488  
00:53:57,549 --> 00:53:55,920

the night sky will look incredibly

1489

00:54:01,030 --> 00:53:57,559

different we will have all new

1490

00:54:04,309 --> 00:54:03,829

and this will all occur between the next

1491

00:54:10,390 --> 00:54:04,319

four

1492

00:54:12,790 --> 00:54:10,400

so it's really the gas within these

1493

00:54:13,430 --> 00:54:12,800

galaxy collisions that make them look so

1494

00:54:15,190 --> 00:54:13,440

dramatic

1495

00:54:17,030 --> 00:54:15,200

and this you can see in the andromeda

1496

00:54:18,710 --> 00:54:17,040

galaxy where these two

1497

00:54:21,030 --> 00:54:18,720

sorry in the antennae galaxy as i'm

1498

00:54:22,230 --> 00:54:21,040

showing here when these two galaxies

1499

00:54:24,309 --> 00:54:22,240

come together

1500

00:54:26,390 --> 00:54:24,319

this collision this collision of the gas

1501  
00:54:28,069 --> 00:54:26,400  
sparks this star formation and it looks

1502  
00:54:31,589 --> 00:54:28,079  
very dramatic

1503  
00:54:35,190 --> 00:54:31,599  
but the separation of the stars

1504  
00:54:37,510 --> 00:54:35,200  
in galaxies is so great that actually

1505  
00:54:38,470 --> 00:54:37,520  
even in this collision of hundreds of

1506  
00:54:42,230 --> 00:54:38,480  
billions or even

1507  
00:54:45,349 --> 00:54:42,240  
trillions of stars it's very unlikely

1508  
00:54:47,670 --> 00:54:45,359  
that even two stars will interact

1509  
00:54:49,349 --> 00:54:47,680  
they will likely just sail right past

1510  
00:54:52,630 --> 00:54:49,359  
each other

1511  
00:54:55,270 --> 00:54:52,640  
so in order to really grasp the vast

1512  
00:54:56,630 --> 00:54:55,280  
scales of space let's take a look at

1513  
00:55:00,630 --> 00:54:56,640

something more familiar

1514

00:55:04,710 --> 00:55:00,640

let's start with our sun and earth

1515

00:55:06,870 --> 00:55:04,720

so our sun is 4.6 billion years old

1516

00:55:09,190 --> 00:55:06,880

our earth formed soon after that around

1517

00:55:11,829 --> 00:55:09,200

4.5 billion years ago

1518

00:55:13,030 --> 00:55:11,839

and our sun is a very average star it's

1519

00:55:15,270 --> 00:55:13,040

in the middle of its life

1520

00:55:17,589 --> 00:55:15,280

it's very steady it's stable it's one of

1521

00:55:20,630 --> 00:55:17,599

these long-lived ones and it's perfect

1522

00:55:23,910 --> 00:55:20,640

for life we now know

1523

00:55:25,030 --> 00:55:23,920

that most stars have at least one planet

1524

00:55:28,069 --> 00:55:25,040

around them

1525

00:55:29,910 --> 00:55:28,079

so that means of just within our galaxy

1526  
00:55:31,990 --> 00:55:29,920  
the milky way

1527  
00:55:33,190 --> 00:55:32,000  
hundreds of the hundreds of billions of

1528  
00:55:35,030 --> 00:55:33,200  
stars

1529  
00:55:36,470 --> 00:55:35,040  
most of them will have at least one

1530  
00:55:39,349 --> 00:55:36,480  
planet

1531  
00:55:41,190 --> 00:55:39,359  
those numbers are huge so with all of

1532  
00:55:43,349 --> 00:55:41,200  
those planets out there

1533  
00:55:46,069 --> 00:55:43,359  
what are the chances that there will be

1534  
00:55:49,430 --> 00:55:46,079  
intelligent life within our galaxy

1535  
00:55:51,349 --> 00:55:49,440  
i would say pretty high

1536  
00:55:52,950 --> 00:55:51,359  
but what are the chances that we will

1537  
00:55:56,069 --> 00:55:52,960  
actually be able to interact

1538  
00:55:59,270 --> 00:55:56,079

with those with any intelligent life

1539

00:56:00,630 --> 00:55:59,280

i would say that's pretty slim and here

1540

00:56:03,990 --> 00:56:00,640

is why

1541

00:56:06,470 --> 00:56:04,000

i think often the concept of earth 2.0

1542

00:56:07,270 --> 00:56:06,480

gets talked about a lot a place that we

1543

00:56:09,990 --> 00:56:07,280

can go to

1544

00:56:11,750 --> 00:56:10,000

when this planet dies and this has

1545

00:56:13,910 --> 00:56:11,760

certainly been the subject of a lot of

1546

00:56:15,990 --> 00:56:13,920

sci-fi films

1547

00:56:17,829 --> 00:56:16,000

and i think it's good to have goals but

1548

00:56:18,950 --> 00:56:17,839

i think it's also good to put this

1549

00:56:22,549 --> 00:56:18,960

particular goal

1550

00:56:24,870 --> 00:56:22,559

in context so let's start with just the

1551

00:56:27,190 --> 00:56:24,880

nearest stars to us

1552

00:56:28,630 --> 00:56:27,200

so our nearest star is a star called

1553

00:56:30,390 --> 00:56:28,640

proxima centauri

1554

00:56:33,750 --> 00:56:30,400

and it's actually just this tiny red

1555

00:56:37,190 --> 00:56:33,760

star just off to the bottom right here

1556

00:56:39,349 --> 00:56:37,200

this very small star is 4.2 light years

1557

00:56:42,230 --> 00:56:39,359

from earth

1558

00:56:44,309 --> 00:56:42,240

it orbits around a double star system

1559

00:56:47,589 --> 00:56:44,319

and their names are alpha centauri

1560

00:56:49,910 --> 00:56:47,599

a and b does a double star system bring

1561

00:56:53,109 --> 00:56:49,920

anything to mind for people

1562

00:56:55,829 --> 00:56:53,119

so this is tatooine from star wars

1563

00:56:56,549 --> 00:56:55,839

and if you live on a planet with a

1564

00:56:58,950 --> 00:56:56,559

doubles

1565

00:57:00,870 --> 00:56:58,960

with in a double star system and that

1566

00:57:02,870 --> 00:57:00,880

actually may be quite common

1567

00:57:05,670 --> 00:57:02,880

you could walk off into a double star

1568

00:57:08,630 --> 00:57:05,680

sunset just like luke skywalker here

1569

00:57:10,789 --> 00:57:08,640

so proxima centauri is the third star in

1570

00:57:13,510 --> 00:57:10,799

this triple star system

1571

00:57:14,870 --> 00:57:13,520

and we know that proxima centauri has a

1572

00:57:18,150 --> 00:57:14,880

planet around it

1573

00:57:20,950 --> 00:57:18,160

so we can just go there well

1574

00:57:21,750 --> 00:57:20,960

rather you than me this is proxima

1575

00:57:24,710 --> 00:57:21,760

centauri

1576  
00:57:25,190 --> 00:57:24,720  
and it's planet proxima b so a reminder

1577  
00:57:28,470 --> 00:57:25,200  
that this

1578  
00:57:29,829 --> 00:57:28,480  
is an artist's impression we have not

1579  
00:57:33,109 --> 00:57:29,839  
been able to take a picture

1580  
00:57:34,789 --> 00:57:33,119  
anywhere like this um and we probably

1581  
00:57:37,750 --> 00:57:34,799  
never will

1582  
00:57:39,910 --> 00:57:37,760  
so proxima centauri is a very small star

1583  
00:57:41,349 --> 00:57:39,920  
it's around a tenth of the size of our

1584  
00:57:43,990 --> 00:57:41,359  
sun

1585  
00:57:45,030 --> 00:57:44,000  
and it's incredibly unstable because

1586  
00:57:47,829 --> 00:57:45,040  
it's so small

1587  
00:57:49,349 --> 00:57:47,839  
it's in a constant battle to produce

1588  
00:57:51,510 --> 00:57:49,359

enough radiative energy

1589

00:57:52,870 --> 00:57:51,520

to be able to support its own weight

1590

00:57:55,190 --> 00:57:52,880

under gravity

1591

00:57:57,430 --> 00:57:55,200

so it's constantly fluctuating and as a

1592

00:58:00,870 --> 00:57:57,440

result it regularly produces

1593

00:58:03,750 --> 00:58:00,880

massive flares of dangerous radiation

1594

00:58:04,950 --> 00:58:03,760

and with proxima b being as close as it

1595

00:58:07,109 --> 00:58:04,960

is to the star

1596

00:58:11,270 --> 00:58:07,119

if any life might have lived there in

1597

00:58:13,030 --> 00:58:11,280

the past it's long since been fried

1598

00:58:15,990 --> 00:58:13,040

so we know that this is a highly

1599

00:58:19,270 --> 00:58:16,000

inhospitable planet to humans

1600

00:58:22,069 --> 00:58:19,280

and this is like a hot dusty rock

1601  
00:58:22,870 --> 00:58:22,079  
so a far cry from our oasis here on

1602  
00:58:25,270 --> 00:58:22,880  
earth

1603  
00:58:27,349 --> 00:58:25,280  
i imagine proxima b to be something like

1604  
00:58:27,670 --> 00:58:27,359  
this scene from mad max with these kind

1605  
00:58:30,710 --> 00:58:27,680  
of

1606  
00:58:34,069 --> 00:58:30,720  
massive dust storms that you get

1607  
00:58:35,589 --> 00:58:34,079  
so you know not ideal but hey just if we

1608  
00:58:38,630 --> 00:58:35,599  
wanted to go and check it out

1609  
00:58:40,390 --> 00:58:38,640  
how long would it take to get there so i

1610  
00:58:43,349 --> 00:58:40,400  
think first it's important to

1611  
00:58:44,390 --> 00:58:43,359  
figure out how far have we gone so far

1612  
00:58:47,270 --> 00:58:44,400  
well the furthest

1613  
00:58:49,829 --> 00:58:47,280

man-made object from earth is the

1614

00:58:52,309 --> 00:58:49,839

voyager 1 spacecraft this was launched

1615

00:58:54,870 --> 00:58:52,319

in 1977

1616

00:58:55,750 --> 00:58:54,880

and towards the end of its mission it

1617

00:58:58,390 --> 00:58:55,760

turned around

1618

00:59:00,549 --> 00:58:58,400

and took one final image this time of

1619

00:59:02,950 --> 00:59:00,559

earth in 1990

1620

00:59:04,950 --> 00:59:02,960

and this was famously requested by carl

1621

00:59:08,470 --> 00:59:04,960

sagan the astronomer and author

1622

00:59:11,829 --> 00:59:08,480

this is the pale blue dot image

1623

00:59:13,670 --> 00:59:11,839

this image was taken 3.7 billion miles

1624

00:59:16,069 --> 00:59:13,680

from earth

1625

00:59:17,270 --> 00:59:16,079

so that was in 1990 how far have we made

1626  
00:59:21,589 --> 00:59:17,280  
it so far

1627  
00:59:25,150 --> 00:59:21,599  
well today voyager 1 is 14.2

1628  
00:59:28,230 --> 00:59:25,160  
billion miles from earth this is 1

1629  
00:59:30,470 --> 00:59:28,240  
500th of a light year

1630  
00:59:32,789 --> 00:59:30,480  
so this is still a long way to go to

1631  
00:59:35,430 --> 00:59:32,799  
make it just to one light year

1632  
00:59:37,109 --> 00:59:35,440  
let alone the 4.2 needed to get to

1633  
00:59:39,670 --> 00:59:37,119  
proxima b

1634  
00:59:41,510 --> 00:59:39,680  
but you know if we still wanted to go

1635  
00:59:43,910 --> 00:59:41,520  
ahead with this

1636  
00:59:44,710 --> 00:59:43,920  
how long would it take to get to proxima

1637  
00:59:46,309 --> 00:59:44,720  
b

1638  
00:59:48,150 --> 00:59:46,319

well we currently don't have the

1639

00:59:50,549 --> 00:59:48,160

technology to get there

1640

00:59:52,789 --> 00:59:50,559

so the first thing we'd need are major

1641

00:59:55,910 --> 00:59:52,799

technological advances

1642

00:59:57,030 --> 00:59:55,920

for both energy generation in the depths

1643

01:00:00,390 --> 00:59:57,040

of space

1644

01:00:03,190 --> 01:00:00,400

and also technology advances to sustain

1645

01:00:04,470 --> 01:00:03,200

human life on a very long interstellar

1646

01:00:08,069 --> 01:00:04,480

journey

1647

01:00:11,430 --> 01:00:08,079

but say for example we very ambitiously

1648

01:00:13,270 --> 01:00:11,440

figured this out in the next 1000 years

1649

01:00:15,190 --> 01:00:13,280

how long could we how long would it take

1650

01:00:17,510 --> 01:00:15,200

to get there well that would depend on

1651

01:00:20,630 --> 01:00:17,520

how fast we traveled

1652

01:00:22,230 --> 01:00:20,640

so what is the fastest thing that humans

1653

01:00:25,190 --> 01:00:22,240

have ever produced

1654

01:00:26,950 --> 01:00:25,200

well this is the fastest man-made object

1655

01:00:30,069 --> 01:00:26,960

this is an amazing mission

1656

01:00:32,630 --> 01:00:30,079

nasa's parker solar probe this was

1657

01:00:33,430 --> 01:00:32,640

launched in 2018 and it's a car-sized

1658

01:00:37,750 --> 01:00:33,440

robot

1659

01:00:41,349 --> 01:00:37,760

that's orbiting the sun and taking data

1660

01:00:44,230 --> 01:00:41,359

on the 21st of january 2021

1661

01:00:44,549 --> 01:00:44,240

so just uh just recently it completed

1662

01:00:48,309 --> 01:00:44,559

its

1663

01:00:52,069 --> 01:00:48,319

seventh orbit of a total of 24 planned

1664

01:00:54,950 --> 01:00:52,079

and it reached a near 290

1665

01:00:56,549 --> 01:00:54,960

000 miles per hour completely smashing

1666

01:00:59,589 --> 01:00:56,559

previous records

1667

01:01:04,150 --> 01:00:59,599

at its peak the parker solar probe

1668

01:01:05,910 --> 01:01:04,160

will reach 430 000 miles per hour

1669

01:01:07,349 --> 01:01:05,920

this is almost double the speed that

1670

01:01:08,789 --> 01:01:07,359

andromeda is moving towards

1671

01:01:11,430 --> 01:01:08,799

us and i think that's absolutely

1672

01:01:14,630 --> 01:01:11,440

incredible it's such a cool mission

1673

01:01:15,670 --> 01:01:14,640

but nasa's parker solar probe doesn't

1674

01:01:18,069 --> 01:01:15,680

need to stop

1675

01:01:19,349 --> 01:01:18,079

it's a death mission it will burn up

1676

01:01:21,750 --> 01:01:19,359

unmanned of course

1677

01:01:22,630 --> 01:01:21,760

it will burn up in the sun's um in the

1678

01:01:24,950 --> 01:01:22,640

sun

1679

01:01:27,190 --> 01:01:24,960

and the hardest thing is slowing down it

1680

01:01:29,030 --> 01:01:27,200

is using the sun's gravity like a

1681

01:01:30,950 --> 01:01:29,040

slingshot to speed up

1682

01:01:32,710 --> 01:01:30,960

but we it would also take the same

1683

01:01:34,309 --> 01:01:32,720

amount of energy to slow down and that's

1684

01:01:34,630 --> 01:01:34,319

something we have not figured out how to

1685

01:01:39,670 --> 01:01:34,640

do

1686

01:01:42,789 --> 01:01:39,680

again in those deep uh areas in space

1687

01:01:45,750 --> 01:01:42,799

but you know in theory if we could get

1688

01:01:48,470 --> 01:01:45,760

a massive spacecraft to move at this

1689

01:01:50,069 --> 01:01:48,480

incredibly ambitious speed

1690

01:01:51,990 --> 01:01:50,079

we'd probably have to go a lot slower

1691

01:01:53,910 --> 01:01:52,000

but you know just saying

1692

01:01:56,470 --> 01:01:53,920

how long would it take to do this

1693

01:01:59,750 --> 01:01:56,480

journey well to get to proxima b

1694

01:02:03,109 --> 01:01:59,760

our closest planet it would take 7

1695

01:02:06,390 --> 01:02:03,119

000 years to travel those 4.2

1696

01:02:07,910 --> 01:02:06,400

light years now if we were traveling at

1697

01:02:10,549 --> 01:02:07,920

the speed of voyager 1

1698

01:02:13,109 --> 01:02:10,559

this journey would actually be over 70

1699

01:02:16,470 --> 01:02:13,119

000 years

1700

01:02:19,430 --> 01:02:16,480

this very optimistic journey length

1701

01:02:20,710 --> 01:02:19,440  
that would be about 200 to 300

1702

01:02:24,069 --> 01:02:20,720  
generations of

1703

01:02:26,390 --> 01:02:24,079  
humans on board one spacecraft

1704

01:02:28,390 --> 01:02:26,400  
and even if we wanted to do it unmanned

1705

01:02:30,549 --> 01:02:28,400  
that would be an incredibly long time to

1706

01:02:31,990 --> 01:02:30,559  
wait for any sort of information

1707

01:02:34,150 --> 01:02:32,000  
particularly when we already know this

1708

01:02:37,430 --> 01:02:34,160  
planet is inhospitable to life

1709

01:02:38,870 --> 01:02:37,440  
and us humans so

1710

01:02:40,710 --> 01:02:38,880  
we already know that one's a bit of a

1711

01:02:44,549 --> 01:02:40,720  
dud so how about

1712

01:02:47,430 --> 01:02:44,559  
we try maybe a more promising star

1713

01:02:47,990 --> 01:02:47,440

well if we take vega for example vega

1714

01:02:50,230 --> 01:02:48,000

appeared

1715

01:02:53,349 --> 01:02:50,240

in carl sagan's book and the film

1716

01:02:55,589 --> 01:02:53,359

contact which is one of my favorites

1717

01:02:56,710 --> 01:02:55,599

using our incredibly ambitious speed it

1718

01:02:59,750 --> 01:02:56,720

would take

1719

01:03:01,349 --> 01:02:59,760

over 40 000 years to reach the start of

1720

01:03:03,589 --> 01:03:01,359

vega

1721

01:03:05,990 --> 01:03:03,599

so you can see that these scales are

1722

01:03:06,950 --> 01:03:06,000

vast in comparison to the length of a

1723

01:03:09,910 --> 01:03:06,960

human life

1724

01:03:13,109 --> 01:03:09,920

so this may not be a viable backup plan

1725

01:03:15,029 --> 01:03:13,119

for the future of humanity

1726

01:03:16,230 --> 01:03:15,039

so even if we just scrap the whole

1727

01:03:18,630 --> 01:03:16,240

travel idea

1728

01:03:20,390 --> 01:03:18,640

and just wanted to send a message that

1729

01:03:21,190 --> 01:03:20,400

message could travel at the speed of

1730

01:03:23,670 --> 01:03:21,200

light

1731

01:03:24,950 --> 01:03:23,680

but even to get a message from one side

1732

01:03:26,950 --> 01:03:24,960

of our galaxy

1733

01:03:29,190 --> 01:03:26,960

to the other side of the galaxy let

1734

01:03:30,069 --> 01:03:29,200

alone all the billions thousands of

1735

01:03:32,870 --> 01:03:30,079

billions of

1736

01:03:33,670 --> 01:03:32,880

galaxies within our universe even just

1737

01:03:36,630 --> 01:03:33,680

to go across

1738

01:03:39,510 --> 01:03:36,640

our galaxy would take a hundred thousand

1739

01:03:41,510 --> 01:03:39,520

years to send that message

1740

01:03:43,670 --> 01:03:41,520

now it's likely that aliens may find us

1741

01:03:46,069 --> 01:03:43,680

at some point

1742

01:03:47,430 --> 01:03:46,079

but if we were to send that message it

1743

01:03:50,549 --> 01:03:47,440

would then take

1744

01:03:53,109 --> 01:03:50,559

that same amount of time to get a reply

1745

01:03:53,910 --> 01:03:53,119

so even if aliens might be listening in

1746

01:03:56,789 --> 01:03:53,920

on us

1747

01:03:57,190 --> 01:03:56,799

given that the first radio signal was

1748

01:04:00,789 --> 01:03:57,200

sent

1749

01:04:02,390 --> 01:04:00,799

in the late 1800s all of the information

1750

01:04:05,109 --> 01:04:02,400

that we have inadvertently

1751

01:04:06,390 --> 01:04:05,119

pumped into space since then all of

1752

01:04:09,190 --> 01:04:06,400

those messages

1753

01:04:10,390 --> 01:04:09,200

have only made it around 100 light years

1754

01:04:12,789 --> 01:04:10,400

or so so still

1755

01:04:15,829 --> 01:04:12,799

only about a thousandth of the distance

1756

01:04:18,069 --> 01:04:15,839

across our galaxy

1757

01:04:20,309 --> 01:04:18,079

i would like to highlight however this

1758

01:04:22,630 --> 01:04:20,319

very new exciting discovery

1759

01:04:23,990 --> 01:04:22,640

by researchers at the university of

1760

01:04:26,230 --> 01:04:24,000

hawaii

1761

01:04:27,990 --> 01:04:26,240

they discovered this planet shown in

1762

01:04:33,430 --> 01:04:28,000

this artist's impression

1763

01:04:35,109 --> 01:04:33,440

toi 561b this planet is 280

1764

01:04:37,029 --> 01:04:35,119

light years from earth so if we were

1765

01:04:40,150 --> 01:04:37,039

using our very ambitious speed

1766

01:04:41,829 --> 01:04:40,160

this would be a mere 440 000 year long

1767

01:04:44,470 --> 01:04:41,839

journey

1768

01:04:45,109 --> 01:04:44,480

this planet is 1.5 times the size of

1769

01:04:47,829 --> 01:04:45,119

earth

1770

01:04:48,390 --> 01:04:47,839

and they found that it has a staggering

1771

01:04:52,069 --> 01:04:48,400

age

1772

01:04:55,270 --> 01:04:52,079

of 10 billion years that's almost

1773

01:04:56,390 --> 01:04:55,280

double earth so when you think about

1774

01:04:59,589 --> 01:04:56,400

that the universe

1775

01:05:01,990 --> 01:04:59,599

is 13.8 billion years old

1776

01:05:03,349 --> 01:05:02,000

our galaxy started forming about 12

1777

01:05:05,750 --> 01:05:03,359

billion years ago

1778

01:05:08,950 --> 01:05:05,760

and this planet started forming pretty

1779

01:05:11,430 --> 01:05:08,960

soon after that while we know

1780

01:05:12,470 --> 01:05:11,440

that this particular planet is an

1781

01:05:15,589 --> 01:05:12,480

inhospitable

1782

01:05:16,390 --> 01:05:15,599

rocky lava ball and it orbits its its

1783

01:05:19,109 --> 01:05:16,400

star

1784

01:05:20,109 --> 01:05:19,119

every 10.5 hours compared to our

1785

01:05:23,190 --> 01:05:20,119

leisurely

1786

01:05:25,029 --> 01:05:23,200

365 days

1787

01:05:26,390 --> 01:05:25,039

it does mean something bigger in the

1788

01:05:29,190 --> 01:05:26,400

context of when

1789

01:05:29,990 --> 01:05:29,200

planets might have formed in this galaxy

1790

01:05:32,630 --> 01:05:30,000

it could

1791

01:05:33,630 --> 01:05:32,640

mean that there were advanced

1792

01:05:36,950 --> 01:05:33,640

intelligent

1793

01:05:40,789 --> 01:05:36,960

civilizations out there billions

1794

01:05:44,150 --> 01:05:40,799

of years ago and just to think how far

1795

01:05:47,349 --> 01:05:44,160

we've come in earth's 4.5 billion years

1796

01:05:49,510 --> 01:05:47,359

from bacteria in the primordial soup

1797

01:05:51,990 --> 01:05:49,520

to conscious beings studying the

1798

01:05:53,990 --> 01:05:52,000

universe with iphones in hand

1799

01:05:55,349 --> 01:05:54,000

it's amazing to think what an extra few

1800

01:05:58,789 --> 01:05:55,359

billion years can mean

1801  
01:06:01,270 --> 01:05:58,799  
for advanced civilizations

1802  
01:06:02,150 --> 01:06:01,280  
so while our prospects of interstellar

1803  
01:06:04,710 --> 01:06:02,160  
travel

1804  
01:06:06,549 --> 01:06:04,720  
aren't looking so hopeful on any sort of

1805  
01:06:10,950 --> 01:06:06,559  
reasonable time scale

1806  
01:06:13,190 --> 01:06:10,960  
given the distances and scales of space

1807  
01:06:15,430 --> 01:06:13,200  
it's still something we can aim towards

1808  
01:06:17,990 --> 01:06:15,440  
and put the groundwork in for

1809  
01:06:20,150 --> 01:06:18,000  
but i don't want us to rely on finding

1810  
01:06:22,549 --> 01:06:20,160  
an earth 2.0

1811  
01:06:23,750 --> 01:06:22,559  
when this planet dies but instead to

1812  
01:06:26,069 --> 01:06:23,760  
really appreciate

1813  
01:06:27,349 --> 01:06:26,079

the gorgeous planet that we have that we

1814

01:06:31,109 --> 01:06:27,359

are perfectly

1815

01:06:33,910 --> 01:06:31,119

adapted for already so

1816

01:06:34,950 --> 01:06:33,920

what will happen to earth in four

1817

01:06:37,750 --> 01:06:34,960

billion years

1818

01:06:39,270 --> 01:06:37,760

when andromeda and the milky way begin

1819

01:06:42,710 --> 01:06:39,280

to collide

1820

01:06:45,270 --> 01:06:42,720

well not a whole lot really as we've

1821

01:06:47,510 --> 01:06:45,280

seen the vast distances of space

1822

01:06:48,390 --> 01:06:47,520

stars will most likely just sail right

1823

01:06:51,029 --> 01:06:48,400

past us

1824

01:06:52,150 --> 01:06:51,039

and we will settle in a new galaxy

1825

01:06:54,309 --> 01:06:52,160

mildrometer

1826

01:06:55,910 --> 01:06:54,319

those stars will likely be as far away

1827

01:06:58,390 --> 01:06:55,920

from us as they are now

1828

01:07:00,309 --> 01:06:58,400

which we know is very far there is a

1829

01:07:02,710 --> 01:07:00,319

small chance we could be one of those

1830

01:07:05,750 --> 01:07:02,720

stars that's flung out into space

1831

01:07:07,829 --> 01:07:05,760

but our earth will still stay in orbit

1832

01:07:08,950 --> 01:07:07,839

around the sun the forces of gravity and

1833

01:07:10,710 --> 01:07:08,960

our solar system

1834

01:07:12,069 --> 01:07:10,720

will be able to withstand that and we

1835

01:07:14,549 --> 01:07:12,079

and that would actually be a relatively

1836

01:07:16,470 --> 01:07:14,559

slow process we would just drift off

1837

01:07:18,950 --> 01:07:16,480

into the abyss

1838

01:07:20,950 --> 01:07:18,960

but you may remember that i told you

1839

01:07:25,510 --> 01:07:20,960

that the sun is halfway through

1840

01:07:27,270 --> 01:07:25,520

its lifetime in 5 billion years

1841

01:07:29,349 --> 01:07:27,280

the sun will begin to die so about

1842

01:07:32,630 --> 01:07:29,359

halfway through this collision

1843

01:07:34,470 --> 01:07:32,640

with um andromeda and in five billion

1844

01:07:35,750 --> 01:07:34,480

years the sun will swell up to what we

1845

01:07:38,789 --> 01:07:35,760

call the red giant

1846

01:07:39,430 --> 01:07:38,799

and it will actually engulf the earth so

1847

01:07:41,910 --> 01:07:39,440

while that

1848

01:07:42,870 --> 01:07:41,920

may sound scary this is all a long way

1849

01:07:45,829 --> 01:07:42,880

off in the future

1850

01:07:47,750 --> 01:07:45,839

and we will be long gone if we are

1851

01:07:50,390 --> 01:07:47,760

fortunate to have

1852

01:07:51,670 --> 01:07:50,400

any descendant species they will likely

1853

01:07:54,549 --> 01:07:51,680

be as different from

1854

01:07:57,190 --> 01:07:54,559

us as we are from the bacteria in the

1855

01:08:00,390 --> 01:07:57,200

primordial soup

1856

01:08:02,630 --> 01:08:00,400

so this may sound like doomsday um

1857

01:08:03,750 --> 01:08:02,640

but you know maybe they will figure out

1858

01:08:05,990 --> 01:08:03,760

interstellar travel

1859

01:08:07,829 --> 01:08:06,000

and maybe they will find a new planet

1860

01:08:11,430 --> 01:08:07,839

and who knows what will be waiting for

1861

01:08:14,630 --> 01:08:11,440

them there

1862

01:08:18,149 --> 01:08:14,640

but first we have another major issue

1863

01:08:20,950 --> 01:08:18,159

to attend to i would like to focus

1864

01:08:23,829 --> 01:08:20,960

on the incredible planet that we have

1865

01:08:25,990 --> 01:08:23,839

and to really emphasize the importance

1866

01:08:28,550 --> 01:08:26,000

of addressing our current

1867

01:08:30,630 --> 01:08:28,560

climate and ecological emergent

1868

01:08:33,269 --> 01:08:30,640

emergency that we are in

1869

01:08:34,950 --> 01:08:33,279

this is the biggest threat to human life

1870

01:08:37,829 --> 01:08:34,960

that we face

1871

01:08:38,950 --> 01:08:37,839

if the goal of any life form is to

1872

01:08:41,030 --> 01:08:38,960

survive

1873

01:08:42,390 --> 01:08:41,040

then we are currently working against

1874

01:08:45,110 --> 01:08:42,400

our best interests

1875

01:08:46,229 --> 01:08:45,120

by killing our habitat and that is not a

1876

01:08:47,990 --> 01:08:46,239

great look

1877

01:08:50,070 --> 01:08:48,000

for a species that believes it's the

1878

01:08:53,349 --> 01:08:50,080

most intelligent on earth

1879

01:08:54,950 --> 01:08:53,359

if we continue as we have been future

1880

01:08:58,470 --> 01:08:54,960

generations will never make it

1881

01:09:01,110 --> 01:08:58,480

anywhere near to even the closest star

1882

01:09:02,390 --> 01:09:01,120

we are on a rapid course for

1883

01:09:05,829 --> 01:09:02,400

irreversible

1884

01:09:09,669 --> 01:09:05,839

extensive damage to the earth within my

1885

01:09:12,789 --> 01:09:09,679

lifetime but this catastrophe

1886

01:09:15,829 --> 01:09:12,799

can be avoided the only way

1887

01:09:18,550 --> 01:09:15,839

for human life to survive and give way

1888

01:09:21,110 --> 01:09:18,560

to this next generation of beings

1889

01:09:23,349 --> 01:09:21,120

is to learn to thrive on earth

1890

01:09:25,189 --> 01:09:23,359

sustainably

1891

01:09:26,709 --> 01:09:25,199

i'd like to highlight this recent quote

1892

01:09:29,349 --> 01:09:26,719

by greta timberg and her

1893

01:09:32,390 --> 01:09:29,359

address to the world economic forum you

1894

01:09:35,269 --> 01:09:32,400

can't negotiate with physics

1895

01:09:39,510 --> 01:09:35,279

this is happening it's a dire situation

1896

01:09:42,950 --> 01:09:41,829

the time for discussion is long gone we

1897

01:09:45,189 --> 01:09:42,960

have to take action

1898

01:09:46,630 --> 01:09:45,199

now and i believe it's everyone's

1899

01:09:50,309 --> 01:09:46,640

responsibility

1900

01:09:53,110 --> 01:09:50,319

to contribute to that action

1901

01:09:55,030 --> 01:09:53,120

a very small suggested step that i'd

1902

01:09:57,110 --> 01:09:55,040

like to highlight here is what the earth

1903

01:09:58,390 --> 01:09:57,120

is asking of us in this slide

1904

01:09:59,990 --> 01:09:58,400

and this is to watch david

1905

01:10:02,310 --> 01:10:00,000

attenborough's new documentary on

1906

01:10:05,590 --> 01:10:02,320

netflix a life on our planet

1907

01:10:06,550 --> 01:10:05,600

as a small suggested first step this is

1908

01:10:10,310 --> 01:10:06,560

a great film

1909

01:10:13,830 --> 01:10:10,320

that draws on current science to really

1910

01:10:16,310 --> 01:10:13,840

highlight the urgency of acting now

1911

01:10:18,070 --> 01:10:16,320

but also offers a surprisingly simple

1912

01:10:20,790 --> 01:10:18,080

and hopeful path forward

1913

01:10:22,229 --> 01:10:20,800

for reversing our course towards mass

1914

01:10:24,070 --> 01:10:22,239

extinction

1915

01:10:26,149 --> 01:10:24,080

and i think it's a great first step if

1916

01:10:27,990 --> 01:10:26,159

you haven't already seen it

1917

01:10:30,229 --> 01:10:28,000

we as individuals can often feel

1918

01:10:33,669 --> 01:10:30,239

helpless but if you only take

1919

01:10:36,709 --> 01:10:33,679

one thing from this talk it's that you

1920

01:10:38,630 --> 01:10:36,719

can make a difference by voting in the

1921

01:10:41,669 --> 01:10:38,640

planet's best interests

1922

01:10:43,350 --> 01:10:41,679

by spending investing eating

1923

01:10:44,950 --> 01:10:43,360

and living in the planet's best

1924

01:10:48,550 --> 01:10:44,960

interests you

1925

01:10:50,870 --> 01:10:48,560

can save the future of humanity

1926

01:10:53,189 --> 01:10:50,880

so in the last couple of slides i will

1927

01:10:55,990 --> 01:10:53,199

just bring the focus back to astronomy

1928

01:10:58,070 --> 01:10:56,000

and i'd like to advertise the upcoming

1929

01:11:01,189 --> 01:10:58,080

james webb space telescope

1930

01:11:01,990 --> 01:11:01,199

this is set for launch in october of

1931

01:11:04,550 --> 01:11:02,000

this year

1932

01:11:05,189 --> 01:11:04,560

on halloween actually and hubble's

1933

01:11:07,669 --> 01:11:05,199

flight

1934

01:11:08,709 --> 01:11:07,679

and science operations will be run from

1935

01:11:10,630 --> 01:11:08,719

baltimore

1936

01:11:12,470 --> 01:11:10,640

at the space telescope science institute

1937

01:11:13,430 --> 01:11:12,480

so james webb will have a direct line of

1938

01:11:16,550 --> 01:11:13,440

communication

1939

01:11:18,630 --> 01:11:16,560

with the scientist here in baltimore

1940

01:11:20,470 --> 01:11:18,640

so james webb is really set to

1941

01:11:21,189 --> 01:11:20,480

revolutionize our understanding of the

1942

01:11:24,790 --> 01:11:21,199

universe

1943

01:11:26,550 --> 01:11:24,800

from from planets through to those very

1944

01:11:29,270 --> 01:11:26,560

early stages in a big bang

1945

01:11:30,390 --> 01:11:29,280

and also how galaxies formed we'll be

1946

01:11:32,550 --> 01:11:30,400

able to fill in

1947

01:11:35,270 --> 01:11:32,560

so many gaps that we currently don't uh

1948

01:11:38,950 --> 01:11:35,280

don't know the answers for

1949

01:11:40,070 --> 01:11:38,960

um james webb will have a large 21 foot

1950

01:11:41,750 --> 01:11:40,080

wide mirror

1951

01:11:44,470 --> 01:11:41,760

and it will also be an infrared

1952

01:11:44,950 --> 01:11:44,480

telescope now the sun is actually a very

1953

01:11:48,070 --> 01:11:44,960

bright

1954

01:11:48,870 --> 01:11:48,080

infrared source and so hubble so web

1955

01:11:50,790 --> 01:11:48,880

will actually be

1956

01:11:51,910 --> 01:11:50,800

always facing away from the sun with

1957

01:11:53,590 --> 01:11:51,920

these giant

1958

01:11:55,350 --> 01:11:53,600

sun shields these are about the size of

1959

01:11:59,270 --> 01:11:55,360

a tennis court

1960

01:12:01,350 --> 01:11:59,280

and unlike hubble that orbits the earth

1961

01:12:02,470 --> 01:12:01,360

james webb will actually be orbiting the

1962

01:12:06,470 --> 01:12:02,480

sun

1963

01:12:08,390 --> 01:12:06,480

the same speed as earth so kind of

1964

01:12:10,229 --> 01:12:08,400

constantly in its shadow

1965

01:12:12,229 --> 01:12:10,239

so you can see here in this artist's

1966

01:12:13,910 --> 01:12:12,239

impression at the bottom left-hand

1967

01:12:16,149 --> 01:12:13,920

corner you can see the very small

1968

01:12:17,270 --> 01:12:16,159

earth and with the moon orbiting and

1969

01:12:20,630 --> 01:12:17,280

then the sun off

1970

01:12:24,390 --> 01:12:20,640

to the distance a little bit further so

1971

01:12:26,790 --> 01:12:24,400

why infrared well here's an example

1972

01:12:28,790 --> 01:12:26,800

of the benefits of using a different

1973

01:12:30,149 --> 01:12:28,800

wavelength of light so these are two

1974

01:12:32,310 --> 01:12:30,159

images from hubble

1975

01:12:34,709 --> 01:12:32,320

both in the optical on the left and in

1976

01:12:37,030 --> 01:12:34,719

the near infrared on the right

1977

01:12:38,470 --> 01:12:37,040

and this is of the pillars of creation

1978

01:12:41,669 --> 01:12:38,480

stellar nurseries

1979

01:12:43,590 --> 01:12:41,679

within the eagle nebula so on the left

1980

01:12:45,350 --> 01:12:43,600

you can see the dust and gas from where

1981

01:12:47,110 --> 01:12:45,360

the stars are formed but it's actually

1982

01:12:49,110 --> 01:12:47,120

obscuring a lot of the light

1983

01:12:50,390 --> 01:12:49,120

and when we look at the infrared we can

1984

01:12:54,070 --> 01:12:50,400

pierce through

1985

01:12:57,510 --> 01:12:54,080

those um dark shields in order to reveal

1986

01:12:59,110 --> 01:12:57,520

new exciting physics so james webb will

1987

01:13:00,310 --> 01:12:59,120

actually be in the infrared to much

1988

01:13:03,189 --> 01:13:00,320

further wavelengths

1989

01:13:04,870 --> 01:13:03,199

than hubble can go and this means that

1990

01:13:07,590 --> 01:13:04,880

we will be able to observe

1991

01:13:09,750 --> 01:13:07,600

the faintest and most distant objects in

1992

01:13:12,310 --> 01:13:09,760

the universe to really understand

1993

01:13:13,189 --> 01:13:12,320

how those very early stages of galaxies

1994

01:13:16,709 --> 01:13:13,199

formed

1995

01:13:18,630 --> 01:13:16,719

and also to reveal new planets as well

1996

01:13:20,470 --> 01:13:18,640

so thank you so much for listening and

1997

01:13:23,270 --> 01:13:20,480

i'll be very happy to answer any

1998

01:13:28,149 --> 01:13:26,390

all right thank you laura and

1999

01:13:29,990 --> 01:13:28,159

i'm actually going to start with a

2000

01:13:33,110 --> 01:13:30,000

comment from the chat that actually

2001

01:13:35,990 --> 01:13:33,120

reflected my own thoughts um

2002

01:13:39,350 --> 01:13:36,000

it said uh i can't remember who this was

2003

01:13:42,070 --> 01:13:39,360

wow we've come a long way in 100 years

2004

01:13:43,750 --> 01:13:42,080

yeah i think that's to me that's exactly

2005

01:13:45,910 --> 01:13:43,760

what your talk is done because

2006

01:13:48,390 --> 01:13:45,920

it started back when we only had one

2007

01:13:51,590 --> 01:13:48,400

galaxy and it was the entire universe

2008

01:13:52,790 --> 01:13:51,600

and goes out to really explain just how

2009

01:13:55,110 --> 01:13:52,800

much we've learned

2010

01:13:56,149 --> 01:13:55,120

about galaxies in the last hundred years

2011

01:13:57,830 --> 01:13:56,159

yeah

2012

01:13:59,189 --> 01:13:57,840

so uh let's see there were a ton of

2013

01:14:00,550 --> 01:13:59,199

questions here and

2014

01:14:02,550 --> 01:14:00,560

grant and i are going to have a heck of

2015

01:14:05,590 --> 01:14:02,560

a time trying to

2016

01:14:08,709 --> 01:14:05,600

figure out the best ones um

2017

01:14:11,110 --> 01:14:08,719

but there were a lot of

2018

01:14:12,470 --> 01:14:11,120

questions about all right are we really

2019

01:14:14,709 --> 01:14:12,480

not going to get

2020

01:14:15,910 --> 01:14:14,719

messed up by this collision okay we

2021

01:14:16,630 --> 01:14:15,920

always get this question about galaxy

2022

01:14:19,669 --> 01:14:16,640

collisions

2023

01:14:22,709 --> 01:14:19,679

and somebody put it um strongly like hey

2024

01:14:23,270 --> 01:14:22,719

we're gonna collide at 250 000 miles per

2025

01:14:25,750 --> 01:14:23,280

hour

2026

01:14:29,669 --> 01:14:25,760

and we won't be messed up what's going

2027

01:14:32,870 --> 01:14:29,679

on here attack that just one more time

2028

01:14:34,149 --> 01:14:32,880

again it's a very good point and i it

2029

01:14:37,189 --> 01:14:34,159

really goes back to those

2030

01:14:40,470 --> 01:14:37,199

scales of space so yes

2031

01:14:42,550 --> 01:14:40,480

gravity is an amazing force and it's

2032

01:14:44,390 --> 01:14:42,560

really driving these two monsters

2033

01:14:47,350 --> 01:14:44,400

together and will completely

2034

01:14:47,750 --> 01:14:47,360

kind of you know reshape them into one

2035

01:14:50,709 --> 01:14:47,760

new

2036

01:14:51,990 --> 01:14:50,719

amazingly named vinyl galaxy milk

2037

01:14:54,070 --> 01:14:52,000

dromeda

2038

01:14:57,030 --> 01:14:54,080

but really the separation between those

2039

01:14:59,669 --> 01:14:57,040

stars means that

2040

01:15:01,110 --> 01:14:59,679

the kind of uh the influence of of that

2041

01:15:03,910 --> 01:15:01,120

star you know of its

2042

01:15:04,470 --> 01:15:03,920

planets it's so close we are so close to

2043

01:15:06,709 --> 01:15:04,480

our sun

2044

01:15:07,990 --> 01:15:06,719

compared to those really vast distances

2045

01:15:09,910 --> 01:15:08,000

in space

2046

01:15:11,350 --> 01:15:09,920

that those stars will likely just really

2047

01:15:14,630 --> 01:15:11,360

kind of

2048

01:15:16,229 --> 01:15:14,640

smoothly pass by each other but there is

2049

01:15:19,990 --> 01:15:16,239

an interesting component there

2050

01:15:21,750 --> 01:15:20,000

there is gas and while this gas and dust

2051

01:15:23,590 --> 01:15:21,760

you know it's not quite like the dust

2052

01:15:24,709 --> 01:15:23,600

you would find in your house this dust

2053

01:15:27,750 --> 01:15:24,719

is like a very

2054

01:15:29,669 --> 01:15:27,760

fine smoke it's a very fine mist so

2055

01:15:31,750 --> 01:15:29,679

maybe this might kind of

2056

01:15:33,430 --> 01:15:31,760

have some effect maybe if that's kind of

2057

01:15:35,110 --> 01:15:33,440

raining down on the earth's atmosphere

2058

01:15:37,430 --> 01:15:35,120

but we have this pretty great

2059

01:15:38,630 --> 01:15:37,440

shield in around the earth's atmosphere

2060

01:15:44,550 --> 01:15:38,640

of our magnetic

2061

01:15:47,910 --> 01:15:44,560

those effects will be relatively minor

2062

01:15:49,270 --> 01:15:47,920

and as i mentioned in five billion years

2063

01:15:51,430 --> 01:15:49,280

we'll have something else to be worrying

2064

01:15:53,669 --> 01:15:51,440

about

2065

01:15:54,709 --> 01:15:53,679

in that the sun will be engulfing the

2066

01:15:58,149 --> 01:15:54,719

earth anyway

2067

01:15:59,910 --> 01:15:58,159

so um yeah it's it's uh

2068

01:16:01,590 --> 01:15:59,920

who knows what's going to get us first

2069

01:16:03,270 --> 01:16:01,600

but obviously we will figure out how to

2070

01:16:03,910 --> 01:16:03,280

move to titan first right or something

2071

01:16:07,430 --> 01:16:03,920

like that

2072

01:16:09,990 --> 01:16:07,440

yeah yeah that could work out yeah okay

2073

01:16:10,550 --> 01:16:10,000

so um grant uh let me bring grant

2074

01:16:12,390 --> 01:16:10,560

justice

2075

01:16:13,830 --> 01:16:12,400

in he's been following the chat and

2076

01:16:17,110 --> 01:16:13,840

answering a few questions in the

2077

01:16:22,229 --> 01:16:17,120

chat grant what uh i love i always love

2078

01:16:27,510 --> 01:16:25,270

for our speaker today all right so

2079

01:16:29,270 --> 01:16:27,520

um i'll get started because i will never

2080

01:16:32,830 --> 01:16:29,280

not take an opportunity to have

2081

01:16:35,990 --> 01:16:32,840

us harp or talk up james webb

2082

01:16:39,030 --> 01:16:36,000

um somebody wanted to see

2083

01:16:42,149 --> 01:16:39,040

if it's true that we cannot see through

2084

01:16:44,550 --> 01:16:42,159

things like the milky way or nebulae or

2085

01:16:47,110 --> 01:16:44,560

like large dust clouds or what have you

2086

01:16:50,470 --> 01:16:47,120

and since this is a james webb thing

2087

01:16:52,870 --> 01:16:50,480

figured we could talk about it yeah so

2088

01:16:54,709 --> 01:16:52,880

using those optical wavelengths so what

2089

01:16:57,990 --> 01:16:54,719

we can see with our eyes

2090

01:16:58,229 --> 01:16:58,000

um a lot of stuff is just obscured from

2091

01:17:00,229 --> 01:16:58,239

us

2092

01:17:02,229 --> 01:17:00,239

but if we move to those redder

2093

01:17:02,950 --> 01:17:02,239

wavelengths like i showed in that last

2094

01:17:06,229 --> 01:17:02,960

slide

2095

01:17:08,390 --> 01:17:06,239

you can pierce through a lot of that

2096

01:17:10,790 --> 01:17:08,400

material and you can start to see

2097

01:17:11,430 --> 01:17:10,800

objects on the other side of that dust

2098

01:17:13,830 --> 01:17:11,440

and gas and

2099

01:17:15,590 --> 01:17:13,840

even within those clouds so it's really

2100

01:17:16,550 --> 01:17:15,600

using those longer wavelengths that

2101  
01:17:19,430 --> 01:17:16,560  
we've built up

2102  
01:17:21,350 --> 01:17:19,440  
a pretty amazing three-dimensional view

2103  
01:17:24,070 --> 01:17:21,360  
of what our galaxy looks like

2104  
01:17:24,470 --> 01:17:24,080  
we can measure you know where the stars

2105  
01:17:26,149 --> 01:17:24,480  
are

2106  
01:17:27,669 --> 01:17:26,159  
in those spiral arms and we can see

2107  
01:17:28,149 --> 01:17:27,679  
where that gas is and everything like

2108  
01:17:29,830 --> 01:17:28,159  
that

2109  
01:17:32,550 --> 01:17:29,840  
so we have this kind of you know we put

2110  
01:17:33,750 --> 01:17:32,560  
on our um infrared goggles and we can

2111  
01:17:37,270 --> 01:17:33,760  
see through

2112  
01:17:38,630 --> 01:17:37,280  
and we can see more of the structure um

2113  
01:17:40,630 --> 01:17:38,640

so it's really using those longer

2114

01:17:42,149 --> 01:17:40,640

wavelengths and and james webb will

2115

01:17:44,790 --> 01:17:42,159

really just open up

2116

01:17:47,189 --> 01:17:44,800

a whole new area of space and you're

2117

01:17:49,189 --> 01:17:47,199

going to see some amazing images come

2118

01:17:50,870 --> 01:17:49,199

from space telescope and the team here

2119

01:17:51,910 --> 01:17:50,880

um yeah it's it's going to be awesome

2120

01:17:53,830 --> 01:17:51,920

when we start to see

2121

01:17:57,189 --> 01:17:53,840

some of the things that we haven't seen

2122

01:18:05,990 --> 01:18:01,350

okay that sounds good uh what what next

2123

01:18:10,390 --> 01:18:08,630

can we measure lateral motion how many

2124

01:18:12,870 --> 01:18:10,400

and by that i think the person meant how

2125

01:18:16,070 --> 01:18:12,880

many axes can we actually

2126  
01:18:16,390 --> 01:18:16,080  
track motion in these celestial objects

2127  
01:18:18,950 --> 01:18:16,400  
like

2128  
01:18:19,669 --> 01:18:18,960  
obviously it's space so there's multiple

2129  
01:18:21,270 --> 01:18:19,679  
yes

2130  
01:18:23,030 --> 01:18:21,280  
and grant i think that was specifically

2131  
01:18:23,830 --> 01:18:23,040  
in terms of the andromeda galaxy wasn't

2132  
01:18:28,229 --> 01:18:23,840  
that

2133  
01:18:28,790 --> 01:18:28,239  
andromeda so thank you for asking i

2134  
01:18:31,030 --> 01:18:28,800  
actually

2135  
01:18:33,350 --> 01:18:31,040  
did have a section of my talk on on the

2136  
01:18:35,030 --> 01:18:33,360  
sideways motion of andromeda but i

2137  
01:18:36,390 --> 01:18:35,040  
cut it because it does go into a bit

2138  
01:18:40,229 --> 01:18:36,400

more detail

2139

01:18:41,030 --> 01:18:40,239

so in theory yes andromeda is hurtling

2140

01:18:44,070 --> 01:18:41,040

towards us

2141

01:18:45,910 --> 01:18:44,080

at this great speed but what if it was

2142

01:18:48,149 --> 01:18:45,920

also traveling sideways

2143

01:18:49,110 --> 01:18:48,159

at an even greater speed it could really

2144

01:18:51,030 --> 01:18:49,120

mean that we're

2145

01:18:52,870 --> 01:18:51,040

not going to collide with andromeda

2146

01:18:55,030 --> 01:18:52,880

anytime soon and it may do kind of a

2147

01:18:57,750 --> 01:18:55,040

slow spiral in

2148

01:18:58,709 --> 01:18:57,760

but using the hubble space telescope

2149

01:19:02,149 --> 01:18:58,719

researchers

2150

01:19:05,750 --> 01:19:02,159

at space telescope actually measured

2151

01:19:08,630 --> 01:19:05,760

the speeds of i think it's

2152

01:19:10,070 --> 01:19:08,640

maybe thousands maybe uh maybe hundreds

2153

01:19:13,350 --> 01:19:10,080

of thousands of stars

2154

01:19:16,470 --> 01:19:13,360

in andromeda they measured the micro

2155

01:19:19,990 --> 01:19:16,480

shifts in those stars and said

2156

01:19:23,750 --> 01:19:20,000

how fast is andromeda moving

2157

01:19:24,470 --> 01:19:23,760

that way on the sky the measurement they

2158

01:19:27,669 --> 01:19:24,480

made

2159

01:19:29,189 --> 01:19:27,679

is so freakily accurate it's one of the

2160

01:19:30,310 --> 01:19:29,199

most accurate measurements made in

2161

01:19:33,110 --> 01:19:30,320

astronomy

2162

01:19:34,709 --> 01:19:33,120

it was i figured it out a long time ago

2163

01:19:37,350 --> 01:19:34,719

it was something like if you were

2164

01:19:38,390 --> 01:19:37,360  
on the international space station

2165

01:19:40,390 --> 01:19:38,400  
orbiting earth

2166

01:19:43,270 --> 01:19:40,400  
it would be like being able to measure

2167

01:19:46,390 --> 01:19:43,280  
like the the growth rate of a human hair

2168

01:19:49,270 --> 01:19:46,400  
it's wild um but

2169

01:19:49,669 --> 01:19:49,280  
what they found is that andromeda isn't

2170

01:19:52,149 --> 01:19:49,679  
really

2171

01:19:54,070 --> 01:19:52,159  
moving sideways it's on a direct

2172

01:19:55,110 --> 01:19:54,080  
collision course it's coming straight

2173

01:19:57,189 --> 01:19:55,120  
towards us

2174

01:19:58,870 --> 01:19:57,199  
so yes we can measure those lateral

2175

01:20:01,830 --> 01:19:58,880  
motions in space

2176  
01:20:02,790 --> 01:20:01,840  
um and some amazing scientists did with

2177  
01:20:05,830 --> 01:20:02,800  
hubble and

2178  
01:20:06,629 --> 01:20:05,840  
yeah it's coming straight for us right

2179  
01:20:08,950 --> 01:20:06,639  
this um

2180  
01:20:09,669 --> 01:20:08,960  
uh relates to what i did in the news

2181  
01:20:11,189 --> 01:20:09,679  
summary

2182  
01:20:12,950 --> 01:20:11,199  
talking about taking uh hubble

2183  
01:20:14,709 --> 01:20:12,960  
observations 20 years apart

2184  
01:20:16,470 --> 01:20:14,719  
and being able to see those really

2185  
01:20:17,990 --> 01:20:16,480  
really really tiny motions

2186  
01:20:19,750 --> 01:20:18,000  
now in what i showed you could actually

2187  
01:20:21,350 --> 01:20:19,760  
physically see them with the eye

2188  
01:20:23,510 --> 01:20:21,360

this was so small that you had to use

2189

01:20:25,830 --> 01:20:23,520

computers to actually go in

2190

01:20:27,430 --> 01:20:25,840

and very finely measure them and yeah i

2191

01:20:29,669 --> 01:20:27,440

will note for the audience that

2192

01:20:30,950 --> 01:20:29,679

what my background here is actually an

2193

01:20:33,830 --> 01:20:30,960

image of

2194

01:20:35,350 --> 01:20:33,840

stars in andromeda this uh this the

2195

01:20:37,350 --> 01:20:35,360

globular cluster over here

2196

01:20:40,470 --> 01:20:37,360

that's a globby cluster in the andromeda

2197

01:20:42,709 --> 01:20:40,480

galaxy not in the milky way

2198

01:20:43,669 --> 01:20:42,719

i i just loved this image because it was

2199

01:20:46,310 --> 01:20:43,679

like whoa

2200

01:20:47,750 --> 01:20:46,320

i mean we're seeing what hubble would

2201

01:20:48,870 --> 01:20:47,760

have you know given his eye teeth to be

2202

01:20:51,990 --> 01:20:48,880

able to see

2203

01:20:55,189 --> 01:20:52,000

yeah and this was all part of a massive

2204

01:20:56,149 --> 01:20:55,199

um survey of andromeda that um raja was

2205

01:20:58,070 --> 01:20:56,159

involved with to

2206

01:20:59,189 --> 01:20:58,080

the fat survey which i think is a great

2207

01:21:01,110 --> 01:20:59,199

name um

2208

01:21:03,189 --> 01:21:01,120

the panchromatic hubble andromeda

2209

01:21:06,070 --> 01:21:03,199

treasury so it's really using

2210

01:21:07,189 --> 01:21:06,080

the huge data set there that they could

2211

01:21:10,470 --> 01:21:07,199

then measure those

2212

01:21:12,550 --> 01:21:10,480

micro shifts over a period of time as

2213

01:21:14,149 --> 01:21:12,560

frank mentioned

2214

01:21:15,990 --> 01:21:14,159

all right we've got an i'm sure we have

2215

01:21:19,350 --> 01:21:16,000

more questions

2216

01:21:22,629 --> 01:21:19,360

yes very much so um all right

2217

01:21:29,750 --> 01:21:24,310

i said i mentioned aliens on youtube so

2218

01:21:32,790 --> 01:21:29,760

i'm not surprised that this film

2219

01:21:34,950 --> 01:21:32,800

we'll avoid those um how can you tell

2220

01:21:35,990 --> 01:21:34,960

cepheid variables apart from other stars

2221

01:21:38,629 --> 01:21:36,000

that pulsate

2222

01:21:39,430 --> 01:21:38,639

or are variable in other ways that you

2223

01:21:42,790 --> 01:21:39,440

can

2224

01:21:43,590 --> 01:21:42,800

identify them this is an excellent

2225

01:21:46,070 --> 01:21:43,600

question

2226

01:21:47,750 --> 01:21:46,080

and one that actually kind of is it is

2227

01:21:50,709 --> 01:21:47,760

quite hard to tell

2228

01:21:51,189 --> 01:21:50,719

there are some variable stars that vary

2229

01:21:55,590 --> 01:21:51,199

but

2230

01:21:57,189 --> 01:21:55,600

not on kind of any regular um time scale

2231

01:21:58,709 --> 01:21:57,199

so there are different types of stars

2232

01:22:02,149 --> 01:21:58,719

mira variable stars

2233

01:22:05,510 --> 01:22:02,159

i did a project on those in andromeda

2234

01:22:06,629 --> 01:22:05,520

so basically spectra are your friend

2235

01:22:09,430 --> 01:22:06,639

here

2236

01:22:11,270 --> 01:22:09,440

when you can measure a spectrum of light

2237

01:22:13,830 --> 01:22:11,280

you can look out for the chemical

2238

01:22:14,629 --> 01:22:13,840

signatures within stars to be able to

2239

01:22:18,229 --> 01:22:14,639

kind of tell

2240

01:22:20,550 --> 01:22:18,239

what they are you can tell um

2241

01:22:22,550 --> 01:22:20,560

kind of how big they are and their mass

2242

01:22:23,189 --> 01:22:22,560

and so that's one way that you can tell

2243

01:22:25,990 --> 01:22:23,199

exactly

2244

01:22:27,189 --> 01:22:26,000

what that type of star is but in those

2245

01:22:29,030 --> 01:22:27,199

early days when

2246

01:22:31,350 --> 01:22:29,040

hubble was really just measuring the

2247

01:22:33,669 --> 01:22:31,360

pulsing variable stars

2248

01:22:34,950 --> 01:22:33,679

he you know broadly said we're just

2249

01:22:37,270 --> 01:22:34,960

going to say they're regular

2250

01:22:38,229 --> 01:22:37,280

and he got a pretty good measurement you

2251

01:22:41,590 --> 01:22:38,239

know

2252

01:22:44,550 --> 01:22:41,600

there's some variable stars that can

2253

01:22:47,430 --> 01:22:44,560

muddy the waters in there

2254

01:22:48,709 --> 01:22:47,440

and in fact hubble got the wrong type of

2255

01:22:50,950 --> 01:22:48,719

variable star

2256

01:22:52,950 --> 01:22:50,960

um so he measured it as being like 500

2257

01:22:55,350 --> 01:22:52,960

kilometers per second instead of

2258

01:22:57,030 --> 01:22:55,360

you know 100 or 50 kilometers per second

2259

01:22:58,870 --> 01:22:57,040

right if i remember correctly he

2260

01:23:00,790 --> 01:22:58,880

there's a type one and a type two as

2261

01:23:02,310 --> 01:23:00,800

astronomers always seem to do

2262

01:23:04,149 --> 01:23:02,320

he thought it was this one and it was

2263

01:23:05,590 --> 01:23:04,159

another one but you know he he

2264

01:23:07,910 --> 01:23:05,600

he proved that you know it was an

2265

01:23:09,669 --> 01:23:07,920

external galaxy first of all that was

2266

01:23:11,910 --> 01:23:09,679

the big thing and then you know the

2267

01:23:14,070 --> 01:23:11,920

number had to then of course be refined

2268

01:23:15,750 --> 01:23:14,080

for the hubble constant there yeah good

2269

01:23:17,430 --> 01:23:15,760

enough and in astronomy order of

2270

01:23:19,990 --> 01:23:17,440

magnitude if you're in the right

2271

01:23:21,430 --> 01:23:20,000

park you can you can certainly rule out

2272

01:23:23,590 --> 01:23:21,440

some things you can rule out that

2273

01:23:26,149 --> 01:23:23,600

andromeda is just sat in the halo

2274

01:23:27,750 --> 01:23:26,159

of the milky way right i keep trying to

2275

01:23:31,430 --> 01:23:27,760

tell my wife that you know factor of two

2276

01:23:37,510 --> 01:23:35,030

what else we got grant all right so

2277

01:23:39,189 --> 01:23:37,520

i'll take one i'll i'll get us one more

2278

01:23:41,750 --> 01:23:39,199

and depending on how we go here

2279

01:23:43,030 --> 01:23:41,760

i have an extra um this one's a little

2280

01:23:46,550 --> 01:23:43,040

bit more out there

2281

01:23:47,350 --> 01:23:46,560

which is for it uh if mass if mass and

2282

01:23:50,310 --> 01:23:47,360

time are

2283

01:23:51,669 --> 01:23:50,320

linked uh would larger objects be more

2284

01:23:55,510 --> 01:23:51,679

affected by time

2285

01:23:58,709 --> 01:23:55,520

and or gravity than smaller objects

2286

01:24:01,750 --> 01:23:58,719

mass and time are linked

2287

01:24:03,350 --> 01:24:01,760

i don't know meaning what what effect

2288

01:24:05,110 --> 01:24:03,360

i i think what this person is trying to

2289

01:24:08,550 --> 01:24:05,120

say is what effect

2290

01:24:11,669 --> 01:24:08,560

uh does our perception of celestial

2291

01:24:14,790 --> 01:24:11,679

objects get affected over distance

2292

01:24:17,990 --> 01:24:14,800

by time and gravity in

2293

01:24:19,910 --> 01:24:18,000

both lensing with the telescopes and in

2294

01:24:22,550 --> 01:24:19,920

how we can observe them over distance

2295

01:24:25,350 --> 01:24:22,560

because i know we use some of that with

2296

01:24:25,830 --> 01:24:25,360

adjusting for like gravitational lensing

2297

01:24:27,669 --> 01:24:25,840

and

2298

01:24:29,270 --> 01:24:27,679

in the cases of things that are very far

2299

01:24:32,310 --> 01:24:29,280

out there uh we

2300

01:24:34,229 --> 01:24:32,320

can also use some of that to establish

2301

01:24:36,470 --> 01:24:34,239

the constant motion

2302

01:24:37,830 --> 01:24:36,480

but are those two things linked in any

2303

01:24:41,350 --> 01:24:37,840

way and how do they help us

2304

01:24:43,110 --> 01:24:41,360

with our science yeah so i mean i think

2305

01:24:44,390 --> 01:24:43,120

for this if i understand the question

2306

01:24:49,430 --> 01:24:44,400

correctly we

2307

01:24:51,990 --> 01:24:49,440

we tend to rely pretty heavily on um

2308

01:24:52,950 --> 01:24:52,000

relativity for this so that link between

2309

01:24:54,950 --> 01:24:52,960

mass and time

2310

01:24:56,550 --> 01:24:54,960

because time is actually quite a

2311

01:24:59,990 --> 01:24:56,560

flexible

2312

01:25:03,430 --> 01:25:00,000

number um and so it uh

2313

01:25:06,629 --> 01:25:03,440

the heavier the gravitational well

2314

01:25:09,669 --> 01:25:06,639

you're in um the slower the time

2315

01:25:13,189 --> 01:25:09,679

goes um and so

2316

01:25:15,750 --> 01:25:13,199

uh yeah we we have to adjust for

2317

01:25:17,189 --> 01:25:15,760

mass and time in some calculations when

2318

01:25:20,070 --> 01:25:17,199

you're thinking about

2319

01:25:21,750 --> 01:25:20,080

um gravitational lenses uh you know you

2320

01:25:22,950 --> 01:25:21,760

have to adjust for this even when you're

2321

01:25:25,990 --> 01:25:22,960

thinking about

2322

01:25:28,550 --> 01:25:26,000

gps systems and and how we you know they

2323

01:25:30,310 --> 01:25:28,560

all have to make that correction um so

2324

01:25:33,350 --> 01:25:30,320

if i think i think i've understood the

2325

01:25:35,110 --> 01:25:33,360

uh question okay but um but yeah so yes

2326

01:25:37,510 --> 01:25:35,120

we always have to factor those in

2327

01:25:38,950 --> 01:25:37,520

and the heavier objects will always have

2328

01:25:40,229 --> 01:25:38,960

those effects more because of that

2329

01:25:41,910 --> 01:25:40,239

relation

2330

01:25:43,270 --> 01:25:41,920

and i would just add because there was a

2331

01:25:45,990 --> 01:25:43,280

lot of conversation

2332

01:25:48,229 --> 01:25:46,000

um in in the chat about this that this

2333

01:25:49,110 --> 01:25:48,239

is a localized effect on the the massive

2334

01:25:51,510 --> 01:25:49,120

objects

2335

01:25:53,750 --> 01:25:51,520

it doesn't really affect globally when

2336

01:25:55,910 --> 01:25:53,760

you compute a cosmology you're not

2337

01:25:56,950 --> 01:25:55,920

you know necessarily having to deal with

2338

01:25:58,550 --> 01:25:56,960

that on that

2339

01:25:59,910 --> 01:25:58,560

it's really with the localized effects

2340

01:26:01,590 --> 01:25:59,920

where you have the the high

2341

01:26:04,629 --> 01:26:01,600

concentrations of mass

2342

01:26:06,070 --> 01:26:04,639

that will take care of that

2343

01:26:09,030 --> 01:26:06,080

let's see i think we have time and more

2344

01:26:10,790 --> 01:26:09,040

question i have one more

2345

01:26:14,950 --> 01:26:10,800

and it's a good one unless you have one

2346

01:26:19,030 --> 01:26:18,070

i'm gonna let you do your job okay all

2347

01:26:21,750 --> 01:26:19,040

right

2348

01:26:24,149 --> 01:26:21,760

dr laura what is your favorite star in

2349

01:26:27,189 --> 01:26:24,159

andromeda

2350

01:26:30,790 --> 01:26:27,199

wow well they don't have names so

2351

01:26:33,590 --> 01:26:30,800

it's quite hard um but so

2352

01:26:35,990 --> 01:26:33,600

the project that i did um with raja

2353

01:26:38,790 --> 01:26:36,000

actually i was looking at stars that had

2354

01:26:40,550 --> 01:26:38,800

emission lines so like those features in

2355

01:26:42,709 --> 01:26:40,560

the spectrum

2356

01:26:44,790 --> 01:26:42,719

um so we were looking at lots of these

2357

01:26:46,229 --> 01:26:44,800

bright blue stars these massive hot

2358

01:26:49,270 --> 01:26:46,239

stars that were

2359

01:26:50,310 --> 01:26:49,280

um giving off these these kind of

2360

01:26:51,910 --> 01:26:50,320

beacons of light

2361

01:26:53,750 --> 01:26:51,920

that we could be able to tell what they

2362

01:26:56,390 --> 01:26:53,760

were so i really like

2363

01:26:58,310 --> 01:26:56,400

that collection of stars so some of them

2364

01:26:59,669 --> 01:26:58,320

were mira variables so a different type

2365

01:27:01,990 --> 01:26:59,679

of variable star

2366

01:27:03,830 --> 01:27:02,000

and some of them were massive really

2367

01:27:04,629 --> 01:27:03,840

massive bright hot blue stars and

2368

01:27:07,270 --> 01:27:04,639

they're spinning

2369

01:27:08,709 --> 01:27:07,280

so fast that they don't look round they

2370

01:27:10,790 --> 01:27:08,719

actually look oblate

2371

01:27:12,870 --> 01:27:10,800

and um so they're really kind of like

2372

01:27:13,750 --> 01:27:12,880

you know squished footballs rugby balls

2373

01:27:16,830 --> 01:27:13,760

if you will

2374

01:27:18,709 --> 01:27:16,840

um that helps with my analogy of

2375

01:27:20,950 --> 01:27:18,719

football

2376

01:27:22,550 --> 01:27:20,960

that's really cool and as i'll pass on

2377

01:27:24,149 --> 01:27:22,560

from the chat before i turn it over to

2378

01:27:26,229 --> 01:27:24,159

frank to bring us home

2379

01:27:27,430 --> 01:27:26,239

uh everyone has been very pleased with

2380

01:27:28,870 --> 01:27:27,440

your analogies

2381

01:27:31,270 --> 01:27:28,880

they say thank you it made it much

2382

01:27:33,750 --> 01:27:31,280

easier to understand great

2383

01:27:34,790 --> 01:27:33,760

thank you thank you thank you everyone

2384

01:27:37,350 --> 01:27:34,800

thank you man

2385

01:27:38,310 --> 01:27:37,360

i'm glad that was anything was clear so

2386

01:27:43,270 --> 01:27:38,320

all right

2387

01:27:43,990 --> 01:27:43,280

we cut off after 90 minutes and we hit

2388

01:27:46,310 --> 01:27:44,000

that

2389

01:27:47,110 --> 01:27:46,320

um thank you again again laura this was

2390

01:27:49,830 --> 01:27:47,120

wonderful

2391

01:27:51,430 --> 01:27:49,840

and um i'm sure you're gonna get lots of

2392

01:27:52,950 --> 01:27:51,440

views on youtube because this

2393

01:27:54,870 --> 01:27:52,960

and people watching it over and over

2394

01:27:56,950 --> 01:27:54,880

again to go you know i didn't get that

2395

01:27:58,629 --> 01:27:56,960

i got to watch that again to really let

2396

01:28:01,030 --> 01:27:58,639

that sink in because

2397

01:28:01,669 --> 01:28:01,040

some of this is mind-blowing uh we will

2398

01:28:05,510 --> 01:28:01,679

be back

2399

01:28:07,910 --> 01:28:05,520

on march 2nd uh with tom brown

2400

01:28:09,669 --> 01:28:07,920

talking about the hubble space telescope

2401

01:28:11,430 --> 01:28:09,679

from cosmological concept

2402

01:28:13,830 --> 01:28:11,440

to alien atmospheres he's going to

2403

01:28:15,990 --> 01:28:13,840

mention aliens too

2404

01:28:17,430 --> 01:28:16,000

i have a great chat back then thank you