

PUBLIC LECTURE SERIES

Dark Energy and New Worlds

Featuring Guest Speaker :
Amber Staughn



1
00:00:04,640 --> 00:00:03,169
I mean you came in if you didn't grab

2
00:00:07,369 --> 00:00:04,650
one there are pictures

3
00:00:10,669 --> 00:00:07,379
tonight's picture is of the Crab Nebula

4
00:00:13,129 --> 00:00:10,679
and that parentheses says m1 which means

5
00:00:15,320 --> 00:00:13,139
it's the first object in Charles Messier

6
00:00:17,990 --> 00:00:15,330
's catalogue of things that aren't

7
00:00:19,640 --> 00:00:18,000
comets because he didn't care about all

8
00:00:21,679 --> 00:00:19,650
these wonderful nebulae and galaxies

9
00:00:24,080 --> 00:00:21,689
that he found he actually cared about

10
00:00:26,990 --> 00:00:24,090
looking for comets this is the very

11
00:00:28,849 --> 00:00:27,000
first object in Messier x' catalog if

12
00:00:30,109 --> 00:00:28,859
you wanted to know more about it well

13
00:00:32,840 --> 00:00:30,119

i'll tell you a little bit more in the

14
00:00:35,479 --> 00:00:32,850
new summary and you can read on the back

15
00:00:36,920 --> 00:00:35,489
about it okay but if you didn't grab one

16
00:00:40,130 --> 00:00:36,930
on the way and please grab one on the

17
00:00:42,410 --> 00:00:40,140
way out tonight's talk will be amber

18
00:00:44,389 --> 00:00:42,420
Straughn from NASA Goddard telling us

19
00:00:47,569 --> 00:00:44,399
about dark energy in new worlds

20
00:00:49,580 --> 00:00:47,579
NASA's W first mission this is a sneak

21
00:00:51,590 --> 00:00:49,590
preview of astronomy that will be coming

22
00:00:56,060 --> 00:00:51,600
in the next decade or so

23
00:00:58,910 --> 00:00:56,070
all right coming up on July our July

24
00:01:01,639 --> 00:00:58,920
talk was normally be on July 4th we are

25
00:01:04,399 --> 00:01:01,649
not going to do that instead we're doing

26
00:01:07,310 --> 00:01:04,409
it on the new week after and our speaker

27
00:01:10,880 --> 00:01:07,320
to fit his schedule we're putting it on

28
00:01:13,840 --> 00:01:10,890
a Monday not a Tuesday Monday night same

29
00:01:18,620 --> 00:01:13,850
time eight o'clock same place right here

30
00:01:21,080 --> 00:01:18,630
how to find an inhabited exoplanet if

31
00:01:22,940 --> 00:01:21,090
that's not an intriguing title I don't

32
00:01:24,710 --> 00:01:22,950
know what could be okay

33
00:01:27,530 --> 00:01:24,720
David Charbonneau from the Harvard

34
00:01:30,440 --> 00:01:27,540
University in August we go back to our

35
00:01:32,539 --> 00:01:30,450
standard first Tuesday with a really

36
00:01:32,929 --> 00:01:32,549
cool talk I'm very much looking forward

37
00:01:35,749 --> 00:01:32,939
to this

38
00:01:38,840 --> 00:01:35,759

Courtney McManus is talking on the view

39

00:01:40,550 --> 00:01:38,850

from Mission Operations one of the cool

40

00:01:42,770 --> 00:01:40,560

things you get by coming to the Space

41

00:01:44,810 --> 00:01:42,780

Telescope Science Institute is yes we

42

00:01:47,389 --> 00:01:44,820

give you all this wonderful science but

43

00:01:49,069 --> 00:01:47,399

we also can give you the background the

44

00:01:50,840 --> 00:01:49,079

details what's happening behind the

45

00:01:53,300 --> 00:01:50,850

scenes so this is definitely a

46

00:01:54,770 --> 00:01:53,310

behind-the-scenes talk and I haven't

47

00:01:56,539 --> 00:01:54,780

heard Courtney's speak before but

48

00:01:58,010 --> 00:01:56,549

everybody tells me she's really

49

00:02:00,109 --> 00:01:58,020

wonderful and she has a great

50

00:02:02,569 --> 00:02:00,119

perspective yes Karen's giving me the

51
00:02:05,959 --> 00:02:02,579
thumbs up there so please come and

52
00:02:08,300 --> 00:02:05,969
August in September Nolan Walborn who

53
00:02:11,210 --> 00:02:08,310
has spoken every other year for me he's

54
00:02:12,920 --> 00:02:11,220
a wonderful reliable speaker for the

55
00:02:13,760 --> 00:02:12,930
public lecture series he's talking about

56
00:02:17,690 --> 00:02:13,770
active

57
00:02:19,790 --> 00:02:17,700
luminous blue variables that's an

58
00:02:22,100 --> 00:02:19,800
intriguing title I'll tell you more

59
00:02:24,770 --> 00:02:22,110
about that next month you want to find

60
00:02:26,270 --> 00:02:24,780
out our list you go to our website go

61
00:02:28,610 --> 00:02:26,280
into your favorite search engine put

62
00:02:31,220 --> 00:02:28,620
Space Telescope public lecture in and

63
00:02:33,350 --> 00:02:31,230

you'll find this webpage where we have

64

00:02:35,450 --> 00:02:33,360

the list of the upcoming lectures we

65

00:02:38,360 --> 00:02:35,460

have the links to watch it live on the s

66

00:02:41,420 --> 00:02:38,370

Space Telescope webcasting as well as on

67

00:02:43,910 --> 00:02:41,430

our hubble site YouTube you can watch

68

00:02:47,960 --> 00:02:43,920

the past lectures we have recorded these

69

00:02:49,640 --> 00:02:47,970

lectures since 2005 that's 12 years of

70

00:02:52,070 --> 00:02:49,650

astronomical goodness

71

00:02:53,780 --> 00:02:52,080

you have to review it'll take if you

72

00:02:57,020 --> 00:02:53,790

want to binge watch it may take you more

73

00:03:01,940 --> 00:02:57,030

than a weekend okay we have several

74

00:03:05,420 --> 00:03:01,950

seasons out there and you can also sign

75

00:03:08,570 --> 00:03:05,430

up for our email announcements I checked

76

00:03:11,260 --> 00:03:08,580

for I had to do a report and we have

77

00:03:13,970 --> 00:03:11,270

over 550 people on our email list so

78

00:03:15,430 --> 00:03:13,980

lots of people a lot of you have signed

79

00:03:18,620 --> 00:03:15,440

up for our email announcements okay

80

00:03:20,660 --> 00:03:18,630

alright speaking of the announcements

81

00:03:22,880 --> 00:03:20,670

sign up at the website you can do this

82

00:03:24,800 --> 00:03:22,890

but yeah it's much easier just through

83

00:03:27,290 --> 00:03:24,810

the website if you would like to contact

84

00:03:29,240 --> 00:03:27,300

us and send us email ask us questions

85

00:03:31,940 --> 00:03:29,250

you got a suggestion for an amazing

86

00:03:36,170 --> 00:03:31,950

speaker or something send email to

87

00:03:38,360 --> 00:03:36,180

public lecture at STScl dot edu you can

88

00:03:41,180 --> 00:03:38,370

also follow us on social media we have

89
00:03:43,700 --> 00:03:41,190
facebook we have two Twitter accounts we

90
00:03:45,170 --> 00:03:43,710
have Google+ we have Pinterest and maybe

91
00:03:47,300 --> 00:03:45,180
a few other things that I'm not quite

92
00:03:48,680 --> 00:03:47,310
aware of but I have to update this

93
00:03:52,040 --> 00:03:48,690
because I know we're starting a new push

94
00:03:54,500 --> 00:03:52,050
in social media next month so and by

95
00:03:56,780 --> 00:03:54,510
August I'll have a slightly revised

96
00:03:59,120 --> 00:03:56,790
version of this slide not this part

97
00:04:00,740 --> 00:03:59,130
because this is all I do i do my blog I

98
00:04:02,500 --> 00:04:00,750
do a little bit of Facebook a little bit

99
00:04:06,950 --> 00:04:02,510
of Google+ and a little bit of Twitter

100
00:04:07,730 --> 00:04:06,960
so don't expect me to be tweeting 20

101
00:04:10,580 --> 00:04:07,740
times a day

102
00:04:14,330 --> 00:04:10,590
the observatory I think the weather is

103
00:04:17,360 --> 00:04:14,340
permitting I didn't get an email but if

104
00:04:20,420 --> 00:04:17,370
weather is permitting the Rini will be

105
00:04:22,940 --> 00:04:20,430
here at 9 o'clock and watch the last

106
00:04:25,880 --> 00:04:22,950
part of Amber's talk and take you across

107
00:04:26,540 --> 00:04:25,890
the street to look through this which is

108
00:04:29,150 --> 00:04:26,550
the

109
00:04:30,950 --> 00:04:29,160
Maryland Space Grant Observatory okay so

110
00:04:32,659 --> 00:04:30,960
make sure I don't forget about this at

111
00:04:33,980 --> 00:04:32,669
the end somebody wave at me and say

112
00:04:35,960 --> 00:04:33,990
Frank don't forget the observatory

113
00:04:37,460 --> 00:04:35,970

because it's easy once we're over on a

114

00:04:41,240 --> 00:04:37,470

roll with all the cool questions people

115

00:04:44,779 --> 00:04:41,250

ask all right and now news from the

116

00:04:48,830 --> 00:04:44,789

universe for June 2017

117

00:04:54,499 --> 00:04:48,840

our first story tonight the final

118

00:04:57,379 --> 00:04:54,509

frontier fields so Hubble has started as

119

00:05:00,469 --> 00:04:57,389

it's going these projects called

120

00:05:02,870 --> 00:05:00,479

Treasury programs these are very large

121

00:05:04,909 --> 00:05:02,880

projects projects it would never get

122

00:05:06,770 --> 00:05:04,919

funded for this amount of Hubble time

123

00:05:08,899 --> 00:05:06,780

unless there was a special program

124

00:05:11,899 --> 00:05:08,909

saying hey yes you can have hundreds of

125

00:05:13,370 --> 00:05:11,909

orbits of Hubble time and one of the

126
00:05:16,370 --> 00:05:13,380
ones we've been talking about the past

127
00:05:20,659 --> 00:05:16,380
couple years is called the frontier

128
00:05:24,939 --> 00:05:20,669
fields it's a very ambitious program to

129
00:05:27,320 --> 00:05:24,949
look at six galaxy clusters okay and

130
00:05:30,620 --> 00:05:27,330
these are they see these red squares

131
00:05:32,779 --> 00:05:30,630
here those are the six galaxy clusters

132
00:05:35,600 --> 00:05:32,789
and these are some of the most massive

133
00:05:37,909 --> 00:05:35,610
galaxy clusters in the universe so

134
00:05:41,330 --> 00:05:37,919
massive that they produce the effect of

135
00:05:43,430 --> 00:05:41,340
gravitational lensing okay and so we

136
00:05:45,200 --> 00:05:43,440
look into these galaxy clusters to see

137
00:05:48,110 --> 00:05:45,210
examples of gravitational lensing which

138
00:05:50,570 --> 00:05:48,120

I'll show you in just a second but they

139

00:05:53,270 --> 00:05:50,580

can also observe at the exact same time

140

00:05:55,999 --> 00:05:53,280

these blue fields which will be some

141

00:05:58,010 --> 00:05:56,009

parallel fields to them and we call them

142

00:06:00,050 --> 00:05:58,020

the parallels but they are also deep

143

00:06:02,629 --> 00:06:00,060

fields like the Hubble Deep Field the

144

00:06:06,110 --> 00:06:02,639

Hubble extreme deep field etc they are

145

00:06:08,899 --> 00:06:06,120

very deep looks at the universe and when

146

00:06:12,230 --> 00:06:08,909

we look at these small deep fields we

147

00:06:15,200 --> 00:06:12,240

get a very small patch of the sky one

148

00:06:17,990 --> 00:06:15,210

Hubble pointing is about 112 millionth

149

00:06:20,029 --> 00:06:18,000

of the entire night sky and so you need

150

00:06:21,770 --> 00:06:20,039

a lot of these deep fields to add up the

151
00:06:24,469 --> 00:06:21,780
statistics to understand the deep

152
00:06:26,559 --> 00:06:24,479
universe so the frontier fields was this

153
00:06:29,689 --> 00:06:26,569
ambitious project to really study these

154
00:06:32,899 --> 00:06:29,699
galaxy clusters as well as study the

155
00:06:35,149 --> 00:06:32,909
deep fields and they've released oh and

156
00:06:37,790 --> 00:06:35,159
over the years they've released five of

157
00:06:39,930 --> 00:06:37,800
these galaxy clusters and just a few

158
00:06:43,500 --> 00:06:39,940
months ago we released

159
00:06:47,850 --> 00:06:43,510
number six this is the galaxy cluster

160
00:06:51,450 --> 00:06:47,860
called a bell 370 okay and all of these

161
00:06:54,090 --> 00:06:51,460
white objects in here are the galaxies

162
00:06:56,880 --> 00:06:54,100
of the cluster and their combined mass

163
00:07:00,540 --> 00:06:56,890

warps the space and produces

164

00:07:02,310 --> 00:07:00,550

gravitational lensing and so the the the

165

00:07:04,430 --> 00:07:02,320

image of a galaxy that passes through

166

00:07:07,680 --> 00:07:04,440

this cluster gets warped and stretched

167

00:07:10,320 --> 00:07:07,690

by the galaxy cluster and one of the

168

00:07:13,950 --> 00:07:10,330

famous examples in there a bell 370 is

169

00:07:18,330 --> 00:07:13,960

something we call the dragon okay this

170

00:07:21,090 --> 00:07:18,340

is not one not two but three images of

171

00:07:24,150 --> 00:07:21,100

the same galaxy all right you can sort

172

00:07:26,010 --> 00:07:24,160

of see it here on the tail on the head

173

00:07:28,530 --> 00:07:26,020

of the dragon you can see that looks

174

00:07:30,300 --> 00:07:28,540

sort of like a normal galaxy right but

175

00:07:32,250 --> 00:07:30,310

here's another image of it in the middle

176
00:07:34,470 --> 00:07:32,260
in the midsection that's become

177
00:07:36,660 --> 00:07:34,480
stretched out due to the gravitational

178
00:07:39,270 --> 00:07:36,670
lensing and then there's another one on

179
00:07:41,520 --> 00:07:39,280
the other end the tail of the dragon

180
00:07:43,590 --> 00:07:41,530
where you can see it's also an image of

181
00:07:45,270 --> 00:07:43,600
the galaxy cluster so the light from

182
00:07:47,940 --> 00:07:45,280
this galaxy has travelled three pass

183
00:07:50,730 --> 00:07:47,950
through the same through the cluster and

184
00:07:53,730 --> 00:07:50,740
through these three distorted images of

185
00:07:55,590 --> 00:07:53,740
this galaxy and we called the dragon

186
00:07:58,650 --> 00:07:55,600
just because it has a nice head and tail

187
00:08:00,930 --> 00:07:58,660
type type features to it and you can see

188
00:08:02,550 --> 00:08:00,940

a lot of other streaky and our key

189

00:08:04,830 --> 00:08:02,560

things through here that are other

190

00:08:07,170 --> 00:08:04,840

evidence of the gravitational lensing

191

00:08:09,090 --> 00:08:07,180

all right and so this is something that

192

00:08:11,070 --> 00:08:09,100

they're searching for very distant

193

00:08:13,170 --> 00:08:11,080

galaxies and really cool examples of

194

00:08:15,900 --> 00:08:13,180

gravitational lensing in this we're also

195

00:08:18,630 --> 00:08:15,910

looking at these deep fields and here is

196

00:08:20,580 --> 00:08:18,640

the deep field that parallels to it and

197

00:08:23,040 --> 00:08:20,590

it looks very much like the other deep

198

00:08:26,040 --> 00:08:23,050

fields and as I said this will augment

199

00:08:29,130 --> 00:08:26,050

the statistics of our understanding of

200

00:08:31,110 --> 00:08:29,140

these deep fields so this is sort of the

201
00:08:33,810 --> 00:08:31,120
announcement of that hey we've got all

202
00:08:35,339 --> 00:08:33,820
the data we haven't by any stretch of

203
00:08:38,010 --> 00:08:35,349
the imagination done all the analysis

204
00:08:41,040 --> 00:08:38,020
but we have all the data for all six

205
00:08:43,110 --> 00:08:41,050
galaxy clusters and all six deep field

206
00:08:44,520 --> 00:08:43,120
it's kind of nice that this project

207
00:08:47,160 --> 00:08:44,530
that's been going on for like three or

208
00:08:49,320 --> 00:08:47,170
four years has finally got all the data

209
00:08:49,770 --> 00:08:49,330
and of course the science that will come

210
00:08:52,500 --> 00:08:49,780
from it

211
00:08:53,610 --> 00:08:52,510
will take many many more years to

212
00:08:55,410 --> 00:08:53,620
continue to trickle out

213
00:08:57,450 --> 00:08:55,420

because we're getting lots and lots of

214

00:08:59,190 --> 00:08:57,460

science out of not just the current

215

00:09:02,820 --> 00:08:59,200

observations but also the archival

216

00:09:06,650 --> 00:09:02,830

observations from Hubble our second

217

00:09:11,430 --> 00:09:06,660

story a dramatic chromatic Crab Nebula

218

00:09:14,160 --> 00:09:11,440

now there's a reason I use this image as

219

00:09:16,880 --> 00:09:14,170

our giveaway tonight the Crab Nebula

220

00:09:19,230 --> 00:09:16,890

because this is the standard image of

221

00:09:22,910 --> 00:09:19,240

Hubble's view of a Crab Nebula -

222

00:09:25,590 --> 00:09:22,920

everyone knows it came from 2000 or 2001

223

00:09:28,230 --> 00:09:25,600

done with the white tail a wide field

224

00:09:30,720 --> 00:09:28,240

planetary camera - and it's a really

225

00:09:32,519 --> 00:09:30,730

cool image it's great and so when people

226

00:09:35,040 --> 00:09:32,529

think of Hubble's Crab Nebula this is

227

00:09:37,320 --> 00:09:35,050

what they think of but there's more that

228

00:09:40,620 --> 00:09:37,330

meets that there's more to the Crab

229

00:09:43,050 --> 00:09:40,630

Nebula than meets the eye so in this

230

00:09:46,950 --> 00:09:43,060

image we see that the different colors

231

00:09:50,430 --> 00:09:46,960

represent different specific elements

232

00:09:52,769 --> 00:09:50,440

like nitrogen or iron or sulfur or

233

00:09:54,870 --> 00:09:52,779

hydrogen very specific elements and they

234

00:09:56,220 --> 00:09:54,880

tell us what's going on for the the

235

00:09:58,170 --> 00:09:56,230

temperatures and densities that

236

00:10:00,660 --> 00:09:58,180

appropriate for the emission of those

237

00:10:03,420 --> 00:10:00,670

spectral lines but what if we went

238

00:10:06,750 --> 00:10:03,430

beyond visible light what have we looked

239

00:10:09,840 --> 00:10:06,760

at the Crab Nebula over many different

240

00:10:12,180 --> 00:10:09,850

wavelengths we would get an even greater

241

00:10:13,860 --> 00:10:12,190

view of it okay actually you know what

242

00:10:15,150 --> 00:10:13,870

there's well there's probably a bunch of

243

00:10:16,920 --> 00:10:15,160

you who don't know what the Crab Nebula

244

00:10:19,340 --> 00:10:16,930

is how many people don't know what the

245

00:10:21,269 --> 00:10:19,350

Crab Nebula is and this is one of these

246

00:10:23,040 --> 00:10:21,279

problems with being an astronomer it's

247

00:10:24,660 --> 00:10:23,050

like oh yeah the Crab Nebula the Crab

248

00:10:27,210 --> 00:10:24,670

Nebula for those who don't know and

249

00:10:30,720 --> 00:10:27,220

actually surprisingly few is a supernova

250

00:10:33,630 --> 00:10:30,730

remnant a star that exploded a thousand

251
00:10:36,060 --> 00:10:33,640
years ago chinese astronomers saw the

252
00:10:39,180 --> 00:10:36,070
explosion in actually I believe it was

253
00:10:42,150 --> 00:10:39,190
July 4th 1054 all right so that was a

254
00:10:45,030 --> 00:10:42,160
little early for Independence Day but in

255
00:10:47,280 --> 00:10:45,040
1054 they saw a guest star appear in the

256
00:10:49,860 --> 00:10:47,290
sky and it was a star that just

257
00:10:52,440 --> 00:10:49,870
basically exploded alright it blew its

258
00:10:54,480 --> 00:10:52,450
guts out into space so a thousand years

259
00:10:57,420 --> 00:10:54,490
ago this all that gas was inside a star

260
00:11:00,199 --> 00:10:57,430
and now it's a nebula that's ten years

261
00:11:02,460 --> 00:11:00,209
ten light years across okay so it's

262
00:11:04,680 --> 00:11:02,470
booming across space at millions of

263
00:11:07,290 --> 00:11:04,690

miles an hour all right so this is the

264

00:11:09,540 --> 00:11:07,300

guts of a star blown out into space

265

00:11:13,860 --> 00:11:09,550

and if this is what we see in visible

266

00:11:16,730 --> 00:11:13,870

light if we look in radio light with the

267

00:11:19,320 --> 00:11:16,740

Very Large Array we get this image and

268

00:11:22,980 --> 00:11:19,330

so these are the radio waves emitted

269

00:11:24,750 --> 00:11:22,990

from the gas that is being energized to

270

00:11:26,579 --> 00:11:24,760

MIT and radio now radio ways are

271

00:11:29,819 --> 00:11:26,589

generally the lower lowest energy that

272

00:11:31,530 --> 00:11:29,829

we look at okay so this is out here you

273

00:11:35,040 --> 00:11:31,540

can see it's the out mostly the

274

00:11:38,220 --> 00:11:35,050

outskirts of the nebula we then step up

275

00:11:40,650 --> 00:11:38,230

to infrared wavelengths from the Spitzer

276

00:11:43,050 --> 00:11:40,660

Space Telescope we see this this is the

277

00:11:46,199 --> 00:11:43,060

cooler gas this is gas around a few

278

00:11:47,639 --> 00:11:46,209

hundred degrees all right 100 a few

279

00:11:49,860 --> 00:11:47,649

hundred degrees and you start to see you

280

00:11:52,290 --> 00:11:49,870

know filament the filament restructure

281

00:11:54,210 --> 00:11:52,300

if we go to the Hubble image and we just

282

00:11:55,769 --> 00:11:54,220

give it a single filter color all right

283

00:11:58,530 --> 00:11:55,779

here we're getting gas that's at

284

00:12:00,269 --> 00:11:58,540

thousands of degrees generally thousands

285

00:12:02,069 --> 00:12:00,279

are tens of thousands of degrees and you

286

00:12:05,699 --> 00:12:02,079

really see that filamentary structure

287

00:12:07,620 --> 00:12:05,709

the gas that's blown out and created all

288

00:12:11,730 --> 00:12:07,630

these beautiful filaments all right if

289

00:12:13,350 --> 00:12:11,740

we then go up to the ultraviolet now

290

00:12:15,240 --> 00:12:13,360

we're looking at gas it's tens of

291

00:12:17,550 --> 00:12:15,250

thousands to hundreds of thousands of

292

00:12:21,569 --> 00:12:17,560

degrees and you sort of see the volume

293

00:12:23,010 --> 00:12:21,579

filling inside the the filamentary

294

00:12:25,860 --> 00:12:23,020

structure that we see in visible light

295

00:12:28,530 --> 00:12:25,870

but you also start to see the appearance

296

00:12:31,850 --> 00:12:28,540

of a disc like in the center of it and

297

00:12:35,880 --> 00:12:31,860

when we go to x-rays the highest energy

298

00:12:38,220 --> 00:12:35,890

you really see that disc and so do you

299

00:12:41,310 --> 00:12:38,230

see the disc of material around this

300

00:12:44,519 --> 00:12:41,320

bright spot in the center that bright

301

00:12:47,639 --> 00:12:44,529

spot in the center is a neutron star

302

00:12:50,220 --> 00:12:47,649

it's the collapsed core of the star that

303

00:12:53,579 --> 00:12:50,230

exploded and this one happens to be

304

00:12:56,639 --> 00:12:53,589

spinning 30 times a second it's a

305

00:12:59,430 --> 00:12:56,649

millisecond pulsar and you can see this

306

00:13:01,949 --> 00:12:59,440

disc of material of material around it

307

00:13:04,560 --> 00:13:01,959

as well as what appeared to be material

308

00:13:07,590 --> 00:13:04,570

streaming out from the poles of it okay

309

00:13:09,810 --> 00:13:07,600

all right so combining all those views

310

00:13:13,110 --> 00:13:09,820

together you get the multi-wavelength

311

00:13:16,610 --> 00:13:13,120

view of the Crab Nebula and this

312

00:13:20,050 --> 00:13:16,620

includes radio infrared visible

313

00:13:22,630 --> 00:13:20,060

ultraviolet and x-ray views

314

00:13:24,790 --> 00:13:22,640

from telescopes and I think it's a

315

00:13:27,730 --> 00:13:24,800

really gorgeous image and it showed I

316

00:13:30,430 --> 00:13:27,740

think it showcases where astronomy has

317

00:13:32,440 --> 00:13:30,440

gone in the last hundred years because a

318

00:13:34,720 --> 00:13:32,450

hundred years ago we were just using

319

00:13:37,450 --> 00:13:34,730

visible light we didn't start using

320

00:13:40,390 --> 00:13:37,460

radio light until the 1930s and we have

321

00:13:42,910 --> 00:13:40,400

developed observations across the entire

322

00:13:45,040 --> 00:13:42,920

electromagnetic spectrum and here is a

323

00:13:50,110 --> 00:13:45,050

gorgeous example of it with the Crab

324

00:13:52,810 --> 00:13:50,120

Nebula the third story is yet Bohr from

325

00:13:54,910 --> 00:13:52,820

the lunatic fringe now those of you

326
00:13:57,610 --> 00:13:54,920
who've been here many times have heard

327
00:14:00,340 --> 00:13:57,620
me to discuss the lunatic fringe before

328
00:14:03,070 --> 00:14:00,350
and what I refer to when with that joke

329
00:14:06,220 --> 00:14:03,080
is first the fringe of the solar system

330
00:14:08,170 --> 00:14:06,230
so here are the orbits of Jupiter Saturn

331
00:14:10,510 --> 00:14:08,180
Uranus and Neptune okay

332
00:14:12,280 --> 00:14:10,520
and so out beyond the orbit of Neptune

333
00:14:14,320 --> 00:14:12,290
is what I'm referring to as the fringe

334
00:14:17,320 --> 00:14:14,330
of the solar system and it's a region we

335
00:14:19,330 --> 00:14:17,330
call the Kuiper belt okay and the Kuiper

336
00:14:22,780 --> 00:14:19,340
belt is something that we didn't know

337
00:14:25,120 --> 00:14:22,790
about until the 1990s we discovered

338
00:14:28,690 --> 00:14:25,130

these thousands of objects out beyond

339

00:14:30,550 --> 00:14:28,700

Neptune well except for two of them all

340

00:14:32,829 --> 00:14:30,560

right except for two of them we

341

00:14:34,360 --> 00:14:32,839

discovered thousands more objects out

342

00:14:36,550 --> 00:14:34,370

beyond the orbit of Neptune they're

343

00:14:38,530 --> 00:14:36,560

small they're I see they have elliptical

344

00:14:40,720 --> 00:14:38,540

orbits they have tilted orbits all right

345

00:14:43,390 --> 00:14:40,730

and they're very much just like they're

346

00:14:47,260 --> 00:14:43,400

most of the the largest object in the

347

00:14:51,400 --> 00:14:47,270

Kuiper belt which is Pluto Pluto was

348

00:14:53,110 --> 00:14:51,410

discovered in 1930 Charon in 1978 I

349

00:14:55,960 --> 00:14:53,120

think although it wasn't verified until

350

00:14:59,230 --> 00:14:55,970

85 something like that all right

351
00:15:00,730 --> 00:14:59,240
and then so Pluto and Charon are the

352
00:15:03,190 --> 00:15:00,740
first two objects discovered in the

353
00:15:05,260 --> 00:15:03,200
Kuiper belt we now know of thousands all

354
00:15:07,090 --> 00:15:05,270
right and when I talk about lunatic

355
00:15:10,480 --> 00:15:07,100
fringe I'm talking about the moons

356
00:15:12,640 --> 00:15:10,490
around Kuiper belt objects and Pluto is

357
00:15:14,860 --> 00:15:12,650
a great example because as I said we

358
00:15:17,200 --> 00:15:14,870
knew about this before Hubble it took

359
00:15:22,090 --> 00:15:17,210
Hubble's resolution to find Nix and

360
00:15:27,550 --> 00:15:22,100
Hydra which we found in 2006 Kerberos I

361
00:15:29,500 --> 00:15:27,560
think in 2010 and Styx in 2012 so Hubble

362
00:15:31,900 --> 00:15:29,510
has been instrumental in finding these

363
00:15:33,670 --> 00:15:31,910

moons around these objects at the fringe

364

00:15:36,190 --> 00:15:33,680

of the solar system all right

365

00:15:38,740 --> 00:15:36,200

so here are here's a graphic of the

366

00:15:40,720 --> 00:15:38,750

eighth largest Kuiper belt objects all

367

00:15:42,070 --> 00:15:40,730

right everyone knows Pluto can anybody

368

00:15:43,150 --> 00:15:42,080

name other Kuiper belt objects

369

00:15:49,290 --> 00:15:43,160

astronomers with us

370

00:15:56,310 --> 00:15:49,300

yes Eris yes how may i yes very good

371

00:15:59,710 --> 00:15:56,320

other ones in the back Makemake

372

00:16:03,040 --> 00:15:59,720

he's heart yes interesting names okay

373

00:16:07,090 --> 00:16:03,050

pluto eris Haumea Makemake those are the

374

00:16:10,870 --> 00:16:07,100

the traditional top four quar Sedna and

375

00:16:15,400 --> 00:16:10,880

orcas okay yes it is pronounced Wawa

376

00:16:17,500 --> 00:16:15,410

okay now you'll notice I have left out a

377

00:16:21,820 --> 00:16:17,510

name for the third largest Kuiper belt

378

00:16:23,850 --> 00:16:21,830

object because it has no name it is

379

00:16:28,540 --> 00:16:23,860

actually known by its catalog number

380

00:16:30,930 --> 00:16:28,550

2007 Oh our 10 it has yet to be given an

381

00:16:33,490 --> 00:16:30,940

actual name which is kind of funky

382

00:16:36,280 --> 00:16:33,500

because there's a lot smaller things out

383

00:16:37,870 --> 00:16:36,290

there that have been given names now

384

00:16:39,640 --> 00:16:37,880

when I talk about the moons of Pluto

385

00:16:41,890 --> 00:16:39,650

there are lots of them but there are

386

00:16:45,040 --> 00:16:41,900

also lots of moons of other Kuiper belt

387

00:16:49,019 --> 00:16:45,050

objects Eris has Disney Mia there's high

388

00:16:51,160 --> 00:16:49,029

aachen Amaka way wat van and mk2 is a

389

00:16:52,390 --> 00:16:51,170

nickname I don't know if it actually has

390

00:16:54,610 --> 00:16:52,400

a real name or it still has the

391

00:16:56,560 --> 00:16:54,620

designation all right so you'll actually

392

00:17:00,970 --> 00:16:56,570

notice of the eighth-largest

393

00:17:04,260 --> 00:17:00,980

cover about objects only Sedna and 2007

394

00:17:10,059 --> 00:17:04,270

or 10 don't have moons or well I say

395

00:17:13,390 --> 00:17:10,069

didn't have moons okay the Kepler space

396

00:17:16,030 --> 00:17:13,400

telescope her mission looked at 2007 or

397

00:17:19,540 --> 00:17:16,040

10 and found that it was rotating slowly

398

00:17:21,699 --> 00:17:19,550

it rotated once every 45 hours generally

399

00:17:22,090 --> 00:17:21,709

Kuiper belt objects rotate in a couple

400

00:17:25,929 --> 00:17:22,100

hours

401
00:17:27,340 --> 00:17:25,939
so having a 45 hour rotation suggested

402
00:17:28,720 --> 00:17:27,350
that some of the angular momentum

403
00:17:31,270 --> 00:17:28,730
instead of being in the spin of the

404
00:17:34,330 --> 00:17:31,280
object was actually in a moon orbiting

405
00:17:37,090 --> 00:17:34,340
around it so people went looking for it

406
00:17:39,520 --> 00:17:37,100
where do they look they looked in the

407
00:17:44,820 --> 00:17:39,530
Hubble archive okay Hubble had already

408
00:17:47,140 --> 00:17:44,830
taken images of 2010 and they saw this

409
00:17:50,170 --> 00:17:47,150
in 2009 and

410
00:17:52,600 --> 00:17:50,180
2010 Hubble took these images so the

411
00:17:54,550 --> 00:17:52,610
bright spot in the center is 2007 Oh are

412
00:17:56,830 --> 00:17:54,560
10 and because it's a solar system

413
00:17:58,870 --> 00:17:56,840

object it moves relative to the

414

00:18:00,610 --> 00:17:58,880

background stars so there's lots of

415

00:18:02,530 --> 00:18:00,620

things like you know this thing and this

416

00:18:04,270 --> 00:18:02,540

thing these are all background stars

417

00:18:07,750 --> 00:18:04,280

moving past the things that are

418

00:18:09,520 --> 00:18:07,760

different in each image are the are the

419

00:18:10,930 --> 00:18:09,530

stars in the background is there

420

00:18:12,730 --> 00:18:10,940

something the same in each image

421

00:18:16,780 --> 00:18:12,740

you betcha otherwise I wouldn't be

422

00:18:20,020 --> 00:18:16,790

talking about it there they discovered

423

00:18:22,570 --> 00:18:20,030

that yes it did have a moon so here's

424

00:18:25,930 --> 00:18:22,580

where it was in 2009 here's where it is

425

00:18:27,850 --> 00:18:25,940

in 2010 unfortunately these two

426
00:18:30,580 --> 00:18:27,860
observations weren't enough to determine

427
00:18:33,760 --> 00:18:30,590
in orbit for it so they don't know the

428
00:18:36,190 --> 00:18:33,770
the actual mass of it but we turned to

429
00:18:37,900 --> 00:18:36,200
the Herschel Space Telescope and they

430
00:18:40,330 --> 00:18:37,910
were able to use far infrared

431
00:18:43,930 --> 00:18:40,340
observations to get a thermal emission

432
00:18:48,220 --> 00:18:43,940
profile for it and estimate its size so

433
00:18:50,110 --> 00:18:48,230
adding that back into the the chart you

434
00:18:53,680 --> 00:18:50,120
can see that the provisional designation

435
00:18:58,260 --> 00:18:53,690
for it here we now have seven of the top

436
00:19:00,990 --> 00:18:58,270
eight Kuiper belt objects with moons now

437
00:19:03,490 --> 00:19:01,000
the really cool science behind it is

438
00:19:07,390 --> 00:19:03,500

well fine you've got these icy things

439

00:19:10,870 --> 00:19:07,400

that have these icy moons but you really

440

00:19:12,910 --> 00:19:10,880

couldn't have formed them as you formed

441

00:19:14,710 --> 00:19:12,920

the Kuiper belt object you think of

442

00:19:17,050 --> 00:19:14,720

Jupiter and it's Galilean moons and

443

00:19:19,960 --> 00:19:17,060

Jupiter forms here and the moons form in

444

00:19:24,340 --> 00:19:19,970

a disk around them how did these moons

445

00:19:27,250 --> 00:19:24,350

form not by accretion around the the

446

00:19:30,670 --> 00:19:27,260

collapsing collapsing body but rather by

447

00:19:33,220 --> 00:19:30,680

a collision and capture so the idea is

448

00:19:35,040 --> 00:19:33,230

that for all of these objects something

449

00:19:37,360 --> 00:19:35,050

smashed into something else and

450

00:19:42,520 --> 00:19:37,370

collected into collected a moon around

451
00:19:44,110 --> 00:19:42,530
it okay so Nix Hydra Nix Kerberos and

452
00:19:46,630 --> 00:19:44,120
Styx by the way these are the actual

453
00:19:49,660 --> 00:19:46,640
sizes those are kind of tiny moons all

454
00:19:51,640 --> 00:19:49,670
right and Charon all have the same orbit

455
00:19:55,120 --> 00:19:51,650
and we believed there was a very large

456
00:19:56,770 --> 00:19:55,130
smash but that produced Pluto Pluto

457
00:19:58,720 --> 00:19:56,780
Charon system okay

458
00:20:00,970 --> 00:19:58,730
and the same for all of these that a

459
00:20:05,230 --> 00:20:00,980
collision produces

460
00:20:07,330 --> 00:20:05,240
captured moons so it's actually adding

461
00:20:09,549 --> 00:20:07,340
to our scientific understanding of the

462
00:20:11,730 --> 00:20:09,559
formation of moons which is kind of

463
00:20:15,810 --> 00:20:11,740

important and it really hits home

464

00:20:18,520 --> 00:20:15,820

because amongst the planets this one is

465

00:20:22,570 --> 00:20:18,530

believed to have had that same process

466

00:20:24,940 --> 00:20:22,580

happen our Moon using rock instead of

467

00:20:27,340 --> 00:20:24,950

ice is believed to have formed when

468

00:20:30,310 --> 00:20:27,350

approximately a mars-sized body hit the

469

00:20:37,320 --> 00:20:30,320

earth about four four and a half billion

470

00:20:39,940 --> 00:20:37,330

years ago so an appreciation of the the

471

00:20:43,409 --> 00:20:39,950

frequency at which these collisions can

472

00:20:45,789 --> 00:20:43,419

happen and produce captured moons is

473

00:20:50,110 --> 00:20:45,799

greatly increasing with our knowledge of

474

00:20:52,020 --> 00:20:50,120

Kuiper belt alright thank you and that's

475

00:20:55,240 --> 00:20:52,030

our news from the universe for tonight

476

00:20:58,000 --> 00:20:55,250

all right now we're gonna go on to our

477

00:21:00,100 --> 00:20:58,010

featured speaker and our speaker is

478

00:21:01,289 --> 00:21:00,110

amber Straughn from NASA Goddard Space

479

00:21:04,720 --> 00:21:01,299

Flight Center

480

00:21:07,450 --> 00:21:04,730

she did her she likes Messiah described

481

00:21:11,470 --> 00:21:07,460

herself as an Arkansas farm girl turned

482

00:21:14,380 --> 00:21:11,480

astrophysicist she did her undergraduate

483

00:21:16,060 --> 00:21:14,390

work at the University of Arkansas then

484

00:21:19,150 --> 00:21:16,070

she did her graduate work at Arizona

485

00:21:20,289 --> 00:21:19,160

State University and she's been she's

486

00:21:22,630 --> 00:21:20,299

down at Goddard Space Flight Center

487

00:21:25,720 --> 00:21:22,640

working on the James Webb Space

488

00:21:27,280 --> 00:21:25,730

Telescope and she has a bunch of cool

489

00:21:28,810 --> 00:21:27,290

things about her one of the things

490

00:21:31,770 --> 00:21:28,820

that's been highlighted a lot is that

491

00:21:35,140 --> 00:21:31,780

she is a pilot she flies her own planes

492

00:21:37,840 --> 00:21:35,150

and she tells me that that's fun but the

493

00:21:42,130 --> 00:21:37,850

really fun thing is she got to go on the

494

00:21:43,990 --> 00:21:42,140

Vomit Comet the hyperbolic repair well

495

00:21:49,570 --> 00:21:44,000

parabolic trajectory plane where you

496

00:21:50,880 --> 00:21:49,580

actually are weightless for how long all

497

00:21:53,360 --> 00:21:50,890

right so

498

00:21:55,710 --> 00:21:53,370

[Laughter]

499

00:21:57,600 --> 00:21:55,720

so you're weightless for 20 to 30

500

00:22:01,260 --> 00:21:57,610

seconds and they do it 20 times in a row

501
00:22:02,160 --> 00:22:01,270
alright and she she kept her lunch down

502
00:22:04,740 --> 00:22:02,170
ha ha ha

503
00:22:07,650 --> 00:22:04,750
so ladies and gentlemen we have a hearty

504
00:22:24,370 --> 00:22:07,660
speaker tonight amber strong

505
00:22:29,030 --> 00:22:26,750
all right can you all hear me in the

506
00:22:32,000 --> 00:22:29,040
back y'all I say you heard I was from

507
00:22:34,250 --> 00:22:32,010
Arkansas so I say y'all I'm so great to

508
00:22:37,010 --> 00:22:34,260
see so many of you tonight I'm really

509
00:22:39,110 --> 00:22:37,020
excited to be here to talk a little bit

510
00:22:41,060 --> 00:22:39,120
about an awesome new mission that we

511
00:22:42,980 --> 00:22:41,070
have coming up and to talk about some of

512
00:22:45,170 --> 00:22:42,990
the science that motivates this mission

513
00:22:46,880 --> 00:22:45,180

so you've heard him from Arkansas and

514

00:22:48,920 --> 00:22:46,890

really what got me interested in

515

00:22:51,320 --> 00:22:48,930

astronomy to begin with was the fact

516

00:22:53,870 --> 00:22:51,330

that I grew up in a rural part of the

517

00:22:56,300 --> 00:22:53,880

country so I grew up in a tiny little

518

00:22:59,030 --> 00:22:56,310

town called B Branch Arkansas which I'm

519

00:23:01,310 --> 00:22:59,040

almost guaranteeing nobody in this

520

00:23:03,950 --> 00:23:01,320

audience has heard of middle of nowhere

521

00:23:07,760 --> 00:23:03,960

North Central Arkansas not a lot to do

522

00:23:09,770 --> 00:23:07,770

but the sky was beautiful so I grew up

523

00:23:11,750 --> 00:23:09,780

under this rule dark sky and that's

524

00:23:13,970 --> 00:23:11,760

really what got me interested in the

525

00:23:17,630 --> 00:23:13,980

stars from the time I was a little kid

526

00:23:20,750 --> 00:23:17,640

and since that time when I was a kid I

527

00:23:22,580 --> 00:23:20,760

decided to I was asking all these

528

00:23:24,350 --> 00:23:22,590

questions about the universe and decided

529

00:23:26,900 --> 00:23:24,360

from a very young age that I wanted to

530

00:23:28,880 --> 00:23:26,910

pursue that dream to find out what was

531

00:23:31,130 --> 00:23:28,890

out there what was beyond what you can

532

00:23:33,110 --> 00:23:31,140

see with your eyes and from the time I

533

00:23:35,960 --> 00:23:33,120

was a kid one of the thing this really

534

00:23:38,510 --> 00:23:35,970

has captivated me about astronomy in

535

00:23:41,390 --> 00:23:38,520

general is that astronomy gets to the

536

00:23:43,460 --> 00:23:41,400

heart of our big questions and these

537

00:23:45,650 --> 00:23:43,470

aren't just questions that scientists

538

00:23:47,300 --> 00:23:45,660

ask these are questions that human

539

00:23:50,240 --> 00:23:47,310

beings ask these are questions that

540

00:23:52,100 --> 00:23:50,250

we've asked over a millennia they get to

541

00:23:54,500 --> 00:23:52,110

the heart of what it means to be a human

542

00:23:57,440 --> 00:23:54,510

being of how do we get here

543

00:23:59,240 --> 00:23:57,450

and what's the universe like and then

544

00:24:01,130 --> 00:23:59,250

that big question that we're still

545

00:24:04,670 --> 00:24:01,140

trying to answer which is are we alone

546

00:24:07,100 --> 00:24:04,680

and so many of our fundamental questions

547

00:24:10,190 --> 00:24:07,110

about the universe have been answered

548

00:24:12,590 --> 00:24:10,200

over the past many decades by telescopes

549

00:24:14,390 --> 00:24:12,600

so we're able to learn a lot about the

550

00:24:17,470 --> 00:24:14,400

universe just from looking at the sky

551
00:24:20,570 --> 00:24:17,480
our ancestors of course learned about

552
00:24:23,960 --> 00:24:20,580
about time we measure time by the way

553
00:24:26,400 --> 00:24:23,970
stars pass in the sky we learned you

554
00:24:27,840 --> 00:24:26,410
know many centuries ago that

555
00:24:29,580 --> 00:24:27,850
there were certain objects in the night

556
00:24:31,230 --> 00:24:29,590
sky that moved a little bit differently

557
00:24:33,300 --> 00:24:31,240
than most of the stars did and those

558
00:24:37,590 --> 00:24:33,310
occur of course turned out to be planets

559
00:24:39,060 --> 00:24:37,600
and so for for centuries for millennia

560
00:24:41,400 --> 00:24:39,070
even people have been looking at the sky

561
00:24:43,020 --> 00:24:41,410
and figuring out how the world works

562
00:24:45,300 --> 00:24:43,030
just from looking at the sky with your

563
00:24:46,950 --> 00:24:45,310

eyes but of course there comes a limit

564

00:24:49,560 --> 00:24:46,960

to what you can learn from looking at

565

00:24:51,750 --> 00:24:49,570

the sky with your eyeballs and so we

566

00:24:54,090 --> 00:24:51,760

build telescopes to help us build on

567

00:24:56,100 --> 00:24:54,100

that knowledge and as an astronomer I've

568

00:24:57,750 --> 00:24:56,110

been really fortunate to observe at some

569

00:25:00,330 --> 00:24:57,760

of the world's biggest telescopes on the

570

00:25:03,180 --> 00:25:00,340

ground telescopes in Hawaii and Chile

571

00:25:05,640 --> 00:25:03,190

but there does also come a limit to what

572

00:25:08,070 --> 00:25:05,650

we can learn from telescopes on the

573

00:25:10,140 --> 00:25:08,080

ground just from the simple fact the

574

00:25:12,270 --> 00:25:10,150

telescopes on the earth have to look

575

00:25:14,340 --> 00:25:12,280

through the atmosphere and so what do we

576

00:25:17,070 --> 00:25:14,350

do of course we put telescopes into

577

00:25:19,110 --> 00:25:17,080

space and the Hubble Space Telescope has

578

00:25:21,210 --> 00:25:19,120

been one of the I believe one of the

579

00:25:23,010 --> 00:25:21,220

most critical scientific instruments

580

00:25:26,640 --> 00:25:23,020

that human beings have ever built so

581

00:25:28,230 --> 00:25:26,650

Hubble has completely transformed our

582

00:25:30,720 --> 00:25:28,240

understanding of the universe in

583

00:25:33,120 --> 00:25:30,730

fundamental ways starting with the

584

00:25:34,770 --> 00:25:33,130

nearby universe of our solar system and

585

00:25:36,900 --> 00:25:34,780

then reaching out to the most distant

586

00:25:39,570 --> 00:25:36,910

things that we can see in the faraway

587

00:25:41,460 --> 00:25:39,580

universe and so I'm here tonight to talk

588

00:25:43,350 --> 00:25:41,470

to you a little bit about some of the

589

00:25:46,410 --> 00:25:43,360

unknown things in the universe dark

590

00:25:48,840 --> 00:25:46,420

energy and alien worlds some of these

591

00:25:51,690 --> 00:25:48,850

big questions that we have but I wanted

592

00:25:54,690 --> 00:25:51,700

to start off by talking a little bit to

593

00:25:57,120 --> 00:25:54,700

preface this this unknown stuff with a

594

00:25:59,310 --> 00:25:57,130

little bit of what we do know and how

595

00:26:01,620 --> 00:25:59,320

we've learned that and the Hubble Space

596

00:26:04,110 --> 00:26:01,630

Telescope has been instrumental in

597

00:26:06,390 --> 00:26:04,120

helping us learn about what our universe

598

00:26:08,340 --> 00:26:06,400

is like and so starting in our own

599

00:26:10,860 --> 00:26:08,350

cosmic backyard of the solar system

600

00:26:12,720 --> 00:26:10,870

Hubble has taught us many many things

601
00:26:15,450 --> 00:26:12,730
about our own solar system including

602
00:26:17,390 --> 00:26:15,460
this beautiful composite image showing

603
00:26:21,150 --> 00:26:17,400
Aurora on Saturn

604
00:26:23,250 --> 00:26:21,160
NASA of course also launches satellites

605
00:26:25,380 --> 00:26:23,260
that go out and visit these distant

606
00:26:27,300 --> 00:26:25,390
worlds in our solar system so this is an

607
00:26:29,430 --> 00:26:27,310
image from NASA's Cassini telescope

608
00:26:31,860 --> 00:26:29,440
which in just a few months will have its

609
00:26:34,250 --> 00:26:31,870
grand finale as it actually crashes into

610
00:26:37,260 --> 00:26:34,260
the planet so be sure and check that out

611
00:26:39,120 --> 00:26:37,270
one of the great things that Cassini has

612
00:26:39,769 --> 00:26:39,130
given us I believe in addition to all

613
00:26:43,009 --> 00:26:39,779

this in

614

00:26:46,129 --> 00:26:43,019

animal science is just a perspective of

615

00:26:47,779 --> 00:26:46,139

us of us humans and this is something

616

00:26:49,940 --> 00:26:47,789

that again goes back to those big

617

00:26:51,649 --> 00:26:49,950

questions that astronomy gets to you

618

00:26:54,080 --> 00:26:51,659

about telling us about our place in the

619

00:26:56,769 --> 00:26:54,090

universe and so this is an image from

620

00:26:59,899 --> 00:26:56,779

Cassini from beyond the orbit of Saturn

621

00:27:02,659 --> 00:26:59,909

looking back and that little tiny dot is

622

00:27:04,430 --> 00:27:02,669

us that's everyone you've ever known in

623

00:27:06,589 --> 00:27:04,440

that little tiny blue dot and of course

624

00:27:10,129 --> 00:27:06,599

this was the blue dot the cross Sagan

625

00:27:12,859 --> 00:27:10,139

talked about and and so much back in in

626
00:27:16,070 --> 00:27:12,869
the early days and in popularized

627
00:27:18,229 --> 00:27:16,080
astronomy in such a such a unique way I

628
00:27:20,479 --> 00:27:18,239
have such a fond spot in my heart for

629
00:27:23,329 --> 00:27:20,489
Carl Sagan and all the great outreach

630
00:27:25,820 --> 00:27:23,339
that he did but missions like Cassini

631
00:27:29,570 --> 00:27:25,830
have given us this have given us this

632
00:27:31,639 --> 00:27:29,580
grand view of what we are and help to to

633
00:27:33,979 --> 00:27:31,649
probe those big questions of our place

634
00:27:36,889 --> 00:27:33,989
in the universe and then very recently

635
00:27:40,129 --> 00:27:36,899
NASA's Juno spacecraft has been sending

636
00:27:43,700 --> 00:27:40,139
back these absolutely incredible images

637
00:27:46,369 --> 00:27:43,710
of our planet Jupiter that sort of go

638
00:27:48,859 --> 00:27:46,379

beyond science and even get into art

639

00:27:51,469 --> 00:27:48,869

this could be a piece of art in a museum

640

00:27:54,349 --> 00:27:51,479

and then of course just a couple of

641

00:27:58,070 --> 00:27:54,359

years ago we all remember the excitement

642

00:28:01,190 --> 00:27:58,080

of NASA's new Horizons mission reaching

643

00:28:03,649 --> 00:28:01,200

Pluto and reeling this heart on Pluto

644

00:28:06,499 --> 00:28:03,659

and revealing the structure of this

645

00:28:09,229 --> 00:28:06,509

outer planet dwarf planet that we'd

646

00:28:11,239 --> 00:28:09,239

never seen before and so all of these

647

00:28:13,399 --> 00:28:11,249

missions have helped to help us learn

648

00:28:14,389 --> 00:28:13,409

more about our solar system and they're

649

00:28:16,459 --> 00:28:14,399

returning to Hubble

650

00:28:19,219 --> 00:28:16,469

of course branching out from the solar

651
00:28:21,950 --> 00:28:19,229
system more distant from Hubble we've

652
00:28:23,989 --> 00:28:21,960
been able to observe star forming

653
00:28:26,599 --> 00:28:23,999
regions within our own galaxy so this is

654
00:28:29,479 --> 00:28:26,609
the Carina Nebula and this curve this

655
00:28:31,759 --> 00:28:29,489
image gives us an overall view of star

656
00:28:33,200 --> 00:28:31,769
formation so lots of new stars are

657
00:28:35,570 --> 00:28:33,210
forming in this part of the universe and

658
00:28:38,119 --> 00:28:35,580
stars are also dying in this part of the

659
00:28:39,729 --> 00:28:38,129
universe there's this giant star here

660
00:28:42,139 --> 00:28:39,739
that's probably about to go supernova

661
00:28:43,639 --> 00:28:42,149
literally any day or it might be a

662
00:28:45,019 --> 00:28:43,649
thousand years but you know it's a tiny

663
00:28:48,679 --> 00:28:45,029

span of time

664

00:28:50,239 --> 00:28:48,689

in astronomical sense and then stars of

665

00:28:53,269 --> 00:28:50,249

course after they're born they have

666

00:28:55,129 --> 00:28:53,279

winds that shed out the dust in the gas

667

00:28:58,009 --> 00:28:55,139

and stars shine forth and these

668

00:28:59,509 --> 00:28:58,019

beautiful giant clusters this is the

669

00:29:00,649 --> 00:28:59,519

image that came from the 25th

670

00:29:03,259 --> 00:29:00,659

anniversary of the Hubble Space

671

00:29:05,689 --> 00:29:03,269

Telescope just a couple years ago and

672

00:29:07,309 --> 00:29:05,699

then we all know that stars when they

673

00:29:09,499 --> 00:29:07,319

live out their lives they often go

674

00:29:11,779 --> 00:29:09,509

through these violent deaths these

675

00:29:13,909 --> 00:29:11,789

explosions that can be either very

676
00:29:15,919 --> 00:29:13,919
dramatic like the Crab Nebula that you

677
00:29:18,769 --> 00:29:15,929
saw in the introduction or can be more

678
00:29:20,809 --> 00:29:18,779
gentle and sort of the Stars blow out

679
00:29:23,539 --> 00:29:20,819
their atmospheres like this example of

680
00:29:26,839 --> 00:29:23,549
the butterfly nebula and so we know that

681
00:29:29,119 --> 00:29:26,849
our Sun well someday undergo a similar

682
00:29:31,689 --> 00:29:29,129
process like this where it will shed its

683
00:29:34,519 --> 00:29:31,699
outer layers it'll grow into a red giant

684
00:29:37,039 --> 00:29:34,529
little and virtually engulf the earth

685
00:29:38,419 --> 00:29:37,049
now this will be several billion years

686
00:29:39,019 --> 00:29:38,429
from now so we don't have to worry about

687
00:29:44,419 --> 00:29:39,029
that

688
00:29:46,609 --> 00:29:44,429

images from Hubble really tell us

689

00:29:49,699 --> 00:29:46,619

something about our origins

690

00:29:52,249 --> 00:29:49,709

so these stellar explosions like

691

00:29:55,249 --> 00:29:52,259

supernovae are the very events that

692

00:29:58,209 --> 00:29:55,259

seeded the universe with the elements

693

00:30:01,549 --> 00:29:58,219

that would eventually become planets and

694

00:30:03,199 --> 00:30:01,559

eventually become life so the iron in

695

00:30:05,689 --> 00:30:03,209

your blood and the calcium in your bones

696

00:30:09,859 --> 00:30:05,699

was literally forged inside of a star

697

00:30:12,409 --> 00:30:09,869

that exploded in a supernova and so what

698

00:30:15,169 --> 00:30:12,419

these images really show us is our sort

699

00:30:17,989 --> 00:30:15,179

of cosmic connection to the universe and

700

00:30:20,029 --> 00:30:17,999

that's one of the things I love this is

701

00:30:22,789 --> 00:30:20,039

an image of also with still within our

702

00:30:25,309 --> 00:30:22,799

own galaxy of a star that under

703

00:30:26,989 --> 00:30:25,319

underwent this really complex confusing

704

00:30:28,729 --> 00:30:26,999

event we still don't really know what's

705

00:30:30,979 --> 00:30:28,739

going on with this star but it's

706

00:30:33,439 --> 00:30:30,989

shedding its layers or it's blowing a

707

00:30:35,749 --> 00:30:33,449

wind out into the surroundings so many

708

00:30:38,719 --> 00:30:35,759

mysteries out there still and then

709

00:30:40,399 --> 00:30:38,729

beyond our own Milky Way galaxy we now

710

00:30:43,699 --> 00:30:40,409

of course know that there are many other

711

00:30:45,499 --> 00:30:43,709

galaxies so this is a nearby galaxy if

712

00:30:47,449 --> 00:30:45,509

you could get outside of our Milky Way

713

00:30:50,059 --> 00:30:47,459

and could look back on it our Milky Way

714

00:30:52,009 --> 00:30:50,069

would look probably a lot like this we

715

00:30:54,649 --> 00:30:52,019

think our millions with other galaxies

716

00:30:56,359 --> 00:30:54,659

so they merge with other galaxies in my

717

00:30:57,170 --> 00:30:56,369

own research I studied galaxy evolution

718

00:30:58,940 --> 00:30:57,180

for

719

00:31:01,580 --> 00:30:58,950

I'm interested in how galaxies change

720

00:31:03,890 --> 00:31:01,590

over time how their stars in their black

721

00:31:06,080 --> 00:31:03,900

holes for him and we think this process

722

00:31:09,170 --> 00:31:06,090

of galaxy collisions is a really key

723

00:31:11,800 --> 00:31:09,180

part of how all of that takes place of

724

00:31:14,840 --> 00:31:11,810

how black holes grow and we think that

725

00:31:16,820 --> 00:31:14,850

there's also gas in the universe that

726

00:31:19,130 --> 00:31:16,830

feeds into galaxies that help black

727

00:31:21,260 --> 00:31:19,140

holes grow over time a lot about this

728

00:31:23,060 --> 00:31:21,270

process that we don't understand but we

729

00:31:25,100 --> 00:31:23,070

think that galaxy mergers play a key

730

00:31:29,210 --> 00:31:25,110

part in the overall evolution of

731

00:31:30,950 --> 00:31:29,220

galaxies over time and then of all the

732

00:31:33,170 --> 00:31:30,960

beautiful images that Hubble has given

733

00:31:35,900 --> 00:31:33,180

us over the past 27 years now that

734

00:31:37,520 --> 00:31:35,910

Hubble's been in space if I had to pick

735

00:31:40,760 --> 00:31:37,530

my absolute favorite when this would be

736

00:31:42,500 --> 00:31:40,770

it so this is the Hubble Ultra Deep

737

00:31:44,240 --> 00:31:42,510

Field this happened to come out when I

738

00:31:46,550 --> 00:31:44,250

was in graduate school so this is one of

739

00:31:48,230 --> 00:31:46,560

the reasons I'm so fond of it I did a

740

00:31:50,840 --> 00:31:48,240

lot of my dissertation research on this

741

00:31:53,870 --> 00:31:50,850

image but this particular version of

742

00:31:55,940 --> 00:31:53,880

this image was about 11 days total the

743

00:31:58,460 --> 00:31:55,950

Hubble stared into space and in this

744

00:32:00,920 --> 00:31:58,470

image Hubble's looking at a tiny tiny

745

00:32:03,470 --> 00:32:00,930

little piece of sky so it's like looking

746

00:32:04,910 --> 00:32:03,480

at the universe through a straw if you

747

00:32:06,920 --> 00:32:04,920

found out your pinky finger you could

748

00:32:09,710 --> 00:32:06,930

cover up this teeny tiny little patch of

749

00:32:12,200 --> 00:32:09,720

sky and every point of light you see in

750

00:32:14,960 --> 00:32:12,210

this image is an individual galaxy

751
00:32:18,470 --> 00:32:14,970
itself filled with hundreds of billions

752
00:32:21,560 --> 00:32:18,480
of other stars and so really what Hubble

753
00:32:25,370 --> 00:32:21,570
has given us in a fundamental sense is

754
00:32:27,950 --> 00:32:25,380
the size of the universe these deep

755
00:32:30,290 --> 00:32:27,960
images with Hubble were revolutionary

756
00:32:33,260 --> 00:32:30,300
and they told us that the universe is

757
00:32:36,140 --> 00:32:33,270
filled with hundreds of billions of

758
00:32:38,990 --> 00:32:36,150
other galaxies and all those galaxies

759
00:32:40,580 --> 00:32:39,000
with hundreds of billions of stars now

760
00:32:44,120 --> 00:32:40,590
in addition to just being a beautiful

761
00:32:47,650 --> 00:32:44,130
image we're able to take spectra of

762
00:32:50,120 --> 00:32:47,660
these galaxies to take the chemical

763
00:32:52,580 --> 00:32:50,130

fingerprints of the galaxies and learn

764

00:32:53,960 --> 00:32:52,590

about their distances and so when we

765

00:32:56,870 --> 00:32:53,970

learn about the distances we can

766

00:32:59,450 --> 00:32:56,880

actually make these images sort of 3d we

767

00:33:01,340 --> 00:32:59,460

assign distances to them and so we can

768

00:33:03,650 --> 00:33:01,350

sort of fly through the images in a

769

00:33:06,740 --> 00:33:03,660

sense to get a bit of a sense of scale

770

00:33:10,820 --> 00:33:06,750

in a sense of distance for these these

771

00:33:13,190 --> 00:33:10,830

images so in the Hubble Ultra Deep Field

772

00:33:15,799 --> 00:33:13,200

again you notice a lot of interesting

773

00:33:18,169 --> 00:33:15,809

things so you notice as we go deeper

774

00:33:20,750 --> 00:33:18,179

into the universe that galaxy's changed

775

00:33:23,269 --> 00:33:20,760

they start to look different nearby

776

00:33:25,009 --> 00:33:23,279

galaxies look sort of similar to our

777

00:33:27,169 --> 00:33:25,019

Milky Way a lot of them they have spiral

778

00:33:29,960 --> 00:33:27,179

arms they're very large they have

779

00:33:32,180 --> 00:33:29,970

organized structure but if you get into

780

00:33:33,970 --> 00:33:32,190

the deeper universe the more distant

781

00:33:36,529 --> 00:33:33,980

universe you see a different picture

782

00:33:38,389 --> 00:33:36,539

galaxies are less well formed they're

783

00:33:41,269 --> 00:33:38,399

smaller they're clumpy they're different

784

00:33:45,080 --> 00:33:41,279

and so learning about how galaxies

785

00:33:48,320 --> 00:33:45,090

change over the course of the last 13.8

786

00:33:50,299 --> 00:33:48,330

billion years of cosmic history is still

787

00:33:51,919 --> 00:33:50,309

a really important part of astronomy

788

00:33:54,169 --> 00:33:51,929

it's it's there's a lot about that

789

00:33:56,419 --> 00:33:54,179

process that we're still really to push

790

00:33:59,509 --> 00:33:56,429

further so as much as we've learned

791

00:34:01,430 --> 00:33:59,519

about the universe since we've put

792

00:34:03,230 --> 00:34:01,440

Hubble into space since we've started

793

00:34:05,690 --> 00:34:03,240

building telescopes on the ground

794

00:34:09,680 --> 00:34:05,700

there's still really a lot that we don't

795

00:34:12,169 --> 00:34:09,690

know and of all of these galaxies of

796

00:34:14,180 --> 00:34:12,179

hundreds of billions of galaxies that we

797

00:34:18,020 --> 00:34:14,190

found filled with hundreds of billions

798

00:34:20,210 --> 00:34:18,030

of stars all of those galaxies all of

799

00:34:23,000 --> 00:34:20,220

those stars what we know now are

800

00:34:26,440 --> 00:34:23,010

probably trillions of planets every

801
00:34:31,089 --> 00:34:26,450
person everything that you've ever known

802
00:34:36,290 --> 00:34:31,099
still all of that only makes up about 5%

803
00:34:38,990 --> 00:34:36,300
of everything in the universe and the

804
00:34:41,000 --> 00:34:39,000
rest of that is when I want to spend the

805
00:34:44,300 --> 00:34:41,010
rest of my time tonight talking to you

806
00:34:47,750 --> 00:34:44,310
about so going back to that previous pie

807
00:34:53,180 --> 00:34:47,760
chart so the 5% that we know about the

808
00:34:55,720 --> 00:34:53,190
galaxies the stars the planets that's

809
00:35:00,160 --> 00:34:55,730
what we know about so look now at the

810
00:35:05,420 --> 00:35:00,170
27% that is dark matter so dark matter

811
00:35:07,370 --> 00:35:05,430
what is it we have no idea but this

812
00:35:10,400 --> 00:35:07,380
poses a really really interesting

813
00:35:13,670 --> 00:35:10,410

question to us as astronomers so we

814

00:35:17,089 --> 00:35:13,680

don't know what it is so how do we know

815

00:35:20,540 --> 00:35:17,099

that it actually exists so we have a few

816

00:35:22,940 --> 00:35:20,550

clues the first thing is by looking at

817

00:35:24,380 --> 00:35:22,950

spiral galaxies so you take a spiral

818

00:35:26,380 --> 00:35:24,390

galaxy like this

819

00:35:31,030 --> 00:35:26,390

and it looks like it's spinning right

820

00:35:35,180 --> 00:35:31,040

that's because it is so back decades ago

821

00:35:38,210 --> 00:35:35,190

astronomers looked at the motions of

822

00:35:40,250 --> 00:35:38,220

stars and spiral galaxies Vera Rubin was

823

00:35:42,590 --> 00:35:40,260

actually one of the pioneers of this an

824

00:35:46,820 --> 00:35:42,600

astronomer astronomer who did this work

825

00:35:49,130 --> 00:35:46,830

back in this 1960s 1970s and what you

826

00:35:52,210 --> 00:35:49,140

expect to see in spiral galaxies is that

827

00:35:55,400 --> 00:35:52,220

as you get out further from the center

828

00:35:58,010 --> 00:35:55,410

you would expect the speeds of these

829

00:35:59,810 --> 00:35:58,020

stars in the matter to be slowing down

830

00:36:02,840 --> 00:35:59,820

that's what Kepler's second law tell us

831

00:36:05,750 --> 00:36:02,850

should that should happen but that's not

832

00:36:08,870 --> 00:36:05,760

what we see so all of these motions

833

00:36:11,840 --> 00:36:08,880

depend on mass depend on the mass that

834

00:36:15,470 --> 00:36:11,850

exists from the center out to the stars

835

00:36:17,390 --> 00:36:15,480

and so when we studied the motions and

836

00:36:19,970 --> 00:36:17,400

outer parts of these galaxies even out

837

00:36:22,700 --> 00:36:19,980

further than what we could see what we

838

00:36:25,190 --> 00:36:22,710

found is that there should be more mass

839

00:36:27,560 --> 00:36:25,200

there than what we're seeing there's

840

00:36:31,040 --> 00:36:27,570

something there that's causing the stars

841

00:36:33,440 --> 00:36:31,050

to move faster in the outskirts can't

842

00:36:35,570 --> 00:36:33,450

see it at all and we know it's not gas

843

00:36:38,660 --> 00:36:35,580

because we can detect gas in other ways

844

00:36:40,730 --> 00:36:38,670

so not gas not stars something hidden in

845

00:36:43,310 --> 00:36:40,740

these galaxies they're causing them to

846

00:36:47,170 --> 00:36:43,320

move in ways that are unexpected the

847

00:36:50,000 --> 00:36:47,180

second big clue came in galaxy clusters

848

00:36:53,990 --> 00:36:50,010

so galaxy clusters are also a really

849

00:36:56,180 --> 00:36:54,000

good way to measure mass so we can look

850

00:36:58,550 --> 00:36:56,190

at individual galaxies and clusters and

851
00:37:00,860 --> 00:36:58,560
measure their speeds fairly easily in

852
00:37:02,810 --> 00:37:00,870
fact and when we look at galaxies

853
00:37:05,270 --> 00:37:02,820
galaxies and clusters we find that

854
00:37:08,960 --> 00:37:05,280
they're moving way faster than they

855
00:37:11,840 --> 00:37:08,970
should be so if it was only the galaxies

856
00:37:14,300 --> 00:37:11,850
only the stars then these clusters

857
00:37:17,570 --> 00:37:14,310
should have blown themselves apart you

858
00:37:19,640 --> 00:37:17,580
know millions of years ago but galaxy

859
00:37:20,960 --> 00:37:19,650
clusters stay together so there's

860
00:37:25,130 --> 00:37:20,970
something there that we're not seeing

861
00:37:28,580 --> 00:37:25,140
and in addition in these galaxy clusters

862
00:37:30,410 --> 00:37:28,590
we've also Frank has already pointed out

863
00:37:32,270 --> 00:37:30,420

a little bit about gravitational lensing

864

00:37:37,049 --> 00:37:32,280

so what's going on there

865

00:37:40,919 --> 00:37:37,059

so we have this big mass of galaxies

866

00:37:43,439 --> 00:37:40,929

and gasps and then beyond that we have

867

00:37:47,309 --> 00:37:43,449

background galaxies and then over here

868

00:37:50,309 --> 00:37:47,319

we have our telescopes so what's going

869

00:37:52,259 --> 00:37:50,319

on with gravitational lensing is that

870

00:37:55,759 --> 00:37:52,269

we're essentially seeing the background

871

00:37:58,489 --> 00:37:55,769

galaxies being lynched by the mass

872

00:38:01,349 --> 00:37:58,499

that's in between them

873

00:38:02,759 --> 00:38:01,359

so this is what theory tells us we

874

00:38:04,439 --> 00:38:02,769

should see if there's a lot of matter

875

00:38:06,779 --> 00:38:04,449

out there or dark matter that's hidden

876

00:38:08,429 --> 00:38:06,789

that we can't see and of course this is

877

00:38:10,649 --> 00:38:08,439

what we see when we take these Hubble

878

00:38:13,019 --> 00:38:10,659

images so in these Hubble images of

879

00:38:15,059 --> 00:38:13,029

galaxy clusters you see all these little

880

00:38:16,559 --> 00:38:15,069

blue arcs in addition to the bright

881

00:38:18,689 --> 00:38:16,569

yellow galaxies

882

00:38:21,059 --> 00:38:18,699

you see these background galaxies that

883

00:38:24,120 --> 00:38:21,069

have been stretched and lens so this is

884

00:38:27,269 --> 00:38:24,130

a smoking gun for dark matter that

885

00:38:29,969 --> 00:38:27,279

exists in these galaxy clusters this is

886

00:38:32,009 --> 00:38:29,979

a very famous galaxy cluster image

887

00:38:33,899 --> 00:38:32,019

called the bullet cluster this is

888

00:38:37,140 --> 00:38:33,909

actually two galaxy clusters that are

889

00:38:39,209 --> 00:38:37,150

crashing together and so what you see

890

00:38:42,149 --> 00:38:39,219

here again all this sort of yellow

891

00:38:45,419 --> 00:38:42,159

orange structures here are individual

892

00:38:49,169 --> 00:38:45,429

galaxies the red the pink and the blue

893

00:38:52,049 --> 00:38:49,179

here represents gas in the galaxies that

894

00:38:54,419 --> 00:38:52,059

were able to image in x-rays and so

895

00:38:57,299 --> 00:38:54,429

these two galaxy clusters are crashing

896

00:39:00,419 --> 00:38:57,309

together and we're able to again look at

897

00:39:03,239 --> 00:39:00,429

its sources behind the clusters and what

898

00:39:05,729 --> 00:39:03,249

these images tell us is that all the

899

00:39:08,279 --> 00:39:05,739

dark matter is centered on the galaxies

900

00:39:10,620 --> 00:39:08,289

and not on the gas so another third sort

901
00:39:15,089 --> 00:39:10,630
of independent clue the Dark Matter

902
00:39:17,069 --> 00:39:15,099
exists in these clusters so we have all

903
00:39:19,130 --> 00:39:17,079
these different independent lines of

904
00:39:23,039 --> 00:39:19,140
evidence that dark matter is out there

905
00:39:25,979 --> 00:39:23,049
and so we have another a third way that

906
00:39:28,469 --> 00:39:25,989
were able to to learn about dark matter

907
00:39:31,140 --> 00:39:28,479
by looking how basically how galaxies

908
00:39:34,529 --> 00:39:31,150
are distributed across the universe and

909
00:39:36,959 --> 00:39:34,539
so just and similarly we're able to to

910
00:39:39,539 --> 00:39:36,969
look at to map out galaxies at different

911
00:39:42,630 --> 00:39:39,549
distances and measure their properties

912
00:39:44,849 --> 00:39:42,640
and those properties tell us again that

913
00:39:46,949 --> 00:39:44,859

there's mass out there that these

914

00:39:48,390 --> 00:39:46,959

galaxies are moving in ways that

915

00:39:49,530 --> 00:39:48,400

indicate that there's matter out there

916

00:39:51,600 --> 00:39:49,540

that exists

917

00:39:55,230 --> 00:39:51,610

that we can't see so we don't know what

918

00:39:59,360 --> 00:39:55,240

it is we have a better idea of what it's

919

00:40:04,830 --> 00:39:59,370

not so we know that it's probably not

920

00:40:06,330 --> 00:40:04,840

regular stars or gas or planets because

921

00:40:08,040 --> 00:40:06,340

we would be able to see those things

922

00:40:10,320 --> 00:40:08,050

we'd be able to see stars that are

923

00:40:13,890 --> 00:40:10,330

bright enough dim stars okay we might

924

00:40:16,320 --> 00:40:13,900

not see the dim stars gas we can see

925

00:40:20,190 --> 00:40:16,330

from the way the Stars are lighting up

926

00:40:22,710 --> 00:40:20,200

the gas but really ordinary matter

927

00:40:25,170 --> 00:40:22,720

baryons neutrons protons and electrons

928

00:40:27,780 --> 00:40:25,180

we would be able to see them in some way

929

00:40:30,150 --> 00:40:27,790

and we can't so we really don't think

930

00:40:33,480 --> 00:40:30,160

it's any of these things now it might be

931

00:40:35,130 --> 00:40:33,490

some very very dim stars but if those

932

00:40:37,980 --> 00:40:35,140

stars exist they would only be a tiny

933

00:40:40,860 --> 00:40:37,990

tiny fraction of what we think has to be

934

00:40:44,070 --> 00:40:40,870

to make up this dark matter population

935

00:40:46,830 --> 00:40:44,080

so we don't think it's regular stuff we

936

00:40:48,750 --> 00:40:46,840

don't really think it's antimatter so we

937

00:40:50,550 --> 00:40:48,760

know antimatter would annihilate with

938

00:40:52,020 --> 00:40:50,560

regular matter and produce gamma-ray

939

00:40:54,120 --> 00:40:52,030

signals that we would be able to detect

940

00:40:56,100 --> 00:40:54,130

we have gamma-ray telescopes that would

941

00:40:57,930 --> 00:40:56,110

be able to see that so we don't think

942

00:40:59,610 --> 00:40:57,940

it's an a' matter we don't really think

943

00:41:01,530 --> 00:40:59,620

it's giant black hole sort of for the

944

00:41:04,470 --> 00:41:01,540

same reasons because we would be able to

945

00:41:06,600 --> 00:41:04,480

see those observational EC signatures of

946

00:41:10,140 --> 00:41:06,610

the black holes in other ways we don't

947

00:41:13,020 --> 00:41:10,150

really see them so what is it well again

948

00:41:16,980 --> 00:41:13,030

we don't know but we think what it

949

00:41:19,980 --> 00:41:16,990

likely is is some sort of yet

950

00:41:22,140 --> 00:41:19,990

undiscovered elementary particle that

951
00:41:25,020 --> 00:41:22,150
really doesn't interact with radiation

952
00:41:27,120 --> 00:41:25,030
in the same way that normal matter is so

953
00:41:30,090 --> 00:41:27,130
that's what we think it is but again we

954
00:41:31,890 --> 00:41:30,100
don't know all right that's dark matter

955
00:41:35,430 --> 00:41:31,900
not very satisfying right we don't know

956
00:41:39,870 --> 00:41:35,440
what it is okay dark energy so almost

957
00:41:43,970 --> 00:41:39,880
70% of the whole universe is made up of

958
00:41:47,490 --> 00:41:43,980
dark energy so what is it any guesses

959
00:41:52,340 --> 00:41:47,500
yeah we really have no idea what dark

960
00:41:56,550 --> 00:41:52,350
energy is but similarly to dark matter

961
00:42:00,360 --> 00:41:56,560
we know that it exists and the really

962
00:42:01,880 --> 00:42:00,370
strange thing about dark energy is that

963
00:42:04,070 --> 00:42:01,890

it's completely gone

964

00:42:07,160 --> 00:42:04,080

founding our ideas about how gravity

965

00:42:09,860 --> 00:42:07,170

works so spaceball sees any baseball

966

00:42:13,550 --> 00:42:09,870

fans out there Orioles fans yeah I would

967

00:42:14,540 --> 00:42:13,560

hope so okay so you have a baseball you

968

00:42:16,460 --> 00:42:14,550

throw it up in the air what do you

969

00:42:17,120 --> 00:42:16,470

expect to happen he comes back down

970

00:42:18,770 --> 00:42:17,130

right

971

00:42:22,310 --> 00:42:18,780

that's our everyday experience of

972

00:42:25,730 --> 00:42:22,320

gravity that's how gravity works what

973

00:42:29,780 --> 00:42:25,740

dark energy tells us is that on large

974

00:42:34,790 --> 00:42:29,790

large distance scales that instead of

975

00:42:36,920 --> 00:42:34,800

pulling the gravity pushes so we

976

00:42:40,640 --> 00:42:36,930

experience gravity as an attractive

977

00:42:43,400 --> 00:42:40,650

force and what all the physics all the

978

00:42:46,760 --> 00:42:43,410

theory all the observations are telling

979

00:42:50,030 --> 00:42:46,770

us is that at large distances gravity

980

00:42:52,850 --> 00:42:50,040

pushes the universe and this is

981

00:42:55,480 --> 00:42:52,860

completely con founding to everything

982

00:43:00,080 --> 00:42:55,490

that we know ok so why do we think this

983

00:43:03,080 --> 00:43:00,090

the first big clue actually won the

984

00:43:07,580 --> 00:43:03,090

Nobel Prize back almost 20 years ago now

985

00:43:10,490 --> 00:43:07,590

so this was looking at distant exploding

986

00:43:12,380 --> 00:43:10,500

stars supernovae in distant galaxies and

987

00:43:14,630 --> 00:43:12,390

actually an astronomer right here at the

988

00:43:16,460 --> 00:43:14,640

Space Telescope Science Institute dr.

989

00:43:18,890 --> 00:43:16,470

Adam riess was one of the Nobel Prize

990

00:43:22,730 --> 00:43:18,900

winners for for this really

991

00:43:25,930 --> 00:43:22,740

groundbreaking discovery and so what is

992

00:43:28,760 --> 00:43:25,940

it about supernovae so supernovae are

993

00:43:31,160 --> 00:43:28,770

what we call in astronomy as standard

994

00:43:33,200 --> 00:43:31,170

candles so they have a certain

995

00:43:38,660 --> 00:43:33,210

brightness you can sort of think of it

996

00:43:41,360 --> 00:43:38,670

as a a light bulb and so the further the

997

00:43:43,250 --> 00:43:41,370

light bulb is away your the luminosity

998

00:43:44,780 --> 00:43:43,260

or the brightness of the light bulb goes

999

00:43:46,820 --> 00:43:44,790

down and that's just a very simple

1000

00:43:49,940 --> 00:43:46,830

physics equation you know if you have a

1001
00:43:52,730 --> 00:43:49,950
standard light if you measure how bright

1002
00:43:55,640 --> 00:43:52,740
it is you can determine how far away it

1003
00:43:59,390 --> 00:43:55,650
is and so that's what astronomers were

1004
00:44:03,140 --> 00:43:59,400
able to do with this supernovae and so

1005
00:44:05,240 --> 00:44:03,150
we know we've known for years since the

1006
00:44:09,830 --> 00:44:05,250
days of Edwin Hubble back in the 1920s

1007
00:44:11,360 --> 00:44:09,840
that the universe is expanding and so we

1008
00:44:13,430 --> 00:44:11,370
know the universe is expanding we know

1009
00:44:15,380 --> 00:44:13,440
galaxies are moving away from each other

1010
00:44:18,920 --> 00:44:15,390
but if all that exists

1011
00:44:21,470 --> 00:44:18,930
the universe is gravity then we would

1012
00:44:24,200 --> 00:44:21,480
expect that the expansion would maybe be

1013
00:44:26,870 --> 00:44:24,210

slowing down maybe the constant didn't

1014

00:44:29,720 --> 00:44:26,880

really know but when when observing

1015

00:44:32,299 --> 00:44:29,730

these supernovae what we found was

1016

00:44:34,279 --> 00:44:32,309

something really interesting was that

1017

00:44:36,950 --> 00:44:34,289

that the most distant supernovae that we

1018

00:44:38,539 --> 00:44:36,960

could see were much fainter not much

1019

00:44:42,500 --> 00:44:38,549

fainter a little bit fainter than what

1020

00:44:44,359 --> 00:44:42,510

we expected and so what this told us was

1021

00:44:45,829 --> 00:44:44,369

that the more distant galaxies that we

1022

00:44:48,230 --> 00:44:45,839

were looking at with these supernovae

1023

00:44:51,170 --> 00:44:48,240

were moving away from us

1024

00:44:53,480 --> 00:44:51,180

much faster than we expected so that

1025

00:44:56,599 --> 00:44:53,490

means the universe is accelerating in

1026
00:44:59,089 --> 00:44:56,609
its expansion completely unexpected

1027
00:45:00,740 --> 00:44:59,099
complete surprise but the universe is

1028
00:45:04,549 --> 00:45:00,750
accelerating something we found out

1029
00:45:06,230 --> 00:45:04,559
almost two decades ago now and so again

1030
00:45:08,319 --> 00:45:06,240
by studying these supernovae was one of

1031
00:45:10,069 --> 00:45:08,329
the ways that that we found this out and

1032
00:45:13,069 --> 00:45:10,079
supernovae have this really great

1033
00:45:16,670 --> 00:45:13,079
property that they're very constant so

1034
00:45:19,099 --> 00:45:16,680
they get their normal stars that blow up

1035
00:45:21,380 --> 00:45:19,109
and they get really really bright in a

1036
00:45:23,809 --> 00:45:21,390
very short period of time and then their

1037
00:45:25,940 --> 00:45:23,819
brightness drops off and so because of

1038
00:45:27,620 --> 00:45:25,950

the regularity of the supernovae we're

1039

00:45:29,509 --> 00:45:27,630

able to study them in detail and again

1040

00:45:33,170 --> 00:45:29,519

determine the distances to galaxies

1041

00:45:36,410 --> 00:45:33,180

which is what confirmed this idea that

1042

00:45:37,759 --> 00:45:36,420

the galaxies the further galaxies the

1043

00:45:38,930 --> 00:45:37,769

most distant galaxies that we could

1044

00:45:41,440 --> 00:45:38,940

observe these in we're moving away

1045

00:45:43,910 --> 00:45:41,450

faster than we expected

1046

00:45:46,039 --> 00:45:43,920

so that's the first line of evidence

1047

00:45:47,990 --> 00:45:46,049

second line of evidence is from the

1048

00:45:50,059 --> 00:45:48,000

Cosmic Microwave Background which I'm

1049

00:45:51,589 --> 00:45:50,069

actually gonna skip because I'm running

1050

00:45:53,509 --> 00:45:51,599

a little short on time we can come back

1051
00:45:57,049 --> 00:45:53,519
and talk about it if we want but this

1052
00:45:59,779 --> 00:45:57,059
third way was again by making these huge

1053
00:46:02,450 --> 00:45:59,789
maps of the nearby universe and looking

1054
00:46:05,390 --> 00:46:02,460
at how galaxies are distributed in space

1055
00:46:08,900 --> 00:46:05,400
and basically from doing this we're also

1056
00:46:10,700 --> 00:46:08,910
able to measure the speeds of distant

1057
00:46:15,109 --> 00:46:10,710
galaxies and this was sort of an

1058
00:46:17,299 --> 00:46:15,119
independent confirmation of how distant

1059
00:46:18,950 --> 00:46:17,309
galaxies removing away faster than we

1060
00:46:21,529 --> 00:46:18,960
thought they should have been so it's

1061
00:46:23,720 --> 00:46:21,539
sort of an independent way to measure

1062
00:46:25,549 --> 00:46:23,730
the stark energy and there are other

1063
00:46:27,589 --> 00:46:25,559

lines of evidence that sort of point

1064

00:46:28,329 --> 00:46:27,599

I'll point to this idea that there's

1065

00:46:30,309 --> 00:46:28,339

this

1066

00:46:32,620 --> 00:46:30,319

serious force in the universe that's

1067

00:46:35,079 --> 00:46:32,630

causing it to accelerate its expansion

1068

00:46:37,660 --> 00:46:35,089

okay so we have no idea what's causing

1069

00:46:40,229 --> 00:46:37,670

this we see that it's happening we don't

1070

00:46:43,749 --> 00:46:40,239

know why we don't know what it is

1071

00:46:44,259 --> 00:46:43,759

but we have a few ideas so what could it

1072

00:46:50,979 --> 00:46:44,269

be

1073

00:46:54,069 --> 00:46:50,989

property of space-time something about

1074

00:46:57,309 --> 00:46:54,079

space itself that's causing the universe

1075

00:47:01,239 --> 00:46:57,319

to expand and so Einstein actually

1076

00:47:04,269 --> 00:47:01,249

predicted this long long ago he did it

1077

00:47:07,870 --> 00:47:04,279

calling it his biggest blunder because

1078

00:47:09,130 --> 00:47:07,880

at the time basically the the leading

1079

00:47:11,019 --> 00:47:09,140

theory was the universe wasn't

1080

00:47:13,900 --> 00:47:11,029

accelerating and now we find out that it

1081

00:47:16,719 --> 00:47:13,910

is so it's just some property of space

1082

00:47:18,819 --> 00:47:16,729

that basically says the empty space is

1083

00:47:21,640 --> 00:47:18,829

not really empty it's always sort of

1084

00:47:24,489 --> 00:47:21,650

creating new space so that's the

1085

00:47:25,079 --> 00:47:24,499

cosmological cosmic constant really

1086

00:47:28,329 --> 00:47:25,089

strange

1087

00:47:30,190 --> 00:47:28,339

so the second idea of what it could be

1088

00:47:34,269 --> 00:47:30,200

used causing this acceleration of the

1089

00:47:36,579 --> 00:47:34,279

universe is basically a new version of

1090

00:47:38,769 --> 00:47:36,589

gravity that we've got our theories of

1091

00:47:41,170 --> 00:47:38,779

gravity wrong and that we need to modify

1092

00:47:44,829 --> 00:47:41,180

then so that would say that general

1093

00:47:47,109 --> 00:47:44,839

relativity is not quite right on on

1094

00:47:50,259 --> 00:47:47,119

these scales so maybe Einstein was wrong

1095

00:47:52,630 --> 00:47:50,269

and then the third idea one of the

1096

00:47:56,200 --> 00:47:52,640

another idea is that there's really just

1097

00:47:58,029 --> 00:47:56,210

some kind of new energy field that we we

1098

00:48:00,370 --> 00:47:58,039

haven't really theorized yet we haven't

1099

00:48:02,469 --> 00:48:00,380

really figured out yet so there's three

1100

00:48:05,769 --> 00:48:02,479

these three new are these three ideas

1101
00:48:09,099 --> 00:48:05,779
and we really don't know people are sort

1102
00:48:10,630 --> 00:48:09,109
of leaning towards the cot the first the

1103
00:48:13,299 --> 00:48:10,640
first idea that there's this

1104
00:48:16,029 --> 00:48:13,309
cosmological constant but what we really

1105
00:48:19,900 --> 00:48:16,039
need is more data and of course that's

1106
00:48:22,209 --> 00:48:19,910
where the W first telescope comes in so

1107
00:48:25,150 --> 00:48:22,219
the W W first stands for a wide field

1108
00:48:28,569 --> 00:48:25,160
Infrared Survey telescope and it is

1109
00:48:31,559 --> 00:48:28,579
specifically designed to tackle this

1110
00:48:34,660 --> 00:48:31,569
question it's specifically designed to

1111
00:48:37,539 --> 00:48:34,670
study this effect of dark energy and

1112
00:48:40,269 --> 00:48:37,549
also of dark matter so how is it going

1113
00:48:41,240 --> 00:48:40,279

to do that one of the ways it's going to

1114

00:48:45,050 --> 00:48:41,250

do it

1115

00:48:47,420 --> 00:48:45,060

is to precisely measure galaxy shapes to

1116

00:48:49,160 --> 00:48:47,430

infer the amount of dark matter that

1117

00:48:52,100 --> 00:48:49,170

exists in the universe and this goes

1118

00:48:55,820 --> 00:48:52,110

back to this idea of gravitational

1119

00:48:57,680 --> 00:48:55,830

lensing so granny galaxy that's in front

1120

00:49:00,410 --> 00:48:57,690

of another galaxy is going to distort

1121

00:49:02,840 --> 00:49:00,420

the shape of the background galaxies and

1122

00:49:05,600 --> 00:49:02,850

by precisely measuring those shapes

1123

00:49:08,900 --> 00:49:05,610

we'll be able to figure out more about

1124

00:49:12,500 --> 00:49:08,910

how the the intervening dark matter

1125

00:49:15,500 --> 00:49:12,510

affects those galaxy shapes and then

1126

00:49:18,080 --> 00:49:15,510

another way is by very accurately

1127

00:49:20,360 --> 00:49:18,090

measuring the positions between galaxies

1128

00:49:22,190 --> 00:49:20,370

so it turns out that these positions

1129

00:49:24,140 --> 00:49:22,200

between the galaxies so if you think of

1130

00:49:26,540 --> 00:49:24,150

the universe in a three-dimensional

1131

00:49:29,360 --> 00:49:26,550

sense the positions that we measure

1132

00:49:31,880 --> 00:49:29,370

between the galaxies traces directly

1133

00:49:34,250 --> 00:49:31,890

back to shortly after the Big Bang and

1134

00:49:39,020 --> 00:49:34,260

to what happened in the universe early

1135

00:49:41,870 --> 00:49:39,030

on so that gets back to to the the very

1136

00:49:43,880 --> 00:49:41,880

early imprints in the universe for dark

1137

00:49:45,530 --> 00:49:43,890

energy and dark matter and all the

1138

00:49:48,260 --> 00:49:45,540

contents of the universe will help us

1139

00:49:51,590 --> 00:49:48,270

learn more about that and then getting

1140

00:49:53,690 --> 00:49:51,600

back to this idea of supernovae the this

1141

00:49:57,710 --> 00:49:53,700

telescope will allow us to take new

1142

00:49:59,150 --> 00:49:57,720

surveys of wider swaths of the sky that

1143

00:50:01,820 --> 00:49:59,160

will help us to determine more

1144

00:50:04,850 --> 00:50:01,830

supernovae basically - to narrow down

1145

00:50:07,700 --> 00:50:04,860

those measurements and to pinpoint some

1146

00:50:10,790 --> 00:50:07,710

of these physical quantities of the

1147

00:50:13,700 --> 00:50:10,800

universe that will help us to establish

1148

00:50:16,310 --> 00:50:13,710

better distances to these galaxies just

1149

00:50:18,020 --> 00:50:16,320

to hone in on these parameters that

1150

00:50:21,170 --> 00:50:18,030

describe the overall physics of the

1151
00:50:23,480 --> 00:50:21,180
universe and so we have these three

1152
00:50:25,850 --> 00:50:23,490
fundamental things that the W first will

1153
00:50:29,180 --> 00:50:25,860
measure about the universe the galaxies

1154
00:50:32,180 --> 00:50:29,190
shapes the positions and the distances

1155
00:50:34,730 --> 00:50:32,190
to these distant galaxies and so these

1156
00:50:36,290 --> 00:50:34,740
things will give us hints in two

1157
00:50:39,290 --> 00:50:36,300
different parts of the universe about

1158
00:50:41,240 --> 00:50:39,300
how structure grows over time not only

1159
00:50:44,350 --> 00:50:41,250
the galaxies but how the galaxies weave

1160
00:50:47,030 --> 00:50:44,360
together in this overall cosmic web and

1161
00:50:49,340 --> 00:50:47,040
then also about how the expansion

1162
00:50:50,390 --> 00:50:49,350
history works again we know the universe

1163
00:50:53,300 --> 00:50:50,400

is expanding

1164

00:50:54,769 --> 00:50:53,310

we know that it's accelerating but we

1165

00:50:56,209 --> 00:50:54,779

don't know what

1166

00:50:58,819 --> 00:50:56,219

three of that has been hasn't always

1167

00:51:01,759 --> 00:50:58,829

been accelerating at the same rate that

1168

00:51:03,409 --> 00:51:01,769

it is now so the further out we can push

1169

00:51:05,479 --> 00:51:03,419

these measurements and the more precise

1170

00:51:07,549 --> 00:51:05,489

we can make them the more we can learn

1171

00:51:10,459 --> 00:51:07,559

about these physical mechanisms that are

1172

00:51:12,949 --> 00:51:10,469

taking place and so what this will

1173

00:51:15,199 --> 00:51:12,959

eventually allow us to do as we hone in

1174

00:51:17,449 --> 00:51:15,209

on these measurements is really to allow

1175

00:51:19,640 --> 00:51:17,459

us to determine how the universe will

1176

00:51:22,759 --> 00:51:19,650

continue how it will end

1177

00:51:25,099 --> 00:51:22,769

if it'll end in a big freeze and a big

1178

00:51:28,939 --> 00:51:25,109

rip all of these different scenarios

1179

00:51:31,390 --> 00:51:28,949

that will allow us to to see how the how

1180

00:51:33,799 --> 00:51:31,400

we think the universe will continue on

1181

00:51:35,989 --> 00:51:33,809

so this again this telescope is

1182

00:51:38,140 --> 00:51:35,999

specifically designed to get at these

1183

00:51:40,609 --> 00:51:38,150

questions of dark energy and dark matter

1184

00:51:42,769 --> 00:51:40,619

but the really cool thing about the

1185

00:51:45,079 --> 00:51:42,779

technology that's going behind building

1186

00:51:48,499 --> 00:51:45,089

this telescope is it's gonna allow us to

1187

00:51:50,349 --> 00:51:48,509

look back also at the five percent and

1188

00:51:53,899 --> 00:51:50,359

about one of the really interesting

1189

00:51:58,219 --> 00:51:53,909

parts of the five percent which is

1190

00:52:00,999 --> 00:51:58,229

exoplanets now when I was a kid we only

1191

00:52:05,239 --> 00:52:01,009

knew of the planets in our solar system

1192

00:52:07,819 --> 00:52:05,249

now thanks to NASA's Kepler telescope we

1193

00:52:10,249 --> 00:52:07,829

know that planets are literally

1194

00:52:13,189 --> 00:52:10,259

everywhere the Milky Way is teeming with

1195

00:52:15,890 --> 00:52:13,199

planets statistically every star in the

1196

00:52:20,179 --> 00:52:15,900

night sky has at least one planet around

1197

00:52:21,859 --> 00:52:20,189

it that's a paradigm shift you know even

1198

00:52:25,130 --> 00:52:21,869

fifteen years ago we didn't know this

1199

00:52:28,039 --> 00:52:25,140

and so what W first is gonna allow us to

1200

00:52:30,380 --> 00:52:28,049

do it's a couple of different things for

1201

00:52:33,529 --> 00:52:30,390

exoplanets so it's gonna help us first

1202

00:52:36,649 --> 00:52:33,539

of all find more nearby exoplanets in a

1203

00:52:38,839 --> 00:52:36,659

different part of the the sort of solar

1204

00:52:41,239 --> 00:52:38,849

system space or the exoplanet system

1205

00:52:42,979 --> 00:52:41,249

space and then it will help us directly

1206

00:52:47,089 --> 00:52:42,989

characterize some of the closest

1207

00:52:49,130 --> 00:52:47,099

exoplanets that we know about today so

1208

00:52:51,939 --> 00:52:49,140

of all of these different planets this

1209

00:52:55,399 --> 00:52:51,949

is of course an artist's illustration

1210

00:52:57,199 --> 00:52:55,409

unfortunately we don't know the details

1211

00:52:58,909 --> 00:52:57,209

of these planets wouldn't be great if we

1212

00:53:01,699 --> 00:52:58,919

could actually draw all the planets we

1213

00:53:04,249 --> 00:53:01,709

know about in a poster like this but we

1214

00:53:06,890 --> 00:53:04,259

don't know what they look like

1215

00:53:09,529 --> 00:53:06,900

we know there are thousands of confirmed

1216

00:53:12,529 --> 00:53:09,539

exoplanets and again statistics just

1217

00:53:15,529 --> 00:53:12,539

tell us tells us that there are hundreds

1218

00:53:17,180 --> 00:53:15,539

of billions of exoplanets in our galaxy

1219

00:53:19,579 --> 00:53:17,190

and there's no reason to think they

1220

00:53:21,979 --> 00:53:19,589

wouldn't be in other galaxies as well we

1221

00:53:23,359 --> 00:53:21,989

don't know what they look like but W

1222

00:53:25,729 --> 00:53:23,369

first will have the capability to

1223

00:53:27,859 --> 00:53:25,739

directly image some of the closest and

1224

00:53:31,279 --> 00:53:27,869

brightest ones so how do we do that so

1225

00:53:34,069 --> 00:53:31,289

all of our our best images actual images

1226

00:53:37,370 --> 00:53:34,079

of exoplanets to date are these tiny

1227

00:53:39,199 --> 00:53:37,380

little blobs not very pretty right so w

1228

00:53:40,219 --> 00:53:39,209

first we'll have an instrument called a

1229

00:53:42,319 --> 00:53:40,229

coronagraph

1230

00:53:44,870 --> 00:53:42,329

which is basically an instrument that

1231

00:53:48,319 --> 00:53:44,880

blocks out the very very bright light of

1232

00:53:51,709 --> 00:53:48,329

a star and allows us to focus in on the

1233

00:53:54,890 --> 00:53:51,719

planets to better image the the planets

1234

00:53:59,150 --> 00:53:54,900

that are orbiting that star now this is

1235

00:54:03,739 --> 00:53:59,160

very difficult planet our stars are very

1236

00:54:05,989 --> 00:54:03,749

very bright stars are tiny or planets or

1237

00:54:08,569 --> 00:54:05,999

stars are bright planets are tiny and

1238

00:54:10,699 --> 00:54:08,579

they're hard to see and so doing this is

1239

00:54:13,489 --> 00:54:10,709

extremely difficult but w first is gonna

1240

00:54:15,140 --> 00:54:13,499

have a new capability to do this in a

1241

00:54:16,759 --> 00:54:15,150

new way now it's not gonna be this

1242

00:54:19,249 --> 00:54:16,769

detail it's not even gonna be close so

1243

00:54:20,959 --> 00:54:19,259

this is a little misleading but it's

1244

00:54:25,339 --> 00:54:20,969

really going to be a new technology a

1245

00:54:28,870 --> 00:54:25,349

new way to do this in a really new way

1246

00:54:31,430 --> 00:54:28,880

and so just to give you a sense here

1247

00:54:33,979 --> 00:54:31,440

this is showing you sort of the area

1248

00:54:36,380 --> 00:54:33,989

that Kepler looks for and all those

1249

00:54:39,529 --> 00:54:36,390

exoplanets a coupler is found we're

1250

00:54:41,870 --> 00:54:39,539

launching a telescope called Tess next

1251

00:54:44,989 --> 00:54:41,880

year in early 2018 it's the transiting

1252

00:54:48,349 --> 00:54:44,999

exoplanet survey satellite from NASA

1253

00:54:51,199 --> 00:54:48,359

so that particular telescope is going to

1254

00:54:53,420 --> 00:54:51,209

look at particularly at the closest

1255

00:54:55,910 --> 00:54:53,430

exoplanet center a milky way and look

1256

00:54:59,449 --> 00:54:55,920

close in at the the planets that are

1257

00:55:01,430 --> 00:54:59,459

really close to their star so what dubby

1258

00:55:04,069 --> 00:55:01,440

first is gonna do is expand that it's

1259

00:55:05,630 --> 00:55:04,079

gonna look look for the bigger planets

1260

00:55:07,969 --> 00:55:05,640

that are orbiting further out from the

1261

00:55:09,979 --> 00:55:07,979

stars and so it's basically gonna help

1262

00:55:12,259 --> 00:55:09,989

us to with these three telescopes and

1263

00:55:13,180 --> 00:55:12,269

others help us to sort of complete the

1264

00:55:16,330 --> 00:55:13,190

fences

1265

00:55:20,170 --> 00:55:16,340

of exoplanet systems in our nearby Milky

1266

00:55:21,610 --> 00:55:20,180

Way galaxy so one of the really neat

1267

00:55:24,820 --> 00:55:21,620

ways that's going to do this is by

1268

00:55:27,070 --> 00:55:24,830

technique called micro lensing so this

1269

00:55:29,320 --> 00:55:27,080

goes back to the same physics principles

1270

00:55:32,050 --> 00:55:29,330

as gravitational lensing is when you

1271

00:55:34,720 --> 00:55:32,060

have one object that passes in front of

1272

00:55:37,210 --> 00:55:34,730

another and in this particular case you

1273

00:55:39,700 --> 00:55:37,220

have a star and a planet that's gonna

1274

00:55:42,700 --> 00:55:39,710

pass in front of a background source and

1275

00:55:45,520 --> 00:55:42,710

what happens when you have this

1276

00:55:48,520 --> 00:55:45,530

particular arrangement is that we get a

1277

00:55:49,720 --> 00:55:48,530

very unique spectral signature that we

1278

00:55:53,050 --> 00:55:49,730

can easily detect

1279

00:55:55,810 --> 00:55:53,060

and that tells us that we have a planet

1280

00:55:58,210 --> 00:55:55,820

now where's a good place to look for

1281

00:56:00,550 --> 00:55:58,220

this in the disk of the Milky Way if we

1282

00:56:03,190 --> 00:56:00,560

look right down the throat of the Milky

1283

00:56:05,500 --> 00:56:03,200

Way galaxy where stars are packed in

1284

00:56:07,180 --> 00:56:05,510

then you're very likely to have this

1285

00:56:10,000 --> 00:56:07,190

occurrence happening happening pretty

1286

00:56:12,670 --> 00:56:10,010

often and so what we expect with the

1287

00:56:15,120 --> 00:56:12,680

dhobi first micro lensing survey is to

1288

00:56:17,890 --> 00:56:15,130

see this micro lensing effect these

1289

00:56:20,560 --> 00:56:17,900

planets and stars passing in front of

1290

00:56:23,530 --> 00:56:20,570

background stars happen very often and

1291

00:56:25,900 --> 00:56:23,540

so this is a plot that shows down here

1292

00:56:28,120 --> 00:56:25,910

on the x-axis this is distance of the

1293

00:56:31,000 --> 00:56:28,130

planet from the star they use

1294

00:56:33,490 --> 00:56:31,010

astronomical units one is the Earth's

1295

00:56:35,800 --> 00:56:33,500

distance from the Sun and here's the

1296

00:56:36,990 --> 00:56:35,810

planet's mass so the earth right there

1297

00:56:40,330 --> 00:56:37,000

one and one

1298

00:56:43,180 --> 00:56:40,340

so with Kepler is found again has been

1299

00:56:45,880 --> 00:56:43,190

mostly sort of smallish planets really

1300

00:56:48,310 --> 00:56:45,890

close to their stars what W first is

1301

00:56:50,380 --> 00:56:48,320

gonna do is push out to find planets

1302

00:56:54,100 --> 00:56:50,390

that are more like our gas giants that

1303

00:56:59,500 --> 00:56:54,110

are orbiting stars close to our close in

1304

00:57:03,030 --> 00:56:59,510

to to our solar system is so W first has

1305

00:57:06,130 --> 00:57:03,040

all of these really sort of grand goals

1306

00:57:08,800 --> 00:57:06,140

it's really being built to answer some

1307

00:57:10,720 --> 00:57:08,810

of the most fundamental puzzling

1308

00:57:14,890 --> 00:57:10,730

questions that we have in astrophysics

1309

00:57:19,630 --> 00:57:14,900

today so how in the world are we gonna

1310

00:57:23,800 --> 00:57:19,640

do this the key thing about w first is

1311

00:57:26,370 --> 00:57:23,810

the enormous size of the camera and of

1312

00:57:29,640 --> 00:57:26,380

the pictures that it will take

1313

00:57:32,430 --> 00:57:29,650

so that little square here it's the size

1314

00:57:33,060 --> 00:57:32,440

of the Hubble's camera so one pointing

1315

00:57:35,280 --> 00:57:33,070

with Hubble

1316

00:57:39,020 --> 00:57:35,290

so that Hubble ultra-deep field I showed

1317

00:57:43,230 --> 00:57:39,030

you all the images of the planets of the

1318

00:57:46,610 --> 00:57:43,240

the nebulae so W first will have an area

1319

00:57:50,640 --> 00:57:46,620

that's a hundred times the area of

1320

00:57:53,670 --> 00:57:50,650

Hubble and this is critical also with

1321

00:57:56,130 --> 00:57:53,680

the same depth and clarity that Hubble

1322

00:57:57,840 --> 00:57:56,140

has now we have telescopes on the ground

1323

00:58:01,860 --> 00:57:57,850

that are able to take these big wide

1324

00:58:05,070 --> 00:58:01,870

images but they are very shallow they're

1325

00:58:07,200 --> 00:58:05,080

very low resolution okay and so what you

1326

00:58:09,540 --> 00:58:07,210

really get with W first is sort of the

1327

00:58:12,210 --> 00:58:09,550

best of both worlds you get the depth

1328

00:58:15,870 --> 00:58:12,220

and the clarity and the precision of

1329

00:58:19,200 --> 00:58:15,880

Hubble with this gigantic field of view

1330

00:58:21,380 --> 00:58:19,210

this giant area and so this is basically

1331

00:58:24,510 --> 00:58:21,390

going to be Hubble times 100

1332

00:58:26,700 --> 00:58:24,520

so with this telescope again we hope to

1333

00:58:29,340 --> 00:58:26,710

sort of start to unlock some of these

1334

00:58:31,050 --> 00:58:29,350

mysteries of dark energy we hope to

1335

00:58:34,350 --> 00:58:31,060

learn more about some of the nearest

1336

00:58:36,390 --> 00:58:34,360

exoplanets in our own Milky Way but this

1337

00:58:39,330 --> 00:58:36,400

telescope is also going to be an

1338

00:58:42,300 --> 00:58:39,340

incredible tool just for general

1339

00:58:44,970 --> 00:58:42,310

astrophysics so all of these surveys

1340

00:58:47,310 --> 00:58:44,980

that W first will take that will help us

1341

00:58:51,180 --> 00:58:47,320

learn about dark energy help us learn

1342

00:58:54,120 --> 00:58:51,190

about exoplanets will be available to

1343

00:58:55,770 --> 00:58:54,130

astronomers and to the public to do what

1344

00:58:57,990 --> 00:58:55,780

I think will be really incredible

1345

00:59:00,900 --> 00:58:58,000

general astrophysics so just to give you

1346

00:59:03,300 --> 00:59:00,910

a couple of examples of that as I

1347

00:59:04,710 --> 00:59:03,310

mentioned to find exoplanets the best

1348

00:59:08,460 --> 00:59:04,720

way to do this is to look down the

1349

00:59:10,890 --> 00:59:08,470

throat of our own Milky Way galaxy so

1350

00:59:13,770 --> 00:59:10,900

again here we have the Hubble field of

1351

00:59:15,990 --> 00:59:13,780

view JT wristy it's very similar to

1352

00:59:19,590 --> 00:59:16,000

Hubble and then it sees a little tiny

1353

00:59:22,650 --> 00:59:19,600

picture on the sky but again dolby first

1354

00:59:25,230 --> 00:59:22,660

we get a hundred times the area and so

1355

00:59:28,560 --> 00:59:25,240

when we survey the center of the Milky

1356

00:59:30,770 --> 00:59:28,570

Way galaxy with W first in as few is

1357

00:59:31,950 --> 00:59:30,780

just you know a few less than ten

1358

00:59:34,710 --> 00:59:31,960

pointings

1359

00:59:37,920 --> 00:59:34,720

of w first you basically survey the

1360

00:59:39,259 --> 00:59:37,930

entire central center part of the Milky

1361

00:59:40,909 --> 00:59:39,269

Way galaxy

1362

00:59:43,549 --> 00:59:40,919

and you're able to learn so much more

1363

00:59:45,979 --> 00:59:43,559

about all of these different ranges of

1364

00:59:47,839 --> 00:59:45,989

astrophysics so what's going on with the

1365

00:59:49,669 --> 00:59:47,849

black the super giant black hole at the

1366

00:59:52,639 --> 00:59:49,679

center of our galaxy what's going on

1367

00:59:56,329 --> 00:59:52,649

with how young star clusters form so a

1368

00:59:58,759 --> 00:59:56,339

huge range of astrophysics that we'll be

1369

00:59:59,809 --> 00:59:58,769

able to do with these surveys and then I

1370

01:00:01,459 --> 00:59:59,819

mentioned that the Hubble Ultra Deep

1371

01:00:02,479 --> 01:00:01,469

Field was my personal favorite because

1372

01:00:05,059 --> 01:00:02,489

that's why I did a lot of my

1373

01:00:07,159 --> 01:00:05,069

dissertation research on so with the

1374

01:00:10,579 --> 01:00:07,169

whole Ultra Deep Field that one little

1375

01:00:14,989 --> 01:00:10,589

tiny piece of sky revealed ten thousand

1376

01:00:17,359 --> 01:00:14,999

galaxies but one pointing with w first

1377

01:00:19,370 --> 01:00:17,369

at a hundred of times the field of view

1378

01:00:23,299 --> 01:00:19,380

that's easy math right we're gonna see a

1379

01:00:26,599 --> 01:00:23,309

million galaxies in just one image with

1380

01:00:28,459 --> 01:00:26,609

W first again with the same depth and

1381

01:00:31,819 --> 01:00:28,469

clarity that we've been able to achieve

1382

01:00:34,039 --> 01:00:31,829

with Hubble and so I really believe me

1383

01:00:35,809 --> 01:00:34,049

being an extra galactic astrophysicist

1384

01:00:38,809 --> 01:00:35,819

that this telescope is gonna

1385

01:00:42,499 --> 01:00:38,819

revolutionize the way that we understand

1386

01:00:44,439 --> 01:00:42,509

how the universe works over the course

1387

01:00:46,759 --> 01:00:44,449

of cosmic history it'll change the way

1388

01:00:51,649 --> 01:00:46,769

that we understand the evolution of

1389

01:00:53,120 --> 01:00:51,659

galaxies over time so all of these

1390

01:00:54,979 --> 01:00:53,130

different things that we have planned

1391

01:00:56,899 --> 01:00:54,989

for the telescope again these specific

1392

01:00:59,809 --> 01:00:56,909

surveys to figure out how dark energy

1393

01:01:03,589 --> 01:00:59,819

works how exoplanet works exoplanets

1394

01:01:04,939 --> 01:01:03,599

work I think for me one of the things

1395

01:01:06,229 --> 01:01:04,949

we're having we're having a science

1396

01:01:09,259 --> 01:01:06,239

conference right now here at the

1397

01:01:10,939 --> 01:01:09,269

Institute on W first science so a bunch

1398

01:01:13,279 --> 01:01:10,949

of astronomers are here from all over

1399

01:01:15,319 --> 01:01:13,289

the country all over the world to think

1400

01:01:17,629 --> 01:01:15,329

about what this awesome Observatory is

1401

01:01:19,399 --> 01:01:17,639

going to do and one of the comments I

1402

01:01:21,139 --> 01:01:19,409

heard yesterday I think is probably

1403

01:01:23,599 --> 01:01:21,149

the most significant thing I've heard

1404

01:01:25,669 --> 01:01:23,609

and it was in reference to the Hubble

1405

01:01:28,099 --> 01:01:25,679

Space Telescope and the continent was

1406

01:01:30,289 --> 01:01:28,109

basically that you know Hubble was built

1407

01:01:33,799 --> 01:01:30,299

to answer a few key science questions of

1408

01:01:37,269 --> 01:01:33,809

its day but if you build a telescope if

1409

01:01:40,789 --> 01:01:37,279

you build a really extraordinary machine

1410

01:01:44,569 --> 01:01:40,799

then the community is going to find new

1411

01:01:46,819 --> 01:01:44,579

and novel ways to use that machine to

1412

01:01:49,549 --> 01:01:46,829

find things about the universe that we

1413

01:01:51,499 --> 01:01:49,559

never dreamed of and to me as a

1414

01:01:52,490 --> 01:01:51,509

scientist that's the most exciting thing

1415

01:01:55,550 --> 01:01:52,500

about being a sign

1416

01:01:57,710 --> 01:01:55,560

is we build these missions with these

1417

01:02:00,140 --> 01:01:57,720

very specific questions in mind these

1418

01:02:02,960 --> 01:02:00,150

these these specific things that we want

1419

01:02:06,320 --> 01:02:02,970

to answer but the fact is is when we

1420

01:02:08,540 --> 01:02:06,330

build these telescopes we find answers

1421

01:02:11,000 --> 01:02:08,550

to questions that we didn't even think

1422

01:02:14,089 --> 01:02:11,010

to ask when we were building them and

1423

01:02:15,589 --> 01:02:14,099

that overall is I believe the promise of

1424

01:02:19,540 --> 01:02:15,599

the universe and why we build these

1425

01:03:03,320 --> 01:02:19,550

missions thanks so much

1426

01:03:03,330 --> 01:03:07,299

[Music]

1427

01:03:19,400 --> 01:03:14,779

so they were meant to seeing wide fields

1428

01:03:21,559 --> 01:03:19,410

for anyway the DoD gave of these years

1429

01:03:24,019 --> 01:03:21,569

right so we're not going down well

1430

01:03:25,370 --> 01:03:24,029

enough of these years I'm launching

1431

01:03:29,719 --> 01:03:25,380

we're planning to launch the

1432

01:03:34,999 --> 01:03:29,729

mid-twenties oh yeah right

1433

01:03:38,269 --> 01:03:35,009

we're building so the James Webb Space

1434

01:03:42,380 --> 01:03:38,279

Telescope gonna be launched next year

1435

01:03:44,359 --> 01:03:42,390

and the Webb telescope is denying answer

1436

01:03:46,969 --> 01:03:44,369

different questions the Webb telescope

1437

01:03:48,429 --> 01:03:46,979

in many ways is really the scientific

1438

01:03:52,160 --> 01:03:48,439

successor to Hubble

1439

01:03:54,169 --> 01:03:52,170

so when is going to be further into the

1440

01:03:57,799 --> 01:03:54,179

infrared so it sees a different part of

1441

01:03:59,809 --> 01:03:57,809

the spectrum so AWS is also an infrared

1442

01:04:01,669 --> 01:03:59,819

telescope but it only sees a little bit

1443

01:04:05,120 --> 01:04:01,679

of a threat and again the key thing

1444

01:04:07,849 --> 01:04:05,130

about 30 verses is why huge trifle of

1445

01:04:10,519 --> 01:04:07,859

you so we're gonna be super Hubble and

1446

01:04:13,279 --> 01:04:10,529

then it sees a little part of this guy

1447

01:04:15,949 --> 01:04:13,289

but when we're going to see much winter

1448

01:04:18,289 --> 01:04:15,959

pearl so what was the deeper than

1449

01:04:20,959 --> 01:04:18,299

problem and what will see deeper and

1450

01:04:24,499 --> 01:04:20,969

don't we first will be more resolution

1451

01:04:26,839 --> 01:04:24,509

that with the web that's right yes but

1452

01:04:28,300 --> 01:04:26,849

we're resolution but also because he's

1453

01:04:30,490 --> 01:04:28,310

further

1454

01:04:35,140 --> 01:04:30,500

the spectrum is able to see different

1455

01:04:37,000 --> 01:04:35,150

things so for example I showed the sort

1456

01:04:39,970 --> 01:04:37,010

of flying through the holiday seal and

1457

01:04:41,950 --> 01:04:39,980

so in the D field we come to an edge and

1458

01:04:43,930 --> 01:04:41,960

what we can see with Hubble and that's

1459

01:04:47,230 --> 01:04:43,940

really the kind of couple cuts off at

1460

01:04:49,180 --> 01:04:47,240

the near-infrared wavelengths so to see

1461

01:04:51,640 --> 01:04:49,190

the most distant galaxies to see for

1462

01:04:53,920 --> 01:04:51,650

example the first segment of galaxies

1463

01:04:55,990 --> 01:04:53,930

that were born in the Big Bang we need

1464

01:04:58,090 --> 01:04:56,000

to see further into the infrared part of

1465

01:05:00,660 --> 01:04:58,100

the spectrum and that's exactly what web

1466

01:05:03,610 --> 01:05:00,670

is designed to do when it will also have

1467

01:05:06,670 --> 01:05:03,620

instruments on born that are designed to

1468

01:05:10,540 --> 01:05:06,680

do transit spectroscopy so web is a

1469

01:05:13,930 --> 01:05:10,550

really really incredible high resolution

1470

01:05:15,580 --> 01:05:13,940

spectrograph that W first inhabited OB

1471

01:05:17,830 --> 01:05:15,590

first has low resolution spectrograph

1472

01:05:20,950 --> 01:05:17,840

it'll allow us to do a different set of

1473

01:05:23,980 --> 01:05:20,960

science so web and dummy first are

1474

01:05:31,540 --> 01:05:23,990

different but they're complementary and

1475

01:05:33,010 --> 01:05:31,550

so look like stronger stream is one cool

1476

01:05:34,960 --> 01:05:33,020

thing that nobody first will be able to

1477

01:05:37,230 --> 01:05:34,970

do with this huge Bible of you

1478

01:05:40,510 --> 01:05:37,240

it's mines are the most rare objects

1479

01:05:43,960 --> 01:05:40,520

okay so you can imagine like the the

1480

01:05:46,150 --> 01:05:43,970

biggest hugest discount distant galaxies

1481

01:05:48,280 --> 01:05:46,160

so now these are very distant but for

1482

01:05:50,140 --> 01:05:48,290

whatever reason have to be huge but so

1483

01:05:52,300 --> 01:05:50,150

they're probably really really rare

1484

01:05:55,120 --> 01:05:52,310

you called it my heads of other things

1485

01:05:57,190 --> 01:05:55,130

like this that were very rare and so you

1486

01:05:59,920 --> 01:05:57,200

know why will you see these rare things

1487

01:06:05,740 --> 01:05:59,930

and so what would be able to find these

1488

01:06:07,690 --> 01:06:05,750

rare things be my nursery but we might

1489

01:06:11,560 --> 01:06:07,700

want to go back to take detailed spectra

1490

01:06:13,750 --> 01:06:11,570

of them and so our hope is definitely

1491

01:06:19,380 --> 01:06:13,760

that double universe will launch in the

1492

01:06:23,770 --> 01:06:19,390

mid 2020s so we'll have morality

1493

01:06:30,350 --> 01:06:26,780

although Hubble doing really great way

1494

01:06:44,150 --> 01:06:30,360

to help Wow to have all three at one

1495

01:06:48,320 --> 01:06:44,160

time first of all is just the detector

1496

01:06:51,230 --> 01:06:48,330

detector technology so so you know Hall

1497

01:06:53,360 --> 01:06:51,240

has a sort of limited amount of space in

1498

01:06:55,610 --> 01:06:53,370

places where you can actually place the

1499

01:06:58,010 --> 01:06:55,620

detectors and of course you know we've

1500

01:07:02,090 --> 01:06:58,020

been doubling down on for the last time

1501
01:07:04,460 --> 01:07:02,100
so we've done our last upgrade but for

1502
01:07:07,640 --> 01:07:04,470
dummy versus specifically focusing on

1503
01:07:10,580 --> 01:07:07,650
these detector arrays that are just huge

1504
01:07:12,980 --> 01:07:10,590
they're massive so it's really just

1505
01:07:14,780 --> 01:07:12,990
hacking those detectors those advanced

1506
01:07:17,720 --> 01:07:14,790
detectors and also detectives that are

1507
01:07:19,730 --> 01:07:17,730
it's just a big focal plane and then

1508
01:07:22,790 --> 01:07:19,740
also having just the configuration in

1509
01:07:24,350 --> 01:07:22,800
the telescope itself makes it such that

1510
01:07:26,720 --> 01:07:24,360
sort of the focal length of the

1511
01:07:29,840 --> 01:07:26,730
telescope allow them to housewife with

1512
01:07:31,700 --> 01:07:29,850
you so if you've done home housing the

1513
01:07:33,980 --> 01:07:31,710

size compare that oh that's a good

1514

01:07:35,930 --> 01:07:33,990

question and we'll get back to that so

1515

01:07:38,030 --> 01:07:35,940

uh so really just you know the

1516

01:07:40,430 --> 01:07:38,040

configuration of a telescope that focal

1517

01:07:42,890 --> 01:07:40,440

length and all of that gives it sort of

1518

01:07:45,560 --> 01:07:42,900

its parameters of how we can see the

1519

01:07:47,690 --> 01:07:45,570

universe so Hubble is sort of this sort

1520

01:07:51,650 --> 01:07:47,700

of long tube but what you think of The

1521

01:07:53,810 --> 01:07:51,660

Bachelor telesco dummy versus people

1522

01:07:56,120 --> 01:07:53,820

sort of affectionately call it a stub

1523

01:07:58,910 --> 01:07:56,130

helpful so it's the same year science

1524

01:08:00,410 --> 01:07:58,920

Hubble but it's sort of sure so it's got

1525

01:08:01,850 --> 01:08:00,420

a different focal length and so it just

1526

01:08:03,710 --> 01:08:01,860

allows the CD universe in a different

1527

01:08:05,510 --> 01:08:03,720

way so just so we're going to build

1528

01:08:07,970 --> 01:08:05,520

differently and then it kind of this

1529

01:08:09,770 --> 01:08:07,980

different detector right combination

1530

01:08:12,970 --> 01:08:09,780

they make sure the be measured in the

1531

01:08:15,910 --> 01:08:12,980

wavelength coverage because

1532

01:08:18,220 --> 01:08:15,920

just read the important first kana me

1533

01:08:26,410 --> 01:08:18,230

you cannot do all about astronomy from

1534

01:08:28,269 --> 01:08:26,420

the ground is really critical here so as

1535

01:08:30,579 --> 01:08:28,279

astronomers we want to see the universe

1536

01:08:31,959 --> 01:08:30,589

in as many ways as we can so why do we

1537

01:08:35,079 --> 01:08:31,969

put all these different telescopes to

1538

01:08:37,620 --> 01:08:35,089

see University and your instead Hubble's

1539

01:08:41,499 --> 01:08:37,630

but only the only telescope we have

1540

01:08:44,170 --> 01:08:41,509

right now they can see the ultimate

1541

01:08:46,300 --> 01:08:44,180

universe and galaxies the only house so

1542

01:08:48,010 --> 01:08:46,310

he has to set a little bit but whether

1543

01:08:50,979 --> 01:08:48,020

you've ability right now Hubble is the

1544

01:08:53,229 --> 01:08:50,989

prime telescope for ultraviolet visible

1545

01:08:55,959 --> 01:08:53,239

and then all things get a little bit as

1546

01:08:58,450 --> 01:08:55,969

we near infrared so dummy first is

1547

01:09:01,390 --> 01:08:58,460

planned to see in the infrared and then

1548

01:09:03,220 --> 01:09:01,400

when will be infrared plus out to the

1549

01:09:06,010 --> 01:09:03,230

mid infrared so it's just sort of about

1550

01:09:07,539 --> 01:09:06,020

covering the whole spectrum and then I'm

1551

01:09:10,690 --> 01:09:07,549

sawing about here but to answer your

1552

01:09:13,840 --> 01:09:10,700

question about size so Hubble it on the

1553

01:09:17,380 --> 01:09:13,850

sides was a school bus roughly it's

1554

01:09:20,950 --> 01:09:17,390

neater it's Mears 2.4 meters that's the

1555

01:09:25,180 --> 01:09:20,960

same size of the W first mirror when is

1556

01:09:28,300 --> 01:09:25,190

its primary mirror is six and a half

1557

01:09:31,510 --> 01:09:28,310

meters so about 22 feet across so what

1558

01:09:35,890 --> 01:09:31,520

is huge to go back to this other picture

1559

01:09:37,780 --> 01:09:35,900

computer when is by are the biggest

1560

01:09:44,320 --> 01:09:37,790

telescope that we've ever sent to space

1561

01:09:45,999 --> 01:09:44,330

can you back to in there we go so top to

1562

01:09:49,380 --> 01:09:46,009

bottom this is six and half meters not

1563

01:09:55,560 --> 01:09:49,390

21 feet what you don't see in this image

1564

01:10:00,669 --> 01:09:57,670

this structure he's looking on the

1565

01:10:03,339 --> 01:10:00,679

bottom a tennis court to talk about

1566

01:10:05,709 --> 01:10:03,349

over three stories tall so it's fun for

1567

01:10:08,199 --> 01:10:05,719

the big telescope we are into space so

1568

01:10:10,390 --> 01:10:08,209

what is it definitely unique in essence

1569

01:10:23,529 --> 01:10:10,400

and how big it is then of course we have

1570

01:10:25,870 --> 01:10:23,539

to fold it up to watch it I just have a

1571

01:10:28,390 --> 01:10:25,880

quick question so you had an image that

1572

01:10:30,609 --> 01:10:28,400

showed the visible matter and the dark

1573

01:10:32,589 --> 01:10:30,619

energy of the dark matter but you had it

1574

01:10:34,089 --> 01:10:32,599

narrowed down to percent so how are you

1575

01:10:42,759 --> 01:10:34,099

able to figure out sixty eight and

1576
01:10:48,350 --> 01:10:42,769
twenty seven and five constraints that

1577
01:10:48,360 --> 01:10:53,819
[Music]

1578
01:11:02,140 --> 01:10:57,640
through this imprint this image of the

1579
01:11:04,330 --> 01:11:02,150
baby universe that it's about 400,000

1580
01:11:08,080 --> 01:11:04,340
years after the Big Bang and we can

1581
01:11:09,879 --> 01:11:08,090
basically measure sort of details about

1582
01:11:12,129 --> 01:11:09,889
that image that tell us a little bit

1583
01:11:13,959 --> 01:11:12,139
about one thing evolution of the

1584
01:11:16,209 --> 01:11:13,969
universal being what the different

1585
01:11:19,540 --> 01:11:16,219
percentages will be so this is deep into

1586
01:11:20,679 --> 01:11:19,550
the theoretical cosmology so mostly what

1587
01:11:23,259 --> 01:11:20,689
I've talked about tonight is

1588
01:11:25,600 --> 01:11:23,269

observational cosmology or observational

1589

01:11:27,549 --> 01:11:25,610

astrophysics I'm a conservationist

1590

01:11:29,049 --> 01:11:27,559

this is families data to study the

1591

01:11:31,270 --> 01:11:29,059

University of courses and there's this

1592

01:11:34,149 --> 01:11:31,280

whole other set of astronomers that we

1593

01:11:40,080 --> 01:11:34,159

work really closely with that do

1594

01:11:42,399 --> 01:11:40,090

complete you know and then there's a

1595

01:11:44,589 --> 01:11:42,409

sort of one that same scale

1596

01:11:47,310 --> 01:11:44,599

there are astronomers that out-of-work

1597

01:11:49,810 --> 01:11:47,320

man was confused those that develop

1598

01:11:51,290 --> 01:11:49,820

computer models of how we work and so

1599

01:11:55,430 --> 01:11:51,300

all these sort of different

1600

01:11:58,470 --> 01:11:55,440

work together so the theoretical

1601

01:12:00,120 --> 01:11:58,480

resistance are the ones that work out

1602

01:12:01,680 --> 01:12:00,130

what these different percentages should

1603

01:12:03,840 --> 01:12:01,690

be we don't think those different

1604

01:12:07,230 --> 01:12:03,850

percentage those percentages have always

1605

01:12:09,660 --> 01:12:07,240

been that so for example the universe

1606

01:12:13,260 --> 01:12:09,670

and the center as we know is expanding

1607

01:12:15,120 --> 01:12:13,270

and so the volume of the universe is

1608

01:12:18,120 --> 01:12:15,130

getting bigger over time so we think

1609

01:12:23,280 --> 01:12:18,130

these percentages have changed over the

1610

01:12:26,130 --> 01:12:23,290

course of time so it's a complex fast by

1611

01:12:29,130 --> 01:12:26,140

nature is a complex question with a

1612

01:12:32,510 --> 01:12:29,140

complex answer there's lots of different

1613

01:12:35,370 --> 01:12:32,520

ways of observation that leads to us

1614

01:12:37,110 --> 01:12:35,380

kind of right at those numbers as one of

1615

01:12:42,200 --> 01:12:37,120

those theorists I can give you a real

1616

01:12:44,280 --> 01:12:42,210

destroyed answer the Spanish computer

1617

01:12:47,490 --> 01:12:44,290

decelerating and then takes over has

1618

01:12:49,500 --> 01:12:47,500

accelerate the timing of that change or

1619

01:13:11,850 --> 01:12:49,510

when it goes from decelerating to

1620

01:13:16,340 --> 01:13:11,860

acceleration is thank you yes on that

1621

01:13:18,930 --> 01:13:16,350

same point so 27% dark matter

1622

01:13:21,090 --> 01:13:18,940

does that mean that the mean density of

1623

01:13:23,340 --> 01:13:21,100

the universe is now greater than the

1624

01:13:25,110 --> 01:13:23,350

critical density meaning that it's a

1625

01:13:27,540 --> 01:13:25,120

finite volume and closed

1626

01:13:30,900 --> 01:13:27,550

this is also for dr. summers to people

1627

01:13:33,420 --> 01:13:30,910

but but beyond that if the universe is

1628

01:13:36,000 --> 01:13:33,430

also expanding meaning the space fabric

1629

01:13:37,950 --> 01:13:36,010

itself is moving in some and though the

1630

01:13:47,040 --> 01:13:37,960

way how then you calculate the volume

1631

01:13:53,800 --> 01:13:48,300

[Music]

1632

01:13:56,170 --> 01:13:53,810

yes we know the universe's so it's

1633

01:14:09,850 --> 01:13:56,180

closed and find a new buyer at this

1634

01:14:12,790 --> 01:14:09,860

point so we're pretty sure that the

1635

01:14:16,090 --> 01:14:12,800

geometry here versus flat we know that

1636

01:14:18,730 --> 01:14:16,100

is expanding we have this celery

1637

01:14:22,000 --> 01:14:18,740

we think that volume is getting bigger

1638

01:14:24,640 --> 01:14:22,010

but again the best theories of dark

1639

01:14:28,600 --> 01:14:24,650

energy tell us that empty space is

1640

01:14:31,660 --> 01:14:28,610

constantly creating new spaces right and

1641

01:14:34,000 --> 01:14:31,670

so on so even though the the volume is

1642

01:14:38,710 --> 01:14:34,010

getting bigger that so the density

1643

01:14:42,370 --> 01:14:38,720

overall is should be going down so in so

1644

01:14:44,620 --> 01:14:42,380

in the past the fraction of dark matter

1645

01:14:46,450 --> 01:14:44,630

would have for example the greater the

1646

01:14:48,730 --> 01:14:46,460

Russian variance would be greater so

1647

01:14:51,970 --> 01:14:48,740

dark meters you have less of an effect

1648

01:14:53,830 --> 01:14:51,980

early on in the universe okay so the

1649

01:15:11,359 --> 01:14:53,840

infected dark energy is getting greater

1650

01:15:49,770 --> 01:15:47,339

the universe extreme acceleration so I

1651

01:15:52,889 --> 01:15:49,780

question W first be able to answer

1652

01:16:24,179 --> 01:15:52,899

whether supernovae are composed of

1653

01:16:34,669 --> 01:16:24,189

single degenerate or BB heads and so we

1654

01:16:34,679 --> 01:16:43,800

the same thing I wanted to be there

1655

01:17:43,150 --> 01:17:39,050

[Music]

1656

01:17:49,730 --> 01:17:47,410

pretty easy fix it something's in space

1657

01:17:52,370 --> 01:17:49,740

in the hole we were able to send

1658

01:17:54,200 --> 01:17:52,380

astronauts up to fit but not being able

1659

01:17:55,310 --> 01:17:54,210

to back sweat what's going to be about

1660

01:17:59,330 --> 01:17:55,320

million miles away

1661

01:18:06,620 --> 01:17:59,340

not these Inhumans to fix it so space is

1662

01:18:09,290 --> 01:18:06,630

hard but we do have so right now at NASA

1663

01:18:10,880 --> 01:18:09,300

there are studies going on these teams

1664

01:18:15,320 --> 01:18:10,890

of astronomers that have gotten together

1665

01:18:19,610 --> 01:18:15,330

and are studying specific concepts for

1666

01:18:21,620 --> 01:18:19,620

the next big telescope so there are four

1667

01:18:24,440 --> 01:18:21,630

these teams and they're each focused on

1668

01:18:28,880 --> 01:18:24,450

different things one is study an x-ray a

1669

01:18:31,970 --> 01:18:28,890

focus telescope one study giant tools go

1670

01:18:34,670 --> 01:18:31,980

that would focus in on exoplanets I want

1671

01:18:37,610 --> 01:18:34,680

to study a different browner telescope

1672

01:18:40,130 --> 01:18:37,620

and I wanted to study a basically a sort

1673

01:18:42,980 --> 01:18:40,140

of a Super Bowl that would do sort of

1674

01:18:44,480 --> 01:18:42,990

you need to infrared actual physics in

1675

01:18:53,470 --> 01:18:44,490

space that will be even bigger than wet

1676

01:19:02,180 --> 01:18:57,040

[Music]

1677

01:19:04,760 --> 01:19:02,190

the W first launches again mid 2020s is

1678

01:19:08,810 --> 01:19:04,770

what we hope so this is next week

1679

01:19:11,959 --> 01:19:08,820

telescope will be selected in the next

1680

01:19:14,419 --> 01:19:11,969

seven years so these big big telescopes

1681

01:19:16,459 --> 01:19:14,429

like Hubble and Webb W first our

1682

01:19:19,010 --> 01:19:16,469

Germany's blanketed everything in here

1683

01:19:20,540 --> 01:19:19,020

so these are part what's called decade

1684

01:19:22,939 --> 01:19:20,550

old survey that some of you may have

1685

01:19:25,250 --> 01:19:22,949

heard of so every 10 years astronomers

1686

01:19:28,340 --> 01:19:25,260

from around the world get together and

1687

01:19:30,410 --> 01:19:28,350

ask what are our biggest questions so

1688

01:19:34,879 --> 01:19:30,420

they cry over time to these astronomy

1689

01:19:36,890 --> 01:19:34,889

questions and then they finally agree on

1690

01:19:38,300 --> 01:19:36,900

them and he's come out these big

1691

01:19:40,490 --> 01:19:38,310

questions come out and what are called

1692

01:19:43,820 --> 01:19:40,500

decadal surveys astronomy take a survey

1693

01:19:45,800 --> 01:19:43,830

and blew those big questions come the

1694

01:19:52,760 --> 01:19:45,810

technology that we need to answer the

1695

01:20:33,010 --> 01:19:52,770

questions so in that technology when it

1696

01:20:39,190 --> 01:20:37,240

in space a lot of good job moving around

1697

01:20:42,160 --> 01:20:39,200

like that - you can't absorb infrared

1698

01:20:43,870 --> 01:20:42,170

from the ground but large parts out that

1699

01:20:46,150 --> 01:20:43,880

our water completely blocked or

1700

01:21:04,240 --> 01:20:46,160

partially block at atmosphere which

1701
01:21:06,400 --> 01:21:04,250
turns out for humans energy dark matter

1702
01:21:25,720 --> 01:21:06,410
is there any difference between those

1703
01:21:27,640 --> 01:21:25,730
two and nothing we know that we have all

1704
01:21:30,370 --> 01:21:27,650
these different lines of evidence for

1705
01:21:34,830 --> 01:21:30,380
both for dark energy interim higher on

1706
01:21:41,260 --> 01:21:34,840
the tell us that there is happy

1707
01:21:44,350 --> 01:21:41,270
observable effects on the universe so it

1708
01:21:47,110 --> 01:21:44,360
is something matter if dark matter is is

1709
01:21:50,260 --> 01:21:47,120
something that gravitationally interacts

1710
01:21:53,050 --> 01:21:50,270
with other matter and we observe that

1711
01:21:55,660 --> 01:21:53,060
so if dark matter is affected by gravity

1712
01:21:57,310 --> 01:21:55,670
in the handle we see that front of the

1713
01:21:59,260 --> 01:21:57,320

rotation curves of spiral galaxies we

1714

01:22:02,050 --> 01:21:59,270

see that from how galaxies and questions

1715

01:22:03,640 --> 01:22:02,060

move we see that from the lensing and

1716

01:22:05,230 --> 01:22:03,650

similarly with dark energy we see all

1717

01:22:08,230 --> 01:22:05,240

these different clues the points on

1718

01:22:11,620 --> 01:22:08,240

there's something out there is causing

1719

01:22:21,970 --> 01:22:11,630

the universe to behave so it is nothing

1720

01:22:37,649 --> 01:22:27,220

[Music]

1721

01:22:43,110 --> 01:22:40,439

us that if the space is not really empty

1722

01:22:45,030 --> 01:22:43,120

that it's sort of always fluctuating and

1723

01:22:46,740 --> 01:22:45,040

always had this out of this one of the

1724

01:22:48,780 --> 01:22:46,750

theories you know dark energy one of the

1725

01:22:51,600 --> 01:22:48,790

candidates that Alice's it's sort of

1726

01:22:54,300 --> 01:22:51,610

vacuum energy this part of the

1727

01:22:57,000 --> 01:22:54,310

space-time that is because of just the

1728

01:23:10,740 --> 01:22:57,010

way it is it has quality of having this

1729

01:23:13,410 --> 01:23:10,750

energy so there was one group working on

1730

01:23:17,300 --> 01:23:13,420

an x-ray telescope but then way or way

1731

01:23:20,370 --> 01:23:17,310

to beginning there was an x-ray image of

1732

01:23:22,020 --> 01:23:20,380

the Crab Nebula so I'm wondering how

1733

01:23:25,040 --> 01:23:22,030

we've got that image and then also if

1734

01:23:38,149 --> 01:23:25,050

there if it's possible to be a gamma ray

1735

01:23:44,939 --> 01:23:42,270

Chandra and it's been up there a long

1736

01:23:47,669 --> 01:23:44,949

time so it's been doing very x-ray

1737

01:23:49,709 --> 01:23:47,679

astrophysics for a very long time so

1738

01:23:53,959 --> 01:23:49,719

yeah the image of show of the galaxy

1739

01:23:56,939 --> 01:23:53,969

clusters of the sort of pink blue so the

1740

01:23:59,760 --> 01:23:56,949

signatures of the gas in those galaxy

1741

01:24:02,399 --> 01:23:59,770

clusters it's really hot hot mountains

1742

01:24:03,660 --> 01:24:02,409

with minutes and the x-rays and so we do

1743

01:24:09,020 --> 01:24:03,670

have this awesome Chandra x-ray

1744

01:24:14,430 --> 01:24:09,030

telescope which has fabulous things

1745

01:24:17,459 --> 01:24:14,440

studying for the next thing surveys and

1746

01:24:20,920 --> 01:24:17,469

in yes we also have very small scales in

1747

01:24:24,220 --> 01:24:20,930

his face the very tools

1748

01:24:24,580 --> 01:24:24,230

is it's been up now gosh almost ten

1749

01:24:28,360 --> 01:24:24,590

years

1750

01:24:30,790 --> 01:24:28,370

decade only and it is primarily focus in

1751

01:24:33,490 --> 01:24:30,800

theatres so it's actually been a lot of

1752

01:24:36,100 --> 01:24:33,500

cool recent study and goal enough layers

1753

01:24:38,590 --> 01:24:36,110

cutting the details but of the money

1754

01:24:42,810 --> 01:24:38,600

waste return is looking for gamma rays

1755

01:24:49,800 --> 01:24:42,820

from these uh basically

1756

01:25:34,270 --> 01:25:31,480

interesting yes exoplanet arena come on

1757

01:25:36,880 --> 01:25:34,280

down arenal am Brady's I guess how you

1758

01:25:38,890 --> 01:25:36,890

pronounce relax close enough okay

1759

01:25:41,050 --> 01:25:38,900

she will take people across to the

1760

01:25:42,520 --> 01:25:41,060

Maryland Space Grant observatory if you

1761

01:25:45,850 --> 01:25:42,530

would like to look through the telescope

1762

01:25:48,100 --> 01:25:45,860

and see what's up there and let us one

1763

01:25:48,940 --> 01:25:48,110

more time give amber a warm round of