

1  
00:00:00,000 --> 00:00:04,650  
I mean you came in if you didn't grab

2  
00:00:03,178 --> 00:00:07,378  
one there are pictures

3  
00:00:04,650 --> 00:00:10,679  
tonight's picture is of the Crab Nebula

4  
00:00:07,378 --> 00:00:13,138  
and that parentheses says m1 which means

5  
00:00:10,679 --> 00:00:15,330  
it's the first object in Charles Messier

6  
00:00:13,138 --> 00:00:18,000  
's catalogue of things that aren't

7  
00:00:15,330 --> 00:00:19,649  
comets because he didn't care about all

8  
00:00:18,000 --> 00:00:21,689  
these wonderful nebulae and galaxies

9  
00:00:19,649 --> 00:00:24,089  
that he found he actually cared about

10  
00:00:21,689 --> 00:00:27,000  
looking for comets this is the very

11  
00:00:24,089 --> 00:00:28,859  
first object in Messier x' catalog if

12  
00:00:27,000 --> 00:00:30,118  
you wanted to know more about it well

13  
00:00:28,859 --> 00:00:32,850  
i'll tell you a little bit more in the

14  
00:00:30,118 --> 00:00:35,488  
new summary and you can read on the back

15  
00:00:32,850 --> 00:00:36,929  
about it okay but if you didn't grab one

16  
00:00:35,488 --> 00:00:40,140  
on the way and please grab one on the

17  
00:00:36,929 --> 00:00:42,420  
way out tonight's talk will be amber

18  
00:00:40,140 --> 00:00:44,399  
Straughn from NASA Goddard telling us

19  
00:00:42,420 --> 00:00:47,579  
about dark energy in new worlds

20  
00:00:44,399 --> 00:00:49,590  
NASA's W first mission this is a sneak

21  
00:00:47,579 --> 00:00:51,600  
preview of astronomy that will be coming

22  
00:00:49,590 --> 00:00:56,070  
in the next decade or so

23  
00:00:51,600 --> 00:00:58,920  
all right coming up on July our July

24  
00:00:56,070 --> 00:01:01,649  
talk was normally be on July 4th we are

25  
00:00:58,920 --> 00:01:04,409  
not going to do that instead we're doing

26  
00:01:01,649 --> 00:01:07,320  
it on the new week after and our speaker

27  
00:01:04,409 --> 00:01:10,890  
to fit his schedule we're putting it on

28  
00:01:07,319 --> 00:01:13,849  
a Monday not a Tuesday Monday night same

29

00:01:10,890 --> 00:01:18,629  
time eight o'clock same place right here

30  
00:01:13,849 --> 00:01:21,089  
how to find an inhabited exoplanet if

31  
00:01:18,629 --> 00:01:22,949  
that's not an intriguing title I don't

32  
00:01:21,090 --> 00:01:24,719  
know what could be okay

33  
00:01:22,950 --> 00:01:27,540  
David Charbonneau from the Harvard

34  
00:01:24,719 --> 00:01:30,450  
University in August we go back to our

35  
00:01:27,540 --> 00:01:32,549  
standard first Tuesday with a really

36  
00:01:30,450 --> 00:01:32,939  
cool talk I'm very much looking forward

37  
00:01:32,549 --> 00:01:35,759  
to this

38  
00:01:32,938 --> 00:01:38,849  
Courtney McManus is talking on the view

39  
00:01:35,759 --> 00:01:40,560  
from Mission Operations one of the cool

40  
00:01:38,849 --> 00:01:42,780  
things you get by coming to the Space

41  
00:01:40,560 --> 00:01:44,820  
Telescope Science Institute is yes we

42  
00:01:42,780 --> 00:01:47,399  
give you all this wonderful science but

43  
00:01:44,819 --> 00:01:49,078

we also can give you the background the

44

00:01:47,399 --> 00:01:50,849

details what's happening behind the

45

00:01:49,078 --> 00:01:53,309

scenes so this is definitely a

46

00:01:50,849 --> 00:01:54,780

behind-the-scenes talk and I haven't

47

00:01:53,310 --> 00:01:56,549

heard Courtney's speak before but

48

00:01:54,780 --> 00:01:58,019

everybody tells me she's really

49

00:01:56,549 --> 00:02:00,118

wonderful and she has a great

50

00:01:58,019 --> 00:02:02,578

perspective yes Karen's giving me the

51

00:02:00,118 --> 00:02:05,968

thumbs up there so please come and

52

00:02:02,578 --> 00:02:08,310

August in September Nolan Walborn who

53

00:02:05,968 --> 00:02:11,219

has spoken every other year for me he's

54

00:02:08,310 --> 00:02:12,930

a wonderful reliable speaker for the

55

00:02:11,219 --> 00:02:13,770

public lecture series he's talking about

56

00:02:12,930 --> 00:02:17,700

active

57

00:02:13,770 --> 00:02:19,800

luminous blue variables that's an

58  
00:02:17,699 --> 00:02:22,109  
intriguing title I'll tell you more

59  
00:02:19,800 --> 00:02:24,780  
about that next month you want to find

60  
00:02:22,110 --> 00:02:26,280  
out our list you go to our website go

61  
00:02:24,780 --> 00:02:28,620  
into your favorite search engine put

62  
00:02:26,280 --> 00:02:31,229  
Space Telescope public lecture in and

63  
00:02:28,620 --> 00:02:33,360  
you'll find this webpage where we have

64  
00:02:31,229 --> 00:02:35,459  
the list of the upcoming lectures we

65  
00:02:33,360 --> 00:02:38,370  
have the links to watch it live on the s

66  
00:02:35,460 --> 00:02:41,430  
Space Telescope webcasting as well as on

67  
00:02:38,370 --> 00:02:43,920  
our hubble site YouTube you can watch

68  
00:02:41,430 --> 00:02:47,969  
the past lectures we have recorded these

69  
00:02:43,919 --> 00:02:49,649  
lectures since 2005 that's 12 years of

70  
00:02:47,969 --> 00:02:52,080  
astronomical goodness

71  
00:02:49,650 --> 00:02:53,789  
you have to review it'll take if you

72  
00:02:52,080 --> 00:02:57,030  
want to binge watch it may take you more

73  
00:02:53,789 --> 00:03:01,949  
than a weekend okay we have several

74  
00:02:57,030 --> 00:03:05,430  
seasons out there and you can also sign

75  
00:03:01,949 --> 00:03:08,579  
up for our email announcements I checked

76  
00:03:05,430 --> 00:03:11,270  
for I had to do a report and we have

77  
00:03:08,580 --> 00:03:13,980  
over 550 people on our email list so

78  
00:03:11,270 --> 00:03:15,439  
lots of people a lot of you have signed

79  
00:03:13,979 --> 00:03:18,629  
up for our email announcements okay

80  
00:03:15,439 --> 00:03:20,669  
alright speaking of the announcements

81  
00:03:18,629 --> 00:03:22,889  
sign up at the website you can do this

82  
00:03:20,669 --> 00:03:24,809  
but yeah it's much easier just through

83  
00:03:22,889 --> 00:03:27,299  
the website if you would like to contact

84  
00:03:24,810 --> 00:03:29,250  
us and send us email ask us questions

85  
00:03:27,300 --> 00:03:31,950  
you got a suggestion for an amazing

86

00:03:29,250 --> 00:03:36,180  
speaker or something send email to

87  
00:03:31,949 --> 00:03:38,369  
public lecture at STScI dot edu you can

88  
00:03:36,180 --> 00:03:41,189  
also follow us on social media we have

89  
00:03:38,370 --> 00:03:43,710  
facebook we have two Twitter accounts we

90  
00:03:41,189 --> 00:03:45,180  
have Google+ we have Pinterest and maybe

91  
00:03:43,710 --> 00:03:47,310  
a few other things that I'm not quite

92  
00:03:45,180 --> 00:03:48,689  
aware of but I have to update this

93  
00:03:47,310 --> 00:03:52,050  
because I know we're starting a new push

94  
00:03:48,689 --> 00:03:54,509  
in social media next month so and by

95  
00:03:52,050 --> 00:03:56,790  
August I'll have a slightly revised

96  
00:03:54,509 --> 00:03:59,129  
version of this slide not this part

97  
00:03:56,789 --> 00:04:00,750  
because this is all I do i do my blog I

98  
00:03:59,129 --> 00:04:02,509  
do a little bit of Facebook a little bit

99  
00:04:00,750 --> 00:04:06,960  
of Google+ and a little bit of Twitter

100  
00:04:02,509 --> 00:04:07,739

so don't expect me to be tweeting 20

101

00:04:06,960 --> 00:04:10,590  
times a day

102

00:04:07,740 --> 00:04:14,340  
the observatory I think the weather is

103

00:04:10,590 --> 00:04:17,370  
permitting I didn't get an email but if

104

00:04:14,340 --> 00:04:20,430  
weather is permitting the Rini will be

105

00:04:17,370 --> 00:04:22,949  
here at 9 o'clock and watch the last

106

00:04:20,430 --> 00:04:25,889  
part of Amber's talk and take you across

107

00:04:22,949 --> 00:04:26,550  
the street to look through this which is

108

00:04:25,889 --> 00:04:29,159  
the

109

00:04:26,550 --> 00:04:30,960  
Maryland Space Grant Observatory okay so

110

00:04:29,160 --> 00:04:32,669  
make sure I don't forget about this at

111

00:04:30,959 --> 00:04:33,989  
the end somebody wave at me and say

112

00:04:32,668 --> 00:04:35,969  
Frank don't forget the observatory

113

00:04:33,990 --> 00:04:37,470  
because it's easy once we're over on a

114

00:04:35,970 --> 00:04:41,250  
roll with all the cool questions people



115  
00:04:37,470 --> 00:04:44,789  
ask all right and now news from the

116  
00:04:41,250 --> 00:04:48,839  
universe for June 2017

117  
00:04:44,788 --> 00:04:54,509  
our first story tonight the final

118  
00:04:48,839 --> 00:04:57,388  
frontier fields so Hubble has started as

119  
00:04:54,509 --> 00:05:00,479  
it's going these projects called

120  
00:04:57,389 --> 00:05:02,879  
Treasury programs these are very large

121  
00:05:00,478 --> 00:05:04,918  
projects projects it would never get

122  
00:05:02,879 --> 00:05:06,779  
funded for this amount of Hubble time

123  
00:05:04,918 --> 00:05:08,908  
unless there was a special program

124  
00:05:06,779 --> 00:05:11,908  
saying hey yes you can have hundreds of

125  
00:05:08,908 --> 00:05:13,379  
orbits of Hubble time and one of the

126  
00:05:11,908 --> 00:05:16,379  
ones we've been talking about the past

127  
00:05:13,379 --> 00:05:20,668  
couple years is called the frontier

128  
00:05:16,379 --> 00:05:24,949  
fields it's a very ambitious program to

129  
00:05:20,668 --> 00:05:27,329  
look at six galaxy clusters okay and

130  
00:05:24,949 --> 00:05:30,629  
these are they see these red squares

131  
00:05:27,329 --> 00:05:32,788  
here those are the six galaxy clusters

132  
00:05:30,629 --> 00:05:35,610  
and these are some of the most massive

133  
00:05:32,788 --> 00:05:37,918  
galaxy clusters in the universe so

134  
00:05:35,610 --> 00:05:41,340  
massive that they produce the effect of

135  
00:05:37,918 --> 00:05:43,439  
gravitational lensing okay and so we

136  
00:05:41,339 --> 00:05:45,209  
look into these galaxy clusters to see

137  
00:05:43,439 --> 00:05:48,120  
examples of gravitational lensing which

138  
00:05:45,209 --> 00:05:50,579  
I'll show you in just a second but they

139  
00:05:48,120 --> 00:05:53,280  
can also observe at the exact same time

140  
00:05:50,579 --> 00:05:56,008  
these blue fields which will be some

141  
00:05:53,279 --> 00:05:58,019  
parallel fields to them and we call them

142  
00:05:56,009 --> 00:06:00,060  
the parallels but they are also deep

143

00:05:58,019 --> 00:06:02,639  
fields like the Hubble Deep Field the

144  
00:06:00,060 --> 00:06:06,120  
Hubble extreme deep field etc they are

145  
00:06:02,639 --> 00:06:08,908  
very deep looks at the universe and when

146  
00:06:06,120 --> 00:06:12,240  
we look at these small deep fields we

147  
00:06:08,908 --> 00:06:15,209  
get a very small patch of the sky one

148  
00:06:12,240 --> 00:06:18,000  
Hubble pointing is about 112 millionth

149  
00:06:15,209 --> 00:06:20,038  
of the entire night sky and so you need

150  
00:06:18,000 --> 00:06:21,779  
a lot of these deep fields to add up the

151  
00:06:20,038 --> 00:06:24,478  
statistics to understand the deep

152  
00:06:21,779 --> 00:06:26,568  
universe so the frontier fields was this

153  
00:06:24,478 --> 00:06:29,699  
ambitious project to really study these

154  
00:06:26,569 --> 00:06:32,908  
galaxy clusters as well as study the

155  
00:06:29,699 --> 00:06:35,158  
deep fields and they've released oh and

156  
00:06:32,908 --> 00:06:37,800  
over the years they've released five of

157  
00:06:35,158 --> 00:06:39,939

these galaxy clusters and just a few

158

00:06:37,800 --> 00:06:43,509  
months ago we released

159

00:06:39,939 --> 00:06:47,860  
number six this is the galaxy cluster

160

00:06:43,509 --> 00:06:51,459  
called a bell 370 okay and all of these

161

00:06:47,860 --> 00:06:54,100  
white objects in here are the galaxies

162

00:06:51,459 --> 00:06:56,889  
of the cluster and their combined mass

163

00:06:54,100 --> 00:07:00,550  
warps the space and produces

164

00:06:56,889 --> 00:07:02,319  
gravitational lensing and so the the the

165

00:07:00,550 --> 00:07:04,439  
image of a galaxy that passes through

166

00:07:02,319 --> 00:07:07,689  
this cluster gets warped and stretched

167

00:07:04,439 --> 00:07:10,329  
by the galaxy cluster and one of the

168

00:07:07,689 --> 00:07:13,959  
famous examples in there a bell 370 is

169

00:07:10,329 --> 00:07:18,339  
something we call the dragon okay this

170

00:07:13,959 --> 00:07:21,099  
is not one not two but three images of

171

00:07:18,339 --> 00:07:24,159  
the same galaxy all right you can sort

172  
00:07:21,100 --> 00:07:26,020  
of see it here on the tail on the head

173  
00:07:24,160 --> 00:07:28,540  
of the dragon you can see that looks

174  
00:07:26,019 --> 00:07:30,310  
sort of like a normal galaxy right but

175  
00:07:28,540 --> 00:07:32,260  
here's another image of it in the middle

176  
00:07:30,310 --> 00:07:34,480  
in the midsection that's become

177  
00:07:32,259 --> 00:07:36,670  
stretched out due to the gravitational

178  
00:07:34,480 --> 00:07:39,280  
lensing and then there's another one on

179  
00:07:36,670 --> 00:07:41,530  
the other end the tail of the dragon

180  
00:07:39,279 --> 00:07:43,599  
where you can see it's also an image of

181  
00:07:41,529 --> 00:07:45,279  
the galaxy cluster so the light from

182  
00:07:43,600 --> 00:07:47,950  
this galaxy has travelled three pass

183  
00:07:45,279 --> 00:07:50,739  
through the same through the cluster and

184  
00:07:47,949 --> 00:07:53,740  
through these three distorted images of

185  
00:07:50,740 --> 00:07:55,600  
this galaxy and we called the dragon

186  
00:07:53,740 --> 00:07:58,660  
just because it has a nice head and tail

187  
00:07:55,600 --> 00:08:00,939  
type type features to it and you can see

188  
00:07:58,660 --> 00:08:02,560  
a lot of other streaky and our key

189  
00:08:00,939 --> 00:08:04,839  
things through here that are other

190  
00:08:02,560 --> 00:08:07,180  
evidence of the gravitational lensing

191  
00:08:04,839 --> 00:08:09,099  
all right and so this is something that

192  
00:08:07,180 --> 00:08:11,079  
they're searching for very distant

193  
00:08:09,100 --> 00:08:13,180  
galaxies and really cool examples of

194  
00:08:11,079 --> 00:08:15,909  
gravitational lensing in this we're also

195  
00:08:13,180 --> 00:08:18,639  
looking at these deep fields and here is

196  
00:08:15,910 --> 00:08:20,590  
the deep field that parallels to it and

197  
00:08:18,639 --> 00:08:23,050  
it looks very much like the other deep

198  
00:08:20,589 --> 00:08:26,049  
fields and as I said this will augment

199  
00:08:23,050 --> 00:08:29,139  
the statistics of our understanding of

200

00:08:26,050 --> 00:08:31,120  
these deep fields so this is sort of the

201  
00:08:29,139 --> 00:08:33,819  
announcement of that hey we've got all

202  
00:08:31,120 --> 00:08:35,349  
the data we haven't by any stretch of

203  
00:08:33,820 --> 00:08:38,020  
the imagination done all the analysis

204  
00:08:35,349 --> 00:08:41,050  
but we have all the data for all six

205  
00:08:38,019 --> 00:08:43,120  
galaxy clusters and all six deep field

206  
00:08:41,049 --> 00:08:44,529  
it's kind of nice that this project

207  
00:08:43,120 --> 00:08:47,169  
that's been going on for like three or

208  
00:08:44,529 --> 00:08:49,329  
four years has finally got all the data

209  
00:08:47,169 --> 00:08:49,779  
and of course the science that will come

210  
00:08:49,330 --> 00:08:52,509  
from it

211  
00:08:49,779 --> 00:08:53,620  
will take many many more years to

212  
00:08:52,509 --> 00:08:55,419  
continue to trickle out

213  
00:08:53,620 --> 00:08:57,460  
because we're getting lots and lots of

214  
00:08:55,419 --> 00:08:59,199

science out of not just the current

215

00:08:57,460 --> 00:09:02,830  
observations but also the archival

216

00:08:59,200 --> 00:09:06,660  
observations from Hubble our second

217

00:09:02,830 --> 00:09:11,440  
story a dramatic chromatic Crab Nebula

218

00:09:06,659 --> 00:09:14,169  
now there's a reason I use this image as

219

00:09:11,440 --> 00:09:16,890  
our giveaway tonight the Crab Nebula

220

00:09:14,169 --> 00:09:19,240  
because this is the standard image of

221

00:09:16,889 --> 00:09:22,919  
Hubble's view of a Crab Nebula -

222

00:09:19,240 --> 00:09:25,600  
everyone knows it came from 2000 or 2001

223

00:09:22,919 --> 00:09:28,240  
done with the white tail a wide field

224

00:09:25,600 --> 00:09:30,730  
planetary camera - and it's a really

225

00:09:28,240 --> 00:09:32,528  
cool image it's great and so when people

226

00:09:30,730 --> 00:09:35,050  
think of Hubble's Crab Nebula this is

227

00:09:32,528 --> 00:09:37,330  
what they think of but there's more that

228

00:09:35,049 --> 00:09:40,629  
meets that there's more to the Crab



229  
00:09:37,330 --> 00:09:43,060  
Nebula than meets the eye so in this

230  
00:09:40,629 --> 00:09:46,960  
image we see that the different colors

231  
00:09:43,059 --> 00:09:50,439  
represent different specific elements

232  
00:09:46,960 --> 00:09:52,778  
like nitrogen or iron or sulfur or

233  
00:09:50,440 --> 00:09:54,880  
hydrogen very specific elements and they

234  
00:09:52,778 --> 00:09:56,230  
tell us what's going on for the the

235  
00:09:54,879 --> 00:09:58,179  
temperatures and densities that

236  
00:09:56,230 --> 00:10:00,670  
appropriate for the emission of those

237  
00:09:58,179 --> 00:10:03,429  
spectral lines but what if we went

238  
00:10:00,669 --> 00:10:06,759  
beyond visible light what have we looked

239  
00:10:03,429 --> 00:10:09,849  
at the Crab Nebula over many different

240  
00:10:06,759 --> 00:10:12,189  
wavelengths we would get an even greater

241  
00:10:09,850 --> 00:10:13,870  
view of it okay actually you know what

242  
00:10:12,190 --> 00:10:15,160  
there's well there's probably a bunch of

243  
00:10:13,870 --> 00:10:16,929  
you who don't know what the Crab Nebula

244  
00:10:15,159 --> 00:10:19,350  
is how many people don't know what the

245  
00:10:16,929 --> 00:10:21,278  
Crab Nebula is and this is one of these

246  
00:10:19,350 --> 00:10:23,050  
problems with being an astronomer it's

247  
00:10:21,278 --> 00:10:24,669  
like oh yeah the Crab Nebula the Crab

248  
00:10:23,049 --> 00:10:27,219  
Nebula for those who don't know and

249  
00:10:24,669 --> 00:10:30,729  
actually surprisingly few is a supernova

250  
00:10:27,220 --> 00:10:33,639  
remnant a star that exploded a thousand

251  
00:10:30,730 --> 00:10:36,070  
years ago chinese astronomers saw the

252  
00:10:33,639 --> 00:10:39,189  
explosion in actually I believe it was

253  
00:10:36,070 --> 00:10:42,160  
July 4th 1054 all right so that was a

254  
00:10:39,190 --> 00:10:45,040  
little early for Independence Day but in

255  
00:10:42,159 --> 00:10:47,289  
1054 they saw a guest star appear in the

256  
00:10:45,039 --> 00:10:49,870  
sky and it was a star that just

257

00:10:47,289 --> 00:10:52,449  
basically exploded alright it blew its

258  
00:10:49,870 --> 00:10:54,490  
guts out into space so a thousand years

259  
00:10:52,450 --> 00:10:57,430  
ago this all that gas was inside a star

260  
00:10:54,490 --> 00:11:00,209  
and now it's a nebula that's ten years

261  
00:10:57,429 --> 00:11:02,469  
ten light years across okay so it's

262  
00:11:00,208 --> 00:11:04,689  
booming across space at millions of

263  
00:11:02,470 --> 00:11:07,300  
miles an hour alright so this is the

264  
00:11:04,690 --> 00:11:09,550  
guts of a star blown out into space

265  
00:11:07,299 --> 00:11:13,870  
and if this is what we see in visible

266  
00:11:09,549 --> 00:11:16,740  
light if we look in radio light with the

267  
00:11:13,870 --> 00:11:19,330  
Very Large Array we get this image and

268  
00:11:16,740 --> 00:11:22,990  
so these are the radio waves emitted

269  
00:11:19,330 --> 00:11:24,759  
from the gas that is being energized to

270  
00:11:22,990 --> 00:11:26,589  
MIT and radio now radio ways are

271  
00:11:24,759 --> 00:11:29,828

generally the lower lowest energy that

272

00:11:26,589 --> 00:11:31,540

we look at okay so this is out here you

273

00:11:29,828 --> 00:11:35,049

can see it's the out mostly the

274

00:11:31,539 --> 00:11:38,230

outskirts of the nebula we then step up

275

00:11:35,049 --> 00:11:40,659

to infrared wavelengths from the Spitzer

276

00:11:38,230 --> 00:11:43,060

Space Telescope we see this this is the

277

00:11:40,659 --> 00:11:46,208

cooler gas this is gas around a few

278

00:11:43,059 --> 00:11:47,649

hundred degrees all right 100 a few

279

00:11:46,208 --> 00:11:49,869

hundred degrees and you start to see you

280

00:11:47,649 --> 00:11:52,299

know filament the filament restructure

281

00:11:49,870 --> 00:11:54,220

if we go to the Hubble image and we just

282

00:11:52,299 --> 00:11:55,778

give it a single filter color all right

283

00:11:54,220 --> 00:11:58,540

here we're getting gas that's at

284

00:11:55,778 --> 00:12:00,278

thousands of degrees generally thousands

285

00:11:58,539 --> 00:12:02,078

are tens of thousands of degrees and you

286  
00:12:00,278 --> 00:12:05,708  
really see that filamentary structure

287  
00:12:02,078 --> 00:12:07,629  
the gas that's blown out and created all

288  
00:12:05,708 --> 00:12:11,739  
these beautiful filaments all right if

289  
00:12:07,629 --> 00:12:13,360  
we then go up to the ultraviolet now

290  
00:12:11,740 --> 00:12:15,250  
we're looking at gas it's tens of

291  
00:12:13,360 --> 00:12:17,560  
thousands to hundreds of thousands of

292  
00:12:15,250 --> 00:12:21,578  
degrees and you sort of see the volume

293  
00:12:17,559 --> 00:12:23,019  
filling inside the the filamentary

294  
00:12:21,578 --> 00:12:25,870  
structure that we see in visible light

295  
00:12:23,019 --> 00:12:28,539  
but you also start to see the appearance

296  
00:12:25,870 --> 00:12:31,860  
of a disc like in the center of it and

297  
00:12:28,539 --> 00:12:35,889  
when we go to x-rays the highest energy

298  
00:12:31,860 --> 00:12:38,230  
you really see that disc and so do you

299  
00:12:35,889 --> 00:12:41,319  
see the disc of material around this

300  
00:12:38,230 --> 00:12:44,528  
bright spot in the center that bright

301  
00:12:41,320 --> 00:12:47,649  
spot in the center is a neutron star

302  
00:12:44,528 --> 00:12:50,230  
it's the collapsed core of the star that

303  
00:12:47,649 --> 00:12:53,589  
exploded and this one happens to be

304  
00:12:50,230 --> 00:12:56,649  
spinning 30 times a second it's a

305  
00:12:53,589 --> 00:12:59,440  
millisecond pulsar and you can see this

306  
00:12:56,649 --> 00:13:01,958  
disc of material of material around it

307  
00:12:59,440 --> 00:13:04,570  
as well as what appeared to be material

308  
00:13:01,958 --> 00:13:07,599  
streaming out from the poles of it okay

309  
00:13:04,570 --> 00:13:09,820  
all right so combining all those views

310  
00:13:07,600 --> 00:13:13,120  
together you get the multi-wavelength

311  
00:13:09,820 --> 00:13:16,620  
view of the Crab Nebula and this

312  
00:13:13,120 --> 00:13:20,060  
includes radio infrared visible

313  
00:13:16,620 --> 00:13:22,639  
ultraviolet and x-ray views

314

00:13:20,059 --> 00:13:24,799  
from telescopes and I think it's a

315  
00:13:22,639 --> 00:13:27,740  
really gorgeous image and it showed I

316  
00:13:24,799 --> 00:13:30,439  
think it showcases where astronomy has

317  
00:13:27,740 --> 00:13:32,450  
gone in the last hundred years because a

318  
00:13:30,440 --> 00:13:34,730  
hundred years ago we were just using

319  
00:13:32,450 --> 00:13:37,460  
visible light we didn't start using

320  
00:13:34,730 --> 00:13:40,399  
radio light until the 1930s and we have

321  
00:13:37,460 --> 00:13:42,920  
developed observations across the entire

322  
00:13:40,399 --> 00:13:45,049  
electromagnetic spectrum and here is a

323  
00:13:42,919 --> 00:13:50,120  
gorgeous example of it with the Crab

324  
00:13:45,049 --> 00:13:52,819  
Nebula the third story is yet Bohr from

325  
00:13:50,120 --> 00:13:54,919  
the lunatic fringe now those of you

326  
00:13:52,820 --> 00:13:57,620  
who've been here many times have heard

327  
00:13:54,919 --> 00:14:00,349  
me to discuss the lunatic fringe before

328  
00:13:57,620 --> 00:14:03,080

and what I refer to when with that joke

329

00:14:00,350 --> 00:14:06,230

is first the fringe of the solar system

330

00:14:03,080 --> 00:14:08,180

so here are the orbits of Jupiter Saturn

331

00:14:06,230 --> 00:14:10,519

Uranus and Neptune okay

332

00:14:08,179 --> 00:14:12,289

and so out beyond the orbit of Neptune

333

00:14:10,519 --> 00:14:14,329

is what I'm referring to as the fringe

334

00:14:12,289 --> 00:14:17,329

of the solar system and it's a region we

335

00:14:14,330 --> 00:14:19,340

call the Kuiper belt okay and the Kuiper

336

00:14:17,330 --> 00:14:22,790

belt is something that we didn't know

337

00:14:19,340 --> 00:14:25,129

about until the 1990s we discovered

338

00:14:22,789 --> 00:14:28,699

these thousands of objects out beyond

339

00:14:25,129 --> 00:14:30,559

Neptune well except for two of them all

340

00:14:28,700 --> 00:14:32,839

right except for two of them we

341

00:14:30,559 --> 00:14:34,369

discovered thousands more objects out

342

00:14:32,839 --> 00:14:36,560

beyond the orbit of Neptune they're



343  
00:14:34,370 --> 00:14:38,539  
small they're I see they have elliptical

344  
00:14:36,559 --> 00:14:40,729  
orbits they have tilted orbits all right

345  
00:14:38,539 --> 00:14:43,399  
and they're very much just like they're

346  
00:14:40,730 --> 00:14:47,269  
most of the the largest object in the

347  
00:14:43,399 --> 00:14:51,409  
Kuiper belt which is Pluto Pluto was

348  
00:14:47,269 --> 00:14:53,120  
discovered in 1930 Charon in 1978 I

349  
00:14:51,409 --> 00:14:55,969  
think although it wasn't verified until

350  
00:14:53,120 --> 00:14:59,240  
85 something like that all right

351  
00:14:55,970 --> 00:15:00,740  
and then so Pluto and Charon are the

352  
00:14:59,240 --> 00:15:03,200  
first two objects discovered in the

353  
00:15:00,740 --> 00:15:05,269  
Kuiper belt we now know of thousands all

354  
00:15:03,200 --> 00:15:07,100  
right and when I talk about lunatic

355  
00:15:05,269 --> 00:15:10,490  
fringe I'm talking about the moons

356  
00:15:07,100 --> 00:15:12,649  
around Kuiper belt objects and Pluto is

357  
00:15:10,490 --> 00:15:14,870  
a great example because as I said we

358  
00:15:12,649 --> 00:15:17,209  
knew about this before Hubble it took

359  
00:15:14,870 --> 00:15:22,100  
Hubble's resolution to find Nix and

360  
00:15:17,210 --> 00:15:27,560  
Hydra which we found in 2006 Kerberos I

361  
00:15:22,100 --> 00:15:29,509  
think in 2010 and Styx in 2012 so Hubble

362  
00:15:27,559 --> 00:15:31,909  
has been instrumental in finding these

363  
00:15:29,509 --> 00:15:33,679  
moons around these objects at the fringe

364  
00:15:31,909 --> 00:15:36,199  
of the solar system all right

365  
00:15:33,679 --> 00:15:38,750  
so here are here's a graphic of the

366  
00:15:36,200 --> 00:15:40,730  
eighth largest Kuiper belt objects all

367  
00:15:38,750 --> 00:15:42,080  
right everyone knows Pluto can anybody

368  
00:15:40,730 --> 00:15:43,159  
name other Kuiper belt objects

369  
00:15:42,080 --> 00:15:49,300  
astronomers with us

370  
00:15:43,159 --> 00:15:56,319  
yes Eris yes how may i yes very good

371

00:15:49,299 --> 00:15:59,719  
other ones in the back Makemake

372  
00:15:56,320 --> 00:16:03,050  
he's heart yes interesting names okay

373  
00:15:59,720 --> 00:16:07,100  
pluto eris Haumea Makemake those are the

374  
00:16:03,049 --> 00:16:10,879  
the traditional top four quar Sedna and

375  
00:16:07,100 --> 00:16:15,409  
orcas okay yes it is pronounced Wawa

376  
00:16:10,879 --> 00:16:17,509  
okay now you'll notice I have left out a

377  
00:16:15,409 --> 00:16:21,829  
name for the third largest Kuiper belt

378  
00:16:17,509 --> 00:16:23,860  
object because it has no name it is

379  
00:16:21,830 --> 00:16:28,550  
actually known by its catalog number

380  
00:16:23,860 --> 00:16:30,940  
2007 Oh our 10 it has yet to be given an

381  
00:16:28,549 --> 00:16:33,500  
actual name which is kind of funky

382  
00:16:30,940 --> 00:16:36,290  
because there's a lot smaller things out

383  
00:16:33,500 --> 00:16:37,879  
there that have been given names now

384  
00:16:36,289 --> 00:16:39,649  
when I talk about the moons of Pluto

385  
00:16:37,879 --> 00:16:41,899

there are lots of them but there are

386

00:16:39,649 --> 00:16:45,049

also lots of moons of other Kuiper belt

387

00:16:41,899 --> 00:16:49,028

objects Eris has Disney Mia there's high

388

00:16:45,049 --> 00:16:51,169

aachen Amaka way wat van and mk2 is a

389

00:16:49,028 --> 00:16:52,399

nickname I don't know if it actually has

390

00:16:51,169 --> 00:16:54,620

a real name or it still has the

391

00:16:52,399 --> 00:16:56,569

designation all right so you'll actually

392

00:16:54,620 --> 00:17:00,980

notice of the eighth-largest

393

00:16:56,570 --> 00:17:04,269

cover about objects only Sedna and 2007

394

00:17:00,980 --> 00:17:10,068

or 10 don't have moons or well I say

395

00:17:04,269 --> 00:17:13,400

didn't have moons okay the Kepler space

396

00:17:10,068 --> 00:17:16,039

telescope her mission looked at 2007 or

397

00:17:13,400 --> 00:17:19,550

10 and found that it was rotating slowly

398

00:17:16,039 --> 00:17:21,709

it rotated once every 45 hours generally

399

00:17:19,549 --> 00:17:22,099

Kuiper belt objects rotate in a couple

400  
00:17:21,709 --> 00:17:25,939  
hours

401  
00:17:22,099 --> 00:17:27,349  
so having a 45 hour rotation suggested

402  
00:17:25,939 --> 00:17:28,730  
that some of the angular momentum

403  
00:17:27,349 --> 00:17:31,279  
instead of being in the spin of the

404  
00:17:28,730 --> 00:17:34,339  
object was actually in a moon orbiting

405  
00:17:31,279 --> 00:17:37,099  
around it so people went looking for it

406  
00:17:34,339 --> 00:17:39,529  
where do they look they looked in the

407  
00:17:37,099 --> 00:17:44,829  
Hubble archive okay Hubble had already

408  
00:17:39,529 --> 00:17:47,149  
taken images of 2010 and they saw this

409  
00:17:44,829 --> 00:17:50,179  
in 2009 and

410  
00:17:47,150 --> 00:17:52,610  
2010 Hubble took these images so the

411  
00:17:50,180 --> 00:17:54,560  
bright spot in the center is 2007 Oh are

412  
00:17:52,609 --> 00:17:56,839  
10 and because it's a solar system

413  
00:17:54,559 --> 00:17:58,879  
object it moves relative to the

414  
00:17:56,839 --> 00:18:00,619  
background stars so there's lots of

415  
00:17:58,880 --> 00:18:02,540  
things like you know this thing and this

416  
00:18:00,619 --> 00:18:04,279  
thing these are all background stars

417  
00:18:02,539 --> 00:18:07,759  
moving past the things that are

418  
00:18:04,279 --> 00:18:09,529  
different in each image are the are the

419  
00:18:07,759 --> 00:18:10,940  
stars in the background is there

420  
00:18:09,529 --> 00:18:12,740  
something the same in each image

421  
00:18:10,940 --> 00:18:16,789  
you betcha otherwise I wouldn't be

422  
00:18:12,740 --> 00:18:20,029  
talking about it there they discovered

423  
00:18:16,789 --> 00:18:22,579  
that yes it did have a moon so here's

424  
00:18:20,029 --> 00:18:25,940  
where it was in 2009 here's where it is

425  
00:18:22,579 --> 00:18:27,859  
in 2010 unfortunately these two

426  
00:18:25,940 --> 00:18:30,590  
observations weren't enough to determine

427  
00:18:27,859 --> 00:18:33,769  
in orbit for it so they don't know the

428

00:18:30,589 --> 00:18:36,199  
the actual mass of it but we turned to

429  
00:18:33,769 --> 00:18:37,910  
the Herschel Space Telescope and they

430  
00:18:36,200 --> 00:18:40,340  
were able to use far infrared

431  
00:18:37,910 --> 00:18:43,940  
observations to get a thermal emission

432  
00:18:40,339 --> 00:18:48,230  
profile for it and estimate its size so

433  
00:18:43,940 --> 00:18:50,120  
adding that back into the the chart you

434  
00:18:48,230 --> 00:18:53,690  
can see that the provisional designation

435  
00:18:50,119 --> 00:18:58,269  
for it here we now have seven of the top

436  
00:18:53,690 --> 00:19:01,000  
eight Kuiper belt objects with moons now

437  
00:18:58,269 --> 00:19:03,500  
the really cool science behind it is

438  
00:19:01,000 --> 00:19:07,400  
well fine you've got these icy things

439  
00:19:03,500 --> 00:19:10,880  
that have these icy moons but you really

440  
00:19:07,400 --> 00:19:12,920  
couldn't have formed them as you formed

441  
00:19:10,880 --> 00:19:14,720  
the Kuiper belt object you think of

442  
00:19:12,920 --> 00:19:17,060

Jupiter and it's Galilean moons and

443

00:19:14,720 --> 00:19:19,970

Jupiter forms here and the moons form in

444

00:19:17,059 --> 00:19:24,349

a disk around them how did these moons

445

00:19:19,970 --> 00:19:27,259

form not by accretion around the the

446

00:19:24,349 --> 00:19:30,679

collapsing collapsing body but rather by

447

00:19:27,259 --> 00:19:33,230

a collision and capture so the idea is

448

00:19:30,680 --> 00:19:35,049

that for all of these objects something

449

00:19:33,230 --> 00:19:37,370

smashed into something else and

450

00:19:35,049 --> 00:19:42,529

collected into collected a moon around

451

00:19:37,369 --> 00:19:44,119

it okay so Nix Hydra Nix Kerberos and

452

00:19:42,529 --> 00:19:46,639

Styx by the way these are the actual

453

00:19:44,119 --> 00:19:49,669

sizes those are kind of tiny moons all

454

00:19:46,640 --> 00:19:51,650

right and Charon all have the same orbit

455

00:19:49,670 --> 00:19:55,130

and we believed there was a very large

456

00:19:51,650 --> 00:19:56,780

smash but that produced Pluto Pluto



457  
00:19:55,130 --> 00:19:58,730  
Charon system okay

458  
00:19:56,779 --> 00:20:00,980  
and the same for all of these that a

459  
00:19:58,730 --> 00:20:05,240  
collision produces

460  
00:20:00,980 --> 00:20:07,339  
captured moons so it's actually adding

461  
00:20:05,240 --> 00:20:09,558  
to our scientific understanding of the

462  
00:20:07,339 --> 00:20:11,740  
formation of moons which is kind of

463  
00:20:09,558 --> 00:20:15,819  
important and it really hits home

464  
00:20:11,740 --> 00:20:18,529  
because amongst the planets this one is

465  
00:20:15,819 --> 00:20:22,579  
believed to have had that same process

466  
00:20:18,529 --> 00:20:24,950  
happen our Moon using rock instead of

467  
00:20:22,579 --> 00:20:27,349  
ice is believed to have formed when

468  
00:20:24,950 --> 00:20:30,319  
approximately a mars-sized body hit the

469  
00:20:27,349 --> 00:20:37,329  
earth about four four and a half billion

470  
00:20:30,319 --> 00:20:39,950  
years ago so an appreciation of the the

471  
00:20:37,329 --> 00:20:43,418  
frequency at which these collisions can

472  
00:20:39,950 --> 00:20:45,798  
happen and produce captured moons is

473  
00:20:43,419 --> 00:20:50,120  
greatly increasing with our knowledge of

474  
00:20:45,798 --> 00:20:52,029  
Kuiper belt alright thank you and that's

475  
00:20:50,119 --> 00:20:55,250  
our news from the universe for tonight

476  
00:20:52,029 --> 00:20:58,009  
all right now we're gonna go on to our

477  
00:20:55,250 --> 00:21:00,109  
featured speaker and our speaker is

478  
00:20:58,009 --> 00:21:01,298  
amber Straughn from NASA Goddard Space

479  
00:21:00,109 --> 00:21:04,729  
Flight Center

480  
00:21:01,298 --> 00:21:07,460  
she did her she likes Messiah described

481  
00:21:04,730 --> 00:21:11,480  
herself as an Arkansas farm girl turned

482  
00:21:07,460 --> 00:21:14,390  
astrophysicist she did her undergraduate

483  
00:21:11,480 --> 00:21:16,069  
work at the University of Arkansas then

484  
00:21:14,390 --> 00:21:19,160  
she did her graduate work at Arizona

485

00:21:16,069 --> 00:21:20,298  
State University and she's been she's

486  
00:21:19,160 --> 00:21:22,640  
down at Goddard Space Flight Center

487  
00:21:20,298 --> 00:21:25,730  
working on the James Webb Space

488  
00:21:22,640 --> 00:21:27,290  
Telescope and she has a bunch of cool

489  
00:21:25,730 --> 00:21:28,819  
things about her one of the things

490  
00:21:27,289 --> 00:21:31,779  
that's been highlighted a lot is that

491  
00:21:28,819 --> 00:21:35,149  
she is a pilot she flies her own planes

492  
00:21:31,779 --> 00:21:37,849  
and she tells me that that's fun but the

493  
00:21:35,150 --> 00:21:42,140  
really fun thing is she got to go on the

494  
00:21:37,849 --> 00:21:44,000  
Vomit Comet the hyperbolic repair well

495  
00:21:42,140 --> 00:21:49,580  
parabolic trajectory plane where you

496  
00:21:44,000 --> 00:21:50,890  
actually are weightless for how long all

497  
00:21:49,579 --> 00:21:53,369  
right so

498  
00:21:50,890 --> 00:21:55,720  
[Laughter]

499  
00:21:53,369 --> 00:21:57,609

so you're weightless for 20 to 30

500

00:21:55,720 --> 00:22:01,269

seconds and they do it 20 times in a row

501

00:21:57,609 --> 00:22:02,169

alright and she she kept her lunch down

502

00:22:01,269 --> 00:22:04,750

ha ha ha

503

00:22:02,170 --> 00:22:07,660

so ladies and gentlemen we have a hearty

504

00:22:04,750 --> 00:22:17,900

speaker tonight amber strong

505

00:22:07,660 --> 00:22:17,900

[Applause]

506

00:22:24,380 --> 00:22:29,040

all right can you all hear me in the

507

00:22:26,759 --> 00:22:32,009

back y'all I say you heard I was from

508

00:22:29,039 --> 00:22:34,259

Arkansas so I say y'all I'm so great to

509

00:22:32,009 --> 00:22:37,019

see so many of you tonight I'm really

510

00:22:34,259 --> 00:22:39,119

excited to be here to talk a little bit

511

00:22:37,019 --> 00:22:41,069

about an awesome new mission that we

512

00:22:39,119 --> 00:22:42,989

have coming up and to talk about some of

513

00:22:41,069 --> 00:22:45,179

the science that motivates this mission

514  
00:22:42,990 --> 00:22:46,890  
so you've heard him from Arkansas and

515  
00:22:45,180 --> 00:22:48,930  
really what got me interested in

516  
00:22:46,890 --> 00:22:51,330  
astronomy to begin with was the fact

517  
00:22:48,930 --> 00:22:53,880  
that I grew up in a rural part of the

518  
00:22:51,329 --> 00:22:56,309  
country so I grew up in a tiny little

519  
00:22:53,880 --> 00:22:59,040  
town called B Branch Arkansas which I'm

520  
00:22:56,309 --> 00:23:01,319  
almost guaranteeing nobody in this

521  
00:22:59,039 --> 00:23:03,960  
audience has heard of middle of nowhere

522  
00:23:01,319 --> 00:23:07,769  
North Central Arkansas not a lot to do

523  
00:23:03,960 --> 00:23:09,779  
but the sky was beautiful so I grew up

524  
00:23:07,769 --> 00:23:11,759  
under this rule dark sky and that's

525  
00:23:09,779 --> 00:23:13,980  
really what got me interested in the

526  
00:23:11,759 --> 00:23:17,640  
stars from the time I was a little kid

527  
00:23:13,980 --> 00:23:20,759  
and since that time when I was a kid I

528  
00:23:17,640 --> 00:23:22,590  
decided to I was asking all these

529  
00:23:20,759 --> 00:23:24,359  
questions about the universe and decided

530  
00:23:22,589 --> 00:23:26,909  
from a very young age that I wanted to

531  
00:23:24,359 --> 00:23:28,889  
pursue that dream to find out what was

532  
00:23:26,910 --> 00:23:31,140  
out there what was beyond what you can

533  
00:23:28,890 --> 00:23:33,120  
see with your eyes and from the time I

534  
00:23:31,140 --> 00:23:35,970  
was a kid one of the thing this really

535  
00:23:33,119 --> 00:23:38,519  
has captivated me about astronomy in

536  
00:23:35,970 --> 00:23:41,400  
general is that astronomy gets to the

537  
00:23:38,519 --> 00:23:43,470  
heart of our big questions and these

538  
00:23:41,400 --> 00:23:45,660  
aren't just questions that scientists

539  
00:23:43,470 --> 00:23:47,309  
ask these are questions that human

540  
00:23:45,660 --> 00:23:50,250  
beings ask these are questions that

541  
00:23:47,309 --> 00:23:52,109  
we've asked over a millennia they get to

542

00:23:50,250 --> 00:23:54,509  
the heart of what it means to be a human

543  
00:23:52,109 --> 00:23:57,449  
being of how do we get here

544  
00:23:54,509 --> 00:23:59,250  
and what's the universe like and then

545  
00:23:57,450 --> 00:24:01,140  
that big question that we're still

546  
00:23:59,250 --> 00:24:04,680  
trying to answer which is are we alone

547  
00:24:01,140 --> 00:24:07,110  
and so many of our fundamental questions

548  
00:24:04,680 --> 00:24:10,200  
about the universe have been answered

549  
00:24:07,109 --> 00:24:12,599  
over the past many decades by telescopes

550  
00:24:10,200 --> 00:24:14,400  
so we're able to learn a lot about the

551  
00:24:12,599 --> 00:24:17,480  
universe just from looking at the sky

552  
00:24:14,400 --> 00:24:20,580  
our ancestors of course learned about

553  
00:24:17,480 --> 00:24:23,970  
about time we measure time by the way

554  
00:24:20,579 --> 00:24:26,409  
stars pass in the sky we learned you

555  
00:24:23,970 --> 00:24:27,850  
know many centuries ago that

556  
00:24:26,410 --> 00:24:29,590

there were certain objects in the night

557

00:24:27,849 --> 00:24:31,240

sky that moved a little bit differently

558

00:24:29,589 --> 00:24:33,309

than most of the stars did and those

559

00:24:31,240 --> 00:24:37,599

occur of course turned out to be planets

560

00:24:33,309 --> 00:24:39,069

and so for for centuries for millennia

561

00:24:37,599 --> 00:24:41,409

even people have been looking at the sky

562

00:24:39,069 --> 00:24:43,029

and figuring out how the world works

563

00:24:41,410 --> 00:24:45,310

just from looking at the sky with your

564

00:24:43,029 --> 00:24:46,960

eyes but of course there comes a limit

565

00:24:45,309 --> 00:24:49,569

to what you can learn from looking at

566

00:24:46,960 --> 00:24:51,759

the sky with your eyeballs and so we

567

00:24:49,569 --> 00:24:54,099

build telescopes to help us build on

568

00:24:51,759 --> 00:24:56,109

that knowledge and as an astronomer I've

569

00:24:54,099 --> 00:24:57,759

been really fortunate to observe at some

570

00:24:56,109 --> 00:25:00,339

of the world's biggest telescopes on the



571  
00:24:57,759 --> 00:25:03,190  
ground telescopes in Hawaii and Chile

572  
00:25:00,339 --> 00:25:05,649  
but there does also come a limit to what

573  
00:25:03,190 --> 00:25:08,080  
we can learn from telescopes on the

574  
00:25:05,650 --> 00:25:10,150  
ground just from the simple fact the

575  
00:25:08,079 --> 00:25:12,279  
telescopes on the earth have to look

576  
00:25:10,150 --> 00:25:14,350  
through the atmosphere and so what do we

577  
00:25:12,279 --> 00:25:17,079  
do of course we put telescopes into

578  
00:25:14,349 --> 00:25:19,119  
space and the Hubble Space Telescope has

579  
00:25:17,079 --> 00:25:21,220  
been one of the I believe one of the

580  
00:25:19,119 --> 00:25:23,019  
most critical scientific instruments

581  
00:25:21,220 --> 00:25:26,650  
that human beings have ever built so

582  
00:25:23,019 --> 00:25:28,240  
Hubble has completely transformed our

583  
00:25:26,650 --> 00:25:30,730  
understanding of the universe in

584  
00:25:28,240 --> 00:25:33,130  
fundamental ways starting with the

585  
00:25:30,730 --> 00:25:34,779  
nearby universe of our solar system and

586  
00:25:33,130 --> 00:25:36,910  
then reaching out to the most distant

587  
00:25:34,779 --> 00:25:39,579  
things that we can see in the faraway

588  
00:25:36,910 --> 00:25:41,470  
universe and so I'm here tonight to talk

589  
00:25:39,579 --> 00:25:43,359  
to you a little bit about some of the

590  
00:25:41,470 --> 00:25:46,420  
unknown things in the universe dark

591  
00:25:43,359 --> 00:25:48,849  
energy and alien worlds some of these

592  
00:25:46,420 --> 00:25:51,700  
big questions that we have but I wanted

593  
00:25:48,849 --> 00:25:54,699  
to start off by talking a little bit to

594  
00:25:51,700 --> 00:25:57,130  
preface this this unknown stuff with a

595  
00:25:54,700 --> 00:25:59,319  
little bit of what we do know and how

596  
00:25:57,130 --> 00:26:01,630  
we've learned that and the Hubble Space

597  
00:25:59,319 --> 00:26:04,119  
Telescope has been instrumental in

598  
00:26:01,630 --> 00:26:06,400  
helping us learn about what our universe

599

00:26:04,119 --> 00:26:08,349  
is like and so starting in our own

600  
00:26:06,400 --> 00:26:10,870  
cosmic backyard of the solar system

601  
00:26:08,349 --> 00:26:12,730  
Hubble has taught us many many things

602  
00:26:10,869 --> 00:26:15,459  
about our own solar system including

603  
00:26:12,730 --> 00:26:17,400  
this beautiful composite image showing

604  
00:26:15,460 --> 00:26:21,160  
Aurora on Saturn

605  
00:26:17,400 --> 00:26:23,259  
NASA of course also launches satellites

606  
00:26:21,160 --> 00:26:25,390  
that go out and visit these distant

607  
00:26:23,259 --> 00:26:27,309  
worlds in our solar system so this is an

608  
00:26:25,390 --> 00:26:29,440  
image from NASA's Cassini telescope

609  
00:26:27,309 --> 00:26:31,869  
which in just a few months will have its

610  
00:26:29,440 --> 00:26:34,259  
grand finale as it actually crashes into

611  
00:26:31,869 --> 00:26:37,269  
the planet so be sure and check that out

612  
00:26:34,259 --> 00:26:39,129  
one of the great things that Cassini has

613  
00:26:37,269 --> 00:26:39,778

given us I believe in addition to all

614

00:26:39,130 --> 00:26:43,019  
this in

615

00:26:39,778 --> 00:26:46,138  
animal science is just a perspective of

616

00:26:43,019 --> 00:26:47,788  
us of us humans and this is something

617

00:26:46,138 --> 00:26:49,949  
that again goes back to those big

618

00:26:47,788 --> 00:26:51,658  
questions that astronomy gets to you

619

00:26:49,950 --> 00:26:54,090  
about telling us about our place in the

620

00:26:51,659 --> 00:26:56,778  
universe and so this is an image from

621

00:26:54,089 --> 00:26:59,908  
Cassini from beyond the orbit of Saturn

622

00:26:56,778 --> 00:27:02,669  
looking back and that little tiny dot is

623

00:26:59,909 --> 00:27:04,440  
us that's everyone you've ever known in

624

00:27:02,669 --> 00:27:06,599  
that little tiny blue dot and of course

625

00:27:04,440 --> 00:27:10,139  
this was the blue dot the cross Sagan

626

00:27:06,598 --> 00:27:12,868  
talked about and and so much back in in

627

00:27:10,138 --> 00:27:16,079  
the early days and in popularized

628  
00:27:12,868 --> 00:27:18,238  
astronomy in such a such a unique way I

629  
00:27:16,079 --> 00:27:20,489  
have such a fond spot in my heart for

630  
00:27:18,239 --> 00:27:23,338  
Carl Sagan and all the great outreach

631  
00:27:20,489 --> 00:27:25,829  
that he did but missions like Cassini

632  
00:27:23,338 --> 00:27:29,579  
have given us this have given us this

633  
00:27:25,829 --> 00:27:31,648  
grand view of what we are and help to to

634  
00:27:29,579 --> 00:27:33,989  
probe those big questions of our place

635  
00:27:31,648 --> 00:27:36,898  
in the universe and then very recently

636  
00:27:33,989 --> 00:27:40,139  
NASA's Juno spacecraft has been sending

637  
00:27:36,898 --> 00:27:43,709  
back these absolutely incredible images

638  
00:27:40,138 --> 00:27:46,378  
of our planet Jupiter that sort of go

639  
00:27:43,710 --> 00:27:48,869  
beyond science and even get into art

640  
00:27:46,378 --> 00:27:51,478  
this could be a piece of art in a museum

641  
00:27:48,868 --> 00:27:54,358  
and then of course just a couple of

642  
00:27:51,479 --> 00:27:58,080  
years ago we all remember the excitement

643  
00:27:54,358 --> 00:28:01,199  
of NASA's new Horizons mission reaching

644  
00:27:58,079 --> 00:28:03,658  
Pluto and reeling this heart on Pluto

645  
00:28:01,200 --> 00:28:06,509  
and revealing the structure of this

646  
00:28:03,659 --> 00:28:09,239  
outer planet dwarf planet that we'd

647  
00:28:06,509 --> 00:28:11,249  
never seen before and so all of these

648  
00:28:09,239 --> 00:28:13,409  
missions have helped to help us learn

649  
00:28:11,249 --> 00:28:14,399  
more about our solar system and they're

650  
00:28:13,409 --> 00:28:16,469  
returning to Hubble

651  
00:28:14,398 --> 00:28:19,228  
of course branching out from the solar

652  
00:28:16,469 --> 00:28:21,960  
system more distant from Hubble we've

653  
00:28:19,229 --> 00:28:23,999  
been able to observe star forming

654  
00:28:21,960 --> 00:28:26,608  
regions within our own galaxy so this is

655  
00:28:23,999 --> 00:28:29,489  
the Carina Nebula and this curve this

656

00:28:26,608 --> 00:28:31,769  
image gives us an overall view of star

657  
00:28:29,489 --> 00:28:33,210  
formation so lots of new stars are

658  
00:28:31,769 --> 00:28:35,579  
forming in this part of the universe and

659  
00:28:33,210 --> 00:28:38,129  
stars are also dying in this part of the

660  
00:28:35,579 --> 00:28:39,739  
universe there's this giant star here

661  
00:28:38,128 --> 00:28:42,148  
that's probably about to go supernova

662  
00:28:39,739 --> 00:28:43,649  
literally any day or it might be a

663  
00:28:42,148 --> 00:28:45,028  
thousand years but you know it's a tiny

664  
00:28:43,648 --> 00:28:48,688  
span of time

665  
00:28:45,028 --> 00:28:50,249  
in astronomical sense and then stars of

666  
00:28:48,689 --> 00:28:53,278  
course after they're born they have

667  
00:28:50,249 --> 00:28:55,139  
winds that shed out the dust in the gas

668  
00:28:53,278 --> 00:28:58,019  
and stars shine forth and these

669  
00:28:55,138 --> 00:28:59,519  
beautiful giant clusters this is the

670  
00:28:58,019 --> 00:29:00,659

image that came from the 25th

671

00:28:59,519 --> 00:29:03,269  
anniversary of the Hubble Space

672

00:29:00,659 --> 00:29:05,699  
Telescope just a couple years ago and

673

00:29:03,269 --> 00:29:07,318  
then we all know that stars when they

674

00:29:05,699 --> 00:29:09,509  
live out their lives they often go

675

00:29:07,318 --> 00:29:11,788  
through these violent deaths these

676

00:29:09,509 --> 00:29:13,919  
explosions that can be either very

677

00:29:11,788 --> 00:29:15,929  
dramatic like the Crab Nebula that you

678

00:29:13,919 --> 00:29:18,778  
saw in the introduction or can be more

679

00:29:15,929 --> 00:29:20,819  
gentle and sort of the Stars blow out

680

00:29:18,778 --> 00:29:23,548  
their atmospheres like this example of

681

00:29:20,818 --> 00:29:26,848  
the butterfly nebula and so we know that

682

00:29:23,548 --> 00:29:29,128  
our Sun well someday undergo a similar

683

00:29:26,848 --> 00:29:31,698  
process like this where it will shed its

684

00:29:29,128 --> 00:29:34,528  
outer layers it'll grow into a red giant



685  
00:29:31,699 --> 00:29:37,048  
little and virtually engulf the earth

686  
00:29:34,528 --> 00:29:38,429  
now this will be several billion years

687  
00:29:37,048 --> 00:29:39,028  
from now so we don't have to worry about

688  
00:29:38,429 --> 00:29:41,639  
that

689  
00:29:39,028 --> 00:29:44,429  
but I love the fact that these beautiful

690  
00:29:41,638 --> 00:29:46,618  
images from Hubble really tell us

691  
00:29:44,429 --> 00:29:49,709  
something about our origins

692  
00:29:46,618 --> 00:29:52,259  
so these stellar explosions like

693  
00:29:49,709 --> 00:29:55,259  
supernovae are the very events that

694  
00:29:52,259 --> 00:29:58,219  
seeded the universe with the elements

695  
00:29:55,259 --> 00:30:01,558  
that would eventually become planets and

696  
00:29:58,219 --> 00:30:03,209  
eventually become life so the iron in

697  
00:30:01,558 --> 00:30:05,699  
your blood and the calcium in your bones

698  
00:30:03,209 --> 00:30:09,869  
was literally forged inside of a star

699  
00:30:05,699 --> 00:30:12,419  
that exploded in a supernova and so what

700  
00:30:09,868 --> 00:30:15,178  
these images really show us is our sort

701  
00:30:12,419 --> 00:30:17,999  
of cosmic connection to the universe and

702  
00:30:15,179 --> 00:30:20,038  
that's one of the things I love this is

703  
00:30:17,999 --> 00:30:22,798  
an image of also with still within our

704  
00:30:20,038 --> 00:30:25,318  
own galaxy of a star that under

705  
00:30:22,798 --> 00:30:26,999  
underwent this really complex confusing

706  
00:30:25,318 --> 00:30:28,739  
event we still don't really know what's

707  
00:30:26,999 --> 00:30:30,989  
going on with this star but it's

708  
00:30:28,739 --> 00:30:33,449  
shedding its layers or it's blowing a

709  
00:30:30,989 --> 00:30:35,759  
wind out into the surroundings so many

710  
00:30:33,449 --> 00:30:38,729  
mysteries out there still and then

711  
00:30:35,759 --> 00:30:40,409  
beyond our own Milky Way galaxy we now

712  
00:30:38,729 --> 00:30:43,709  
of course know that there are many other

713

00:30:40,409 --> 00:30:45,509  
galaxies so this is a nearby galaxy if

714  
00:30:43,709 --> 00:30:47,459  
you could get outside of our Milky Way

715  
00:30:45,509 --> 00:30:50,068  
and could look back on it our Milky Way

716  
00:30:47,459 --> 00:30:52,019  
would look probably a lot like this we

717  
00:30:50,068 --> 00:30:54,658  
think our millions with other galaxies

718  
00:30:52,019 --> 00:30:56,368  
so they merge with other galaxies in my

719  
00:30:54,659 --> 00:30:57,180  
own research I studied galaxy evolution

720  
00:30:56,368 --> 00:30:58,949  
for

721  
00:30:57,180 --> 00:31:01,590  
I'm interested in how galaxies change

722  
00:30:58,950 --> 00:31:03,900  
over time how their stars in their black

723  
00:31:01,589 --> 00:31:06,089  
holes for him and we think this process

724  
00:31:03,900 --> 00:31:09,180  
of galaxy collisions is a really key

725  
00:31:06,089 --> 00:31:11,809  
part of how all of that takes place of

726  
00:31:09,180 --> 00:31:14,850  
how black holes grow and we think that

727  
00:31:11,809 --> 00:31:16,829

there's also gas in the universe that

728

00:31:14,849 --> 00:31:19,139

feeds into galaxies that help black

729

00:31:16,829 --> 00:31:21,269

holes grow over time a lot about this

730

00:31:19,140 --> 00:31:23,070

process that we don't understand but we

731

00:31:21,269 --> 00:31:25,109

think that galaxy mergers play a key

732

00:31:23,069 --> 00:31:29,220

part in the overall evolution of

733

00:31:25,109 --> 00:31:30,959

galaxies over time and then of all the

734

00:31:29,220 --> 00:31:33,180

beautiful images that Hubble has given

735

00:31:30,960 --> 00:31:35,910

us over the past 27 years now that

736

00:31:33,180 --> 00:31:37,529

Hubble's been in space if I had to pick

737

00:31:35,910 --> 00:31:40,769

my absolute favorite when this would be

738

00:31:37,529 --> 00:31:42,509

it so this is the Hubble Ultra Deep

739

00:31:40,769 --> 00:31:44,250

Field this happened to come out when I

740

00:31:42,509 --> 00:31:46,559

was in graduate school so this is one of

741

00:31:44,250 --> 00:31:48,240

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

742  
00:31:46,559 --> 00:31:50,849  
lot of my dissertation research on this

743  
00:31:48,240 --> 00:31:53,880  
image but this particular version of

744  
00:31:50,849 --> 00:31:55,949  
this image was about 11 days total the

745  
00:31:53,880 --> 00:31:58,470  
Hubble stared into space and in this

746  
00:31:55,950 --> 00:32:00,930  
image Hubble's looking at a tiny tiny

747  
00:31:58,470 --> 00:32:03,480  
little piece of sky so it's like looking

748  
00:32:00,930 --> 00:32:04,920  
at the universe through a straw if you

749  
00:32:03,480 --> 00:32:06,930  
found out your pinky finger you could

750  
00:32:04,920 --> 00:32:09,720  
cover up this teeny tiny little patch of

751  
00:32:06,930 --> 00:32:12,210  
sky and every point of light you see in

752  
00:32:09,720 --> 00:32:14,970  
this image is an individual galaxy

753  
00:32:12,210 --> 00:32:18,480  
itself filled with hundreds of billions

754  
00:32:14,970 --> 00:32:21,569  
of other stars and so really what Hubble

755  
00:32:18,480 --> 00:32:25,380  
has given us in a fundamental sense is

756  
00:32:21,569 --> 00:32:27,960  
the size of the universe these deep

757  
00:32:25,380 --> 00:32:30,300  
images with Hubble were revolutionary

758  
00:32:27,960 --> 00:32:33,269  
and they told us that the universe is

759  
00:32:30,299 --> 00:32:36,149  
filled with hundreds of billions of

760  
00:32:33,269 --> 00:32:39,000  
other galaxies and all those galaxies

761  
00:32:36,150 --> 00:32:40,590  
with hundreds of billions of stars now

762  
00:32:39,000 --> 00:32:44,130  
in addition to just being a beautiful

763  
00:32:40,589 --> 00:32:47,659  
image we're able to take spectra of

764  
00:32:44,130 --> 00:32:50,130  
these galaxies to take the chemical

765  
00:32:47,660 --> 00:32:52,590  
fingerprints of the galaxies and learn

766  
00:32:50,130 --> 00:32:53,970  
about their distances and so when we

767  
00:32:52,589 --> 00:32:56,879  
learn about the distances we can

768  
00:32:53,970 --> 00:32:59,460  
actually make these images sort of 3d we

769  
00:32:56,880 --> 00:33:01,350  
assign distances to them and so we can

770

00:32:59,460 --> 00:33:03,660  
sort of fly through the images in a

771  
00:33:01,349 --> 00:33:06,750  
sense to get a bit of a sense of scale

772  
00:33:03,660 --> 00:33:10,830  
in a sense of distance for these these

773  
00:33:06,750 --> 00:33:13,200  
images so in the Hubble Ultra Deep Field

774  
00:33:10,829 --> 00:33:15,808  
again you notice a lot of interesting

775  
00:33:13,200 --> 00:33:18,179  
things so you notice as we go deeper

776  
00:33:15,808 --> 00:33:20,759  
into the universe that galaxy's changed

777  
00:33:18,179 --> 00:33:23,278  
they start to look different nearby

778  
00:33:20,759 --> 00:33:25,019  
galaxies look sort of similar to our

779  
00:33:23,278 --> 00:33:27,179  
Milky Way a lot of them they have spiral

780  
00:33:25,019 --> 00:33:29,970  
arms they're very large they have

781  
00:33:27,179 --> 00:33:32,190  
organized structure but if you get into

782  
00:33:29,970 --> 00:33:33,980  
the deeper universe the more distant

783  
00:33:32,190 --> 00:33:36,538  
universe you see a different picture

784  
00:33:33,980 --> 00:33:38,399

galaxies are less well formed they're

785

00:33:36,538 --> 00:33:41,278

smaller they're clumpy they're different

786

00:33:38,398 --> 00:33:45,089

and so learning about how galaxies

787

00:33:41,278 --> 00:33:48,329

change over the course of the last 13.8

788

00:33:45,089 --> 00:33:50,308

billion years of cosmic history is still

789

00:33:48,329 --> 00:33:51,928

a really important part of astronomy

790

00:33:50,308 --> 00:33:54,178

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

791

00:33:51,929 --> 00:33:56,429

process that we're still really to push

792

00:33:54,179 --> 00:33:59,519

further so as much as we've learned

793

00:33:56,429 --> 00:34:01,440

about the universe since we've put

794

00:33:59,519 --> 00:34:03,240

Hubble into space since we've started

795

00:34:01,440 --> 00:34:05,700

building telescopes on the ground

796

00:34:03,240 --> 00:34:09,690

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

797

00:34:05,700 --> 00:34:12,179

know and of all of these galaxies of

798

00:34:09,690 --> 00:34:14,190

hundreds of billions of galaxies that we



799  
00:34:12,179 --> 00:34:18,030  
found filled with hundreds of billions

800  
00:34:14,190 --> 00:34:20,220  
of stars all of those galaxies all of

801  
00:34:18,030 --> 00:34:23,010  
those stars what we know now are

802  
00:34:20,219 --> 00:34:26,449  
probably trillions of planets every

803  
00:34:23,010 --> 00:34:31,099  
person everything that you've ever known

804  
00:34:26,449 --> 00:34:36,299  
still all of that only makes up about 5%

805  
00:34:31,099 --> 00:34:39,000  
of everything in the universe and the

806  
00:34:36,300 --> 00:34:41,010  
rest of that is when I want to spend the

807  
00:34:39,000 --> 00:34:44,309  
rest of my time tonight talking to you

808  
00:34:41,010 --> 00:34:47,760  
about so going back to that previous pie

809  
00:34:44,309 --> 00:34:53,190  
chart so the 5% that we know about the

810  
00:34:47,760 --> 00:34:55,730  
galaxies the stars the planets that's

811  
00:34:53,190 --> 00:35:00,170  
what we know about so look now at the

812  
00:34:55,730 --> 00:35:05,429  
27% that is dark matter so dark matter

813  
00:35:00,170 --> 00:35:07,380  
what is it we have no idea but this

814  
00:35:05,429 --> 00:35:10,409  
poses a really really interesting

815  
00:35:07,380 --> 00:35:13,680  
question to us as astronomers so we

816  
00:35:10,409 --> 00:35:17,098  
don't know what it is so how do we know

817  
00:35:13,679 --> 00:35:20,549  
that it actually exists so we have a few

818  
00:35:17,099 --> 00:35:22,950  
clues the first thing is by looking at

819  
00:35:20,550 --> 00:35:24,390  
spiral galaxies so you take a spiral

820  
00:35:22,949 --> 00:35:26,389  
galaxy like this

821  
00:35:24,389 --> 00:35:31,039  
and it looks like it's spinning right

822  
00:35:26,389 --> 00:35:35,190  
that's because it is so back decades ago

823  
00:35:31,039 --> 00:35:38,219  
astronomers looked at the motions of

824  
00:35:35,190 --> 00:35:40,260  
stars and spiral galaxies Vera Rubin was

825  
00:35:38,219 --> 00:35:42,599  
actually one of the pioneers of this an

826  
00:35:40,260 --> 00:35:46,830  
astronomer astronomer who did this work

827

00:35:42,599 --> 00:35:49,139  
back in this 1960s 1970s and what you

828  
00:35:46,829 --> 00:35:52,219  
expect to see in spiral galaxies is that

829  
00:35:49,139 --> 00:35:55,409  
as you get out further from the center

830  
00:35:52,219 --> 00:35:58,019  
you would expect the speeds of these

831  
00:35:55,409 --> 00:35:59,819  
stars in the matter to be slowing down

832  
00:35:58,019 --> 00:36:02,849  
that's what Kepler's second law tell us

833  
00:35:59,820 --> 00:36:05,760  
should that should happen but that's not

834  
00:36:02,849 --> 00:36:08,880  
what we see so all of these motions

835  
00:36:05,760 --> 00:36:11,850  
depend on mass depend on the mass that

836  
00:36:08,880 --> 00:36:15,480  
exists from the center out to the stars

837  
00:36:11,849 --> 00:36:17,400  
and so when we studied the motions and

838  
00:36:15,480 --> 00:36:19,980  
outer parts of these galaxies even out

839  
00:36:17,400 --> 00:36:22,710  
further than what we could see what we

840  
00:36:19,980 --> 00:36:25,199  
found is that there should be more mass

841  
00:36:22,710 --> 00:36:27,570

there than what we're seeing there's

842

00:36:25,199 --> 00:36:31,049

something there that's causing the stars

843

00:36:27,570 --> 00:36:33,450

to move faster in the outskirts can't

844

00:36:31,050 --> 00:36:35,580

see it at all and we know it's not gas

845

00:36:33,449 --> 00:36:38,669

because we can detect gas in other ways

846

00:36:35,579 --> 00:36:40,739

so not gas not stars something hidden in

847

00:36:38,670 --> 00:36:43,320

these galaxies they're causing them to

848

00:36:40,739 --> 00:36:47,179

move in ways that are unexpected the

849

00:36:43,320 --> 00:36:50,010

second big clue came in galaxy clusters

850

00:36:47,179 --> 00:36:54,000

so galaxy clusters are also a really

851

00:36:50,010 --> 00:36:56,190

good way to measure mass so we can look

852

00:36:54,000 --> 00:36:58,559

at individual galaxies and clusters and

853

00:36:56,190 --> 00:37:00,869

measure their speeds fairly easily in

854

00:36:58,559 --> 00:37:02,820

fact and when we look at galaxies

855

00:37:00,869 --> 00:37:05,279

galaxies and clusters we find that

856  
00:37:02,820 --> 00:37:08,970  
they're moving way faster than they

857  
00:37:05,280 --> 00:37:11,850  
should be so if it was only the galaxies

858  
00:37:08,969 --> 00:37:14,309  
only the stars then these clusters

859  
00:37:11,849 --> 00:37:17,579  
should have blown themselves apart you

860  
00:37:14,309 --> 00:37:19,650  
know millions of years ago but galaxy

861  
00:37:17,579 --> 00:37:20,969  
clusters stay together so there's

862  
00:37:19,650 --> 00:37:25,139  
something there that we're not seeing

863  
00:37:20,969 --> 00:37:28,589  
and in addition in these galaxy clusters

864  
00:37:25,139 --> 00:37:30,420  
we've also Frank has already pointed out

865  
00:37:28,590 --> 00:37:32,280  
a little bit about gravitational lensing

866  
00:37:30,420 --> 00:37:37,059  
so what's going on there

867  
00:37:32,280 --> 00:37:40,929  
so we have this big mass of galaxies

868  
00:37:37,059 --> 00:37:43,449  
and gasps and then beyond that we have

869  
00:37:40,929 --> 00:37:47,318  
background galaxies and then over here

870  
00:37:43,449 --> 00:37:50,318  
we have our telescopes so what's going

871  
00:37:47,318 --> 00:37:52,268  
on with gravitational lensing is that

872  
00:37:50,318 --> 00:37:55,768  
we're essentially seeing the background

873  
00:37:52,268 --> 00:37:58,498  
galaxies being lynched by the mass

874  
00:37:55,768 --> 00:38:01,358  
that's in between them

875  
00:37:58,498 --> 00:38:02,768  
so this is what theory tells us we

876  
00:38:01,358 --> 00:38:04,449  
should see if there's a lot of matter

877  
00:38:02,768 --> 00:38:06,788  
out there or dark matter that's hidden

878  
00:38:04,449 --> 00:38:08,438  
that we can't see and of course this is

879  
00:38:06,789 --> 00:38:10,659  
what we see when we take these Hubble

880  
00:38:08,438 --> 00:38:13,028  
images so in these Hubble images of

881  
00:38:10,659 --> 00:38:15,068  
galaxy clusters you see all these little

882  
00:38:13,028 --> 00:38:16,568  
blue arcs in addition to the bright

883  
00:38:15,068 --> 00:38:18,699  
yellow galaxies

884

00:38:16,568 --> 00:38:21,068  
you see these background galaxies that

885  
00:38:18,699 --> 00:38:24,130  
have been stretched and lens so this is

886  
00:38:21,068 --> 00:38:27,278  
a smoking gun for dark matter that

887  
00:38:24,130 --> 00:38:29,979  
exists in these galaxy clusters this is

888  
00:38:27,278 --> 00:38:32,018  
a very famous galaxy cluster image

889  
00:38:29,978 --> 00:38:33,908  
called the bullet cluster this is

890  
00:38:32,018 --> 00:38:37,149  
actually two galaxy clusters that are

891  
00:38:33,909 --> 00:38:39,219  
crashing together and so what you see

892  
00:38:37,150 --> 00:38:42,159  
here again all this sort of yellow

893  
00:38:39,219 --> 00:38:45,429  
orange structures here are individual

894  
00:38:42,159 --> 00:38:49,179  
galaxies the red the pink and the blue

895  
00:38:45,429 --> 00:38:52,059  
here represents gas in the galaxies that

896  
00:38:49,179 --> 00:38:54,429  
were able to image in x-rays and so

897  
00:38:52,059 --> 00:38:57,309  
these two galaxy clusters are crashing

898  
00:38:54,429 --> 00:39:00,429

together and we're able to again look at

899

00:38:57,309 --> 00:39:03,249

its sources behind the clusters and what

900

00:39:00,429 --> 00:39:05,739

these images tell us is that all the

901

00:39:03,248 --> 00:39:08,288

dark matter is centered on the galaxies

902

00:39:05,739 --> 00:39:10,630

and not on the gas so another third sort

903

00:39:08,289 --> 00:39:15,099

of independent clue the Dark Matter

904

00:39:10,630 --> 00:39:17,079

exists in these clusters so we have all

905

00:39:15,099 --> 00:39:19,140

these different independent lines of

906

00:39:17,079 --> 00:39:23,048

evidence that dark matter is out there

907

00:39:19,139 --> 00:39:25,989

and so we have another a third way that

908

00:39:23,048 --> 00:39:28,478

were able to to learn about dark matter

909

00:39:25,989 --> 00:39:31,150

by looking how basically how galaxies

910

00:39:28,478 --> 00:39:34,538

are distributed across the universe and

911

00:39:31,150 --> 00:39:36,969

so just and similarly we're able to to

912

00:39:34,539 --> 00:39:39,549

look at to map out galaxies at different



913  
00:39:36,969 --> 00:39:42,639  
distances and measure their properties

914  
00:39:39,548 --> 00:39:44,858  
and those properties tell us again that

915  
00:39:42,639 --> 00:39:46,958  
there's mass out there that these

916  
00:39:44,858 --> 00:39:48,400  
galaxies are moving in ways that

917  
00:39:46,958 --> 00:39:49,539  
indicate that there's matter out there

918  
00:39:48,400 --> 00:39:51,610  
that exists

919  
00:39:49,539 --> 00:39:55,239  
that we can't see so we don't know what

920  
00:39:51,610 --> 00:39:59,370  
it is we have a better idea of what it's

921  
00:39:55,239 --> 00:40:04,839  
not so we know that it's probably not

922  
00:39:59,369 --> 00:40:06,339  
regular stars or gas or planets because

923  
00:40:04,840 --> 00:40:08,050  
we would be able to see those things

924  
00:40:06,340 --> 00:40:10,329  
we'd be able to see stars that are

925  
00:40:08,050 --> 00:40:13,900  
bright enough dim stars okay we might

926  
00:40:10,329 --> 00:40:16,329  
not see the dim stars gas we can see

927  
00:40:13,900 --> 00:40:20,200  
from the way the Stars are lighting up

928  
00:40:16,329 --> 00:40:22,719  
the gas but really ordinary matter

929  
00:40:20,199 --> 00:40:25,179  
baryons neutrons protons and electrons

930  
00:40:22,719 --> 00:40:27,789  
we would be able to see them in some way

931  
00:40:25,179 --> 00:40:30,159  
and we can't so we really don't think

932  
00:40:27,789 --> 00:40:33,489  
it's any of these things now it might be

933  
00:40:30,159 --> 00:40:35,139  
some very very dim stars but if those

934  
00:40:33,489 --> 00:40:37,989  
stars exist they would only be a tiny

935  
00:40:35,139 --> 00:40:40,869  
tiny fraction of what we think has to be

936  
00:40:37,989 --> 00:40:44,079  
to make up this dark matter population

937  
00:40:40,869 --> 00:40:46,839  
so we don't think it's regular stuff we

938  
00:40:44,079 --> 00:40:48,759  
don't really think it's antimatter so we

939  
00:40:46,840 --> 00:40:50,559  
know antimatter would annihilate with

940  
00:40:48,760 --> 00:40:52,030  
regular matter and produce gamma-ray

941

00:40:50,559 --> 00:40:54,130  
signals that we would be able to detect

942  
00:40:52,030 --> 00:40:56,110  
we have gamma-ray telescopes that would

943  
00:40:54,130 --> 00:40:57,940  
be able to see that so we don't think

944  
00:40:56,110 --> 00:40:59,620  
it's an a' matter we don't really think

945  
00:40:57,940 --> 00:41:01,539  
it's giant black hole sort of for the

946  
00:40:59,619 --> 00:41:04,480  
same reasons because we would be able to

947  
00:41:01,539 --> 00:41:06,610  
see those observational EC signatures of

948  
00:41:04,480 --> 00:41:10,150  
the black holes in other ways we don't

949  
00:41:06,610 --> 00:41:13,030  
really see them so what is it well again

950  
00:41:10,150 --> 00:41:16,990  
we don't know but we think what it

951  
00:41:13,030 --> 00:41:19,990  
likely is is some sort of yet

952  
00:41:16,989 --> 00:41:22,149  
undiscovered elementary particle that

953  
00:41:19,989 --> 00:41:25,029  
really doesn't interact with radiation

954  
00:41:22,150 --> 00:41:27,130  
in the same way that normal matter is so

955  
00:41:25,030 --> 00:41:30,100

that's what we think it is but again we

956

00:41:27,130 --> 00:41:31,900

don't know all right that's dark matter

957

00:41:30,099 --> 00:41:35,440

not very satisfying right we don't know

958

00:41:31,900 --> 00:41:39,880

what it is okay dark energy so almost

959

00:41:35,440 --> 00:41:43,980

70% of the whole universe is made up of

960

00:41:39,880 --> 00:41:47,500

dark energy so what is it any guesses

961

00:41:43,980 --> 00:41:52,349

yeah we really have no idea what dark

962

00:41:47,500 --> 00:41:56,559

energy is but similarly to dark matter

963

00:41:52,349 --> 00:42:00,369

we know that it exists and the really

964

00:41:56,559 --> 00:42:01,889

strange thing about dark energy is that

965

00:42:00,369 --> 00:42:04,079

it's completely gone

966

00:42:01,889 --> 00:42:07,170

founding our ideas about how gravity

967

00:42:04,079 --> 00:42:09,869

works so spaceball sees any baseball

968

00:42:07,170 --> 00:42:13,559

fans out there Orioles fans yeah I would

969

00:42:09,869 --> 00:42:14,549

hope so okay so you have a baseball you

970  
00:42:13,559 --> 00:42:16,469  
throw it up in the air what do you

971  
00:42:14,550 --> 00:42:17,130  
expect to happen he comes back down

972  
00:42:16,469 --> 00:42:18,779  
right

973  
00:42:17,130 --> 00:42:22,320  
that's our everyday experience of

974  
00:42:18,780 --> 00:42:25,740  
gravity that's how gravity works what

975  
00:42:22,320 --> 00:42:29,789  
dark energy tells us is that on large

976  
00:42:25,739 --> 00:42:34,799  
large distance scales that instead of

977  
00:42:29,789 --> 00:42:36,929  
pulling the gravity pushes so we

978  
00:42:34,800 --> 00:42:40,650  
experience gravity as an attractive

979  
00:42:36,929 --> 00:42:43,409  
force and what all the physics all the

980  
00:42:40,650 --> 00:42:46,769  
theory all the observations are telling

981  
00:42:43,409 --> 00:42:50,039  
us is that at large distances gravity

982  
00:42:46,769 --> 00:42:52,860  
pushes the universe and this is

983  
00:42:50,039 --> 00:42:55,489  
completely con founding to everything

984  
00:42:52,860 --> 00:43:00,090  
that we know ok so why do we think this

985  
00:42:55,489 --> 00:43:03,089  
the first big clue actually won the

986  
00:43:00,090 --> 00:43:07,590  
Nobel Prize back almost 20 years ago now

987  
00:43:03,090 --> 00:43:10,500  
so this was looking at distant exploding

988  
00:43:07,590 --> 00:43:12,390  
stars supernovae in distant galaxies and

989  
00:43:10,500 --> 00:43:14,639  
actually an astronomer right here at the

990  
00:43:12,389 --> 00:43:16,469  
Space Telescope Science Institute dr.

991  
00:43:14,639 --> 00:43:18,900  
Adam riess was one of the Nobel Prize

992  
00:43:16,469 --> 00:43:22,739  
winners for for this really

993  
00:43:18,900 --> 00:43:25,940  
groundbreaking discovery and so what is

994  
00:43:22,739 --> 00:43:28,769  
it about supernovae so supernovae are

995  
00:43:25,940 --> 00:43:31,170  
what we call in astronomy as standard

996  
00:43:28,769 --> 00:43:33,210  
candles so they have a certain

997  
00:43:31,170 --> 00:43:38,670  
brightness you can sort of think of it

998

00:43:33,210 --> 00:43:41,369  
as a a light bulb and so the further the

999  
00:43:38,670 --> 00:43:43,260  
light bulb is away your the luminosity

1000  
00:43:41,369 --> 00:43:44,789  
or the brightness of the light bulb goes

1001  
00:43:43,260 --> 00:43:46,830  
down and that's just a very simple

1002  
00:43:44,789 --> 00:43:49,949  
physics equation you know if you have a

1003  
00:43:46,829 --> 00:43:52,739  
standard light if you measure how bright

1004  
00:43:49,949 --> 00:43:55,649  
it is you can determine how far away it

1005  
00:43:52,739 --> 00:43:59,399  
is and so that's what astronomers were

1006  
00:43:55,650 --> 00:44:03,150  
able to do with this supernovae and so

1007  
00:43:59,400 --> 00:44:05,250  
we know we've known for years since the

1008  
00:44:03,150 --> 00:44:09,840  
days of Edwin Hubble back in the 1920s

1009  
00:44:05,250 --> 00:44:11,369  
that the universe is expanding and so we

1010  
00:44:09,840 --> 00:44:13,440  
know the universe is expanding we know

1011  
00:44:11,369 --> 00:44:15,389  
galaxies are moving away from each other

1012  
00:44:13,440 --> 00:44:18,929

but if all that exists

1013

00:44:15,389 --> 00:44:21,480

the universe is gravity then we would

1014

00:44:18,929 --> 00:44:24,210

expect that the expansion would maybe be

1015

00:44:21,480 --> 00:44:26,880

slowing down maybe the constant didn't

1016

00:44:24,210 --> 00:44:29,730

really know but when when observing

1017

00:44:26,880 --> 00:44:32,309

these supernovae what we found was

1018

00:44:29,730 --> 00:44:34,289

something really interesting was that

1019

00:44:32,309 --> 00:44:36,960

that the most distant supernovae that we

1020

00:44:34,289 --> 00:44:38,549

could see were much fainter not much

1021

00:44:36,960 --> 00:44:42,510

fainter a little bit fainter than what

1022

00:44:38,548 --> 00:44:44,369

we expected and so what this told us was

1023

00:44:42,510 --> 00:44:45,839

that the more distant galaxies that we

1024

00:44:44,369 --> 00:44:48,240

were looking at with these supernovae

1025

00:44:45,838 --> 00:44:51,179

were moving away from us

1026

00:44:48,239 --> 00:44:53,489

much faster than we expected so that



1027  
00:44:51,179 --> 00:44:56,608  
means the universe is accelerating in

1028  
00:44:53,489 --> 00:44:59,098  
its expansion completely unexpected

1029  
00:44:56,608 --> 00:45:00,750  
complete surprise but the universe is

1030  
00:44:59,099 --> 00:45:04,559  
accelerating something we found out

1031  
00:45:00,750 --> 00:45:06,239  
almost two decades ago now and so again

1032  
00:45:04,559 --> 00:45:08,329  
by studying these supernovae was one of

1033  
00:45:06,239 --> 00:45:10,078  
the ways that that we found this out and

1034  
00:45:08,329 --> 00:45:13,079  
supernovae have this really great

1035  
00:45:10,079 --> 00:45:16,680  
property that they're very constant so

1036  
00:45:13,079 --> 00:45:19,109  
they get their normal stars that blow up

1037  
00:45:16,679 --> 00:45:21,389  
and they get really really bright in a

1038  
00:45:19,108 --> 00:45:23,818  
very short period of time and then their

1039  
00:45:21,389 --> 00:45:25,949  
brightness drops off and so because of

1040  
00:45:23,818 --> 00:45:27,630  
the regularity of the supernovae we're

1041  
00:45:25,949 --> 00:45:29,518  
able to study them in detail and again

1042  
00:45:27,630 --> 00:45:33,180  
determine the distances to galaxies

1043  
00:45:29,518 --> 00:45:36,419  
which is what confirmed this idea that

1044  
00:45:33,179 --> 00:45:37,768  
the galaxies the further galaxies the

1045  
00:45:36,420 --> 00:45:38,940  
most distant galaxies that we could

1046  
00:45:37,768 --> 00:45:41,449  
observe these in we're moving away

1047  
00:45:38,940 --> 00:45:43,920  
faster than we expected

1048  
00:45:41,449 --> 00:45:46,048  
so that's the first line of evidence

1049  
00:45:43,920 --> 00:45:48,000  
second line of evidence is from the

1050  
00:45:46,048 --> 00:45:50,068  
Cosmic Microwave Background which I'm

1051  
00:45:48,000 --> 00:45:51,599  
actually gonna skip because I'm running

1052  
00:45:50,068 --> 00:45:53,518  
a little short on time we can come back

1053  
00:45:51,599 --> 00:45:57,059  
and talk about it if we want but this

1054  
00:45:53,518 --> 00:45:59,788  
third way was again by making these huge

1055

00:45:57,059 --> 00:46:02,460  
maps of the nearby universe and looking

1056  
00:45:59,789 --> 00:46:05,400  
at how galaxies are distributed in space

1057  
00:46:02,460 --> 00:46:08,909  
and basically from doing this we're also

1058  
00:46:05,400 --> 00:46:10,710  
able to measure the speeds of distant

1059  
00:46:08,909 --> 00:46:15,118  
galaxies and this was sort of an

1060  
00:46:10,710 --> 00:46:17,309  
independent confirmation of how distant

1061  
00:46:15,119 --> 00:46:18,960  
galaxies removing away faster than we

1062  
00:46:17,309 --> 00:46:21,539  
thought they should have been so it's

1063  
00:46:18,960 --> 00:46:23,730  
sort of an independent way to measure

1064  
00:46:21,539 --> 00:46:25,559  
the stark energy and there are other

1065  
00:46:23,730 --> 00:46:27,599  
lines of evidence that sort of point

1066  
00:46:25,559 --> 00:46:28,339  
I'll point to this idea that there's

1067  
00:46:27,599 --> 00:46:30,318  
this

1068  
00:46:28,338 --> 00:46:32,630  
serious force in the universe that's

1069  
00:46:30,318 --> 00:46:35,088

causing it to accelerate its expansion

1070

00:46:32,630 --> 00:46:37,670

okay so we have no idea what's causing

1071

00:46:35,088 --> 00:46:40,239

this we see that it's happening we don't

1072

00:46:37,670 --> 00:46:43,759

know why we don't know what it is

1073

00:46:40,239 --> 00:46:44,269

but we have a few ideas so what could it

1074

00:46:43,759 --> 00:46:47,869

be

1075

00:46:44,268 --> 00:46:50,988

so it could be some sort of intrinsic

1076

00:46:47,869 --> 00:46:54,079

property of space-time something about

1077

00:46:50,989 --> 00:46:57,318

space itself that's causing the universe

1078

00:46:54,079 --> 00:47:01,249

to expand and so Einstein actually

1079

00:46:57,318 --> 00:47:04,278

predicted this long long ago he did it

1080

00:47:01,248 --> 00:47:07,879

calling it his biggest blunder because

1081

00:47:04,278 --> 00:47:09,139

at the time basically the the leading

1082

00:47:07,880 --> 00:47:11,028

theory was the universe wasn't

1083

00:47:09,139 --> 00:47:13,909

accelerating and now we find out that it

1084  
00:47:11,028 --> 00:47:16,728  
is so it's just some property of space

1085  
00:47:13,909 --> 00:47:18,828  
that basically says the empty space is

1086  
00:47:16,728 --> 00:47:21,649  
not really empty it's always sort of

1087  
00:47:18,829 --> 00:47:24,499  
creating new space so that's the

1088  
00:47:21,650 --> 00:47:25,088  
cosmological cosmic constant really

1089  
00:47:24,498 --> 00:47:28,338  
strange

1090  
00:47:25,088 --> 00:47:30,199  
so the second idea of what it could be

1091  
00:47:28,338 --> 00:47:34,278  
used causing this acceleration of the

1092  
00:47:30,199 --> 00:47:36,588  
universe is basically a new version of

1093  
00:47:34,278 --> 00:47:38,778  
gravity that we've got our theories of

1094  
00:47:36,588 --> 00:47:41,179  
gravity wrong and that we need to modify

1095  
00:47:38,778 --> 00:47:44,838  
then so that would say that general

1096  
00:47:41,179 --> 00:47:47,118  
relativity is not quite right on on

1097  
00:47:44,838 --> 00:47:50,268  
these scales so maybe Einstein was wrong

1098  
00:47:47,119 --> 00:47:52,640  
and then the third idea one of the

1099  
00:47:50,268 --> 00:47:56,209  
another idea is that there's really just

1100  
00:47:52,639 --> 00:47:58,038  
some kind of new energy field that we we

1101  
00:47:56,210 --> 00:48:00,380  
haven't really theorized yet we haven't

1102  
00:47:58,039 --> 00:48:02,479  
really figured out yet so there's three

1103  
00:48:00,380 --> 00:48:05,778  
these three new are these three ideas

1104  
00:48:02,478 --> 00:48:09,108  
and we really don't know people are sort

1105  
00:48:05,778 --> 00:48:10,639  
of leaning towards the cot the first the

1106  
00:48:09,108 --> 00:48:13,308  
first idea that there's this

1107  
00:48:10,639 --> 00:48:16,038  
cosmological constant but what we really

1108  
00:48:13,309 --> 00:48:19,910  
need is more data and of course that's

1109  
00:48:16,039 --> 00:48:22,219  
where the W first telescope comes in so

1110  
00:48:19,909 --> 00:48:25,159  
the W W first stands for a wide field

1111  
00:48:22,219 --> 00:48:28,579  
Infrared Survey telescope and it is

1112

00:48:25,159 --> 00:48:31,568  
specifically designed to tackle this

1113  
00:48:28,579 --> 00:48:34,670  
question it's specifically designed to

1114  
00:48:31,568 --> 00:48:37,548  
study this effect of dark energy and

1115  
00:48:34,670 --> 00:48:40,278  
also of dark matter so how is it going

1116  
00:48:37,548 --> 00:48:41,250  
to do that one of the ways it's going to

1117  
00:48:40,278 --> 00:48:45,059  
do it

1118  
00:48:41,250 --> 00:48:47,429  
is to precisely measure galaxy shapes to

1119  
00:48:45,059 --> 00:48:49,170  
infer the amount of dark matter that

1120  
00:48:47,429 --> 00:48:52,109  
exists in the universe and this goes

1121  
00:48:49,170 --> 00:48:55,829  
back to this idea of gravitational

1122  
00:48:52,110 --> 00:48:57,690  
lensing so granny galaxy that's in front

1123  
00:48:55,829 --> 00:49:00,420  
of another galaxy is going to distort

1124  
00:48:57,690 --> 00:49:02,849  
the shape of the background galaxies and

1125  
00:49:00,420 --> 00:49:05,610  
by precisely measuring those shapes

1126  
00:49:02,849 --> 00:49:08,909

we'll be able to figure out more about

1127

00:49:05,610 --> 00:49:12,510

how the the intervening dark matter

1128

00:49:08,909 --> 00:49:15,509

affects those galaxy shapes and then

1129

00:49:12,510 --> 00:49:18,090

another way is by very accurately

1130

00:49:15,510 --> 00:49:20,370

measuring the positions between galaxies

1131

00:49:18,090 --> 00:49:22,200

so it turns out that these positions

1132

00:49:20,369 --> 00:49:24,150

between the galaxies so if you think of

1133

00:49:22,199 --> 00:49:26,549

the universe in a three-dimensional

1134

00:49:24,150 --> 00:49:29,369

sense the positions that we measure

1135

00:49:26,550 --> 00:49:31,890

between the galaxies traces directly

1136

00:49:29,369 --> 00:49:34,259

back to shortly after the Big Bang and

1137

00:49:31,889 --> 00:49:39,029

to what happened in the universe early

1138

00:49:34,260 --> 00:49:41,880

on so that gets back to to the the very

1139

00:49:39,030 --> 00:49:43,890

early imprints in the universe for dark

1140

00:49:41,880 --> 00:49:45,539

energy and dark matter and all the



1141  
00:49:43,889 --> 00:49:48,269  
contents of the universe will help us

1142  
00:49:45,539 --> 00:49:51,599  
learn more about that and then getting

1143  
00:49:48,269 --> 00:49:53,699  
back to this idea of supernovae the this

1144  
00:49:51,599 --> 00:49:57,719  
telescope will allow us to take new

1145  
00:49:53,699 --> 00:49:59,159  
surveys of wider swaths of the sky that

1146  
00:49:57,719 --> 00:50:01,829  
will help us to determine more

1147  
00:49:59,159 --> 00:50:04,859  
supernovae basically - to narrow down

1148  
00:50:01,829 --> 00:50:07,710  
those measurements and to pinpoint some

1149  
00:50:04,860 --> 00:50:10,800  
of these physical quantities of the

1150  
00:50:07,710 --> 00:50:13,710  
universe that will help us to establish

1151  
00:50:10,800 --> 00:50:16,320  
better distances to these galaxies just

1152  
00:50:13,710 --> 00:50:18,030  
to hone in on these parameters that

1153  
00:50:16,320 --> 00:50:21,180  
describe the overall physics of the

1154  
00:50:18,030 --> 00:50:23,490  
universe and so we have these three

1155  
00:50:21,179 --> 00:50:25,859  
fundamental things that the W first will

1156  
00:50:23,489 --> 00:50:29,189  
measure about the universe the galaxies

1157  
00:50:25,860 --> 00:50:32,190  
shapes the positions and the distances

1158  
00:50:29,190 --> 00:50:34,740  
to these distant galaxies and so these

1159  
00:50:32,190 --> 00:50:36,300  
things will give us hints in two

1160  
00:50:34,739 --> 00:50:39,299  
different parts of the universe about

1161  
00:50:36,300 --> 00:50:41,250  
how structure grows over time not only

1162  
00:50:39,300 --> 00:50:44,360  
the galaxies but how the galaxies weave

1163  
00:50:41,250 --> 00:50:47,039  
together in this overall cosmic web and

1164  
00:50:44,360 --> 00:50:49,349  
then also about how the expansion

1165  
00:50:47,039 --> 00:50:50,400  
history works again we know the universe

1166  
00:50:49,349 --> 00:50:53,309  
is expanding

1167  
00:50:50,400 --> 00:50:54,778  
we know that it's accelerating but we

1168  
00:50:53,309 --> 00:50:56,219  
don't know what

1169

00:50:54,778 --> 00:50:58,829  
three of that has been hasn't always

1170  
00:50:56,219 --> 00:51:01,769  
been accelerating at the same rate that

1171  
00:50:58,829 --> 00:51:03,419  
it is now so the further out we can push

1172  
00:51:01,768 --> 00:51:05,488  
these measurements and the more precise

1173  
00:51:03,418 --> 00:51:07,558  
we can make them the more we can learn

1174  
00:51:05,489 --> 00:51:10,469  
about these physical mechanisms that are

1175  
00:51:07,559 --> 00:51:12,959  
taking place and so what this will

1176  
00:51:10,469 --> 00:51:15,208  
eventually allow us to do as we hone in

1177  
00:51:12,958 --> 00:51:17,458  
on these measurements is really to allow

1178  
00:51:15,208 --> 00:51:19,649  
us to determine how the universe will

1179  
00:51:17,458 --> 00:51:22,768  
continue how it will end

1180  
00:51:19,650 --> 00:51:25,108  
if it'll end in a big freeze and a big

1181  
00:51:22,768 --> 00:51:28,948  
rip all of these different scenarios

1182  
00:51:25,108 --> 00:51:31,400  
that will allow us to to see how the how

1183  
00:51:28,949 --> 00:51:33,809

we think the universe will continue on

1184

00:51:31,400 --> 00:51:35,999

so this again this telescope is

1185

00:51:33,809 --> 00:51:38,150

specifically designed to get at these

1186

00:51:35,998 --> 00:51:40,618

questions of dark energy and dark matter

1187

00:51:38,150 --> 00:51:42,778

but the really cool thing about the

1188

00:51:40,619 --> 00:51:45,088

technology that's going behind building

1189

00:51:42,778 --> 00:51:48,509

this telescope is it's gonna allow us to

1190

00:51:45,088 --> 00:51:50,358

look back also at the five percent and

1191

00:51:48,509 --> 00:51:53,909

about one of the really interesting

1192

00:51:50,358 --> 00:51:58,228

parts of the five percent which is

1193

00:51:53,909 --> 00:52:01,009

exoplanets now when I was a kid we only

1194

00:51:58,228 --> 00:52:05,248

knew of the planets in our solar system

1195

00:52:01,009 --> 00:52:07,829

now thanks to NASA's Kepler telescope we

1196

00:52:05,248 --> 00:52:10,259

know that planets are literally

1197

00:52:07,829 --> 00:52:13,199

everywhere the Milky Way is teeming with

1198  
00:52:10,259 --> 00:52:15,900  
planets statistically every star in the

1199  
00:52:13,199 --> 00:52:20,188  
night sky has at least one planet around

1200  
00:52:15,900 --> 00:52:21,869  
it that's a paradigm shift you know even

1201  
00:52:20,188 --> 00:52:25,139  
fifteen years ago we didn't know this

1202  
00:52:21,869 --> 00:52:28,048  
and so what W first is gonna allow us to

1203  
00:52:25,139 --> 00:52:30,389  
do it's a couple of different things for

1204  
00:52:28,048 --> 00:52:33,538  
exoplanets so it's gonna help us first

1205  
00:52:30,389 --> 00:52:36,658  
of all find more nearby exoplanets in a

1206  
00:52:33,539 --> 00:52:38,849  
different part of the the sort of solar

1207  
00:52:36,659 --> 00:52:41,249  
system space or the exoplanet system

1208  
00:52:38,849 --> 00:52:42,989  
space and then it will help us directly

1209  
00:52:41,248 --> 00:52:47,098  
characterize some of the closest

1210  
00:52:42,989 --> 00:52:49,139  
exoplanets that we know about today so

1211  
00:52:47,099 --> 00:52:51,949  
of all of these different planets this

1212  
00:52:49,139 --> 00:52:55,408  
is of course an artist's illustration

1213  
00:52:51,949 --> 00:52:57,209  
unfortunately we don't know the details

1214  
00:52:55,409 --> 00:52:58,919  
of these planets wouldn't be great if we

1215  
00:52:57,208 --> 00:53:01,708  
could actually draw all the planets we

1216  
00:52:58,918 --> 00:53:04,259  
know about in a poster like this but we

1217  
00:53:01,708 --> 00:53:06,899  
don't know what they look like

1218  
00:53:04,259 --> 00:53:09,539  
we know there are thousands of confirmed

1219  
00:53:06,900 --> 00:53:12,539  
exoplanets and again statistics just

1220  
00:53:09,539 --> 00:53:15,539  
tell us tells us that there are hundreds

1221  
00:53:12,539 --> 00:53:17,190  
of billions of exoplanets in our galaxy

1222  
00:53:15,539 --> 00:53:19,589  
and there's no reason to think they

1223  
00:53:17,190 --> 00:53:21,989  
wouldn't be in other galaxies as well we

1224  
00:53:19,588 --> 00:53:23,369  
don't know what they look like but W

1225  
00:53:21,989 --> 00:53:25,739  
first will have the capability to

1226

00:53:23,369 --> 00:53:27,869  
directly image some of the closest and

1227  
00:53:25,739 --> 00:53:31,289  
brightest ones so how do we do that so

1228  
00:53:27,869 --> 00:53:34,079  
all of our our best images actual images

1229  
00:53:31,289 --> 00:53:37,380  
of exoplanets to date are these tiny

1230  
00:53:34,079 --> 00:53:39,209  
little blobs not very pretty right so w

1231  
00:53:37,380 --> 00:53:40,229  
first we'll have an instrument called a

1232  
00:53:39,208 --> 00:53:42,328  
coronagraph

1233  
00:53:40,228 --> 00:53:44,879  
which is basically an instrument that

1234  
00:53:42,329 --> 00:53:48,329  
blocks out the very very bright light of

1235  
00:53:44,880 --> 00:53:51,719  
a star and allows us to focus in on the

1236  
00:53:48,329 --> 00:53:54,900  
planets to better image the the planets

1237  
00:53:51,719 --> 00:53:59,159  
that are orbiting that star now this is

1238  
00:53:54,900 --> 00:54:03,749  
very difficult planet our stars are very

1239  
00:53:59,159 --> 00:54:05,998  
very bright stars are tiny or planets or

1240  
00:54:03,748 --> 00:54:08,578

stars are bright planets are tiny and

1241  
00:54:05,998 --> 00:54:10,708  
they're hard to see and so doing this is

1242  
00:54:08,579 --> 00:54:13,499  
extremely difficult but w first is gonna

1243  
00:54:10,708 --> 00:54:15,149  
have a new capability to do this in a

1244  
00:54:13,498 --> 00:54:16,768  
new way now it's not gonna be this

1245  
00:54:15,150 --> 00:54:19,259  
detail it's not even gonna be close so

1246  
00:54:16,768 --> 00:54:20,968  
this is a little misleading but it's

1247  
00:54:19,259 --> 00:54:25,349  
really going to be a new technology a

1248  
00:54:20,969 --> 00:54:28,880  
new way to do this in a really new way

1249  
00:54:25,349 --> 00:54:31,440  
and so just to give you a sense here

1250  
00:54:28,880 --> 00:54:33,989  
this is showing you sort of the area

1251  
00:54:31,440 --> 00:54:36,389  
that Kepler looks for and all those

1252  
00:54:33,989 --> 00:54:39,539  
exoplanets a coupler is found we're

1253  
00:54:36,389 --> 00:54:41,879  
launching a telescope called Tess next

1254  
00:54:39,539 --> 00:54:44,999  
year in early 2018 it's the transiting



1255  
00:54:41,880 --> 00:54:48,358  
exoplanet survey satellite from NASA

1256  
00:54:44,998 --> 00:54:51,208  
so that particular telescope is going to

1257  
00:54:48,358 --> 00:54:53,429  
look at particularly at the closest

1258  
00:54:51,208 --> 00:54:55,919  
exoplanet center a milky way and look

1259  
00:54:53,429 --> 00:54:59,458  
close in at the the planets that are

1260  
00:54:55,920 --> 00:55:01,440  
really close to their star so what dubby

1261  
00:54:59,458 --> 00:55:04,078  
first is gonna do is expand that it's

1262  
00:55:01,440 --> 00:55:05,639  
gonna look look for the bigger planets

1263  
00:55:04,079 --> 00:55:07,979  
that are orbiting further out from the

1264  
00:55:05,639 --> 00:55:09,989  
stars and so it's basically gonna help

1265  
00:55:07,978 --> 00:55:12,268  
us to with these three telescopes and

1266  
00:55:09,989 --> 00:55:13,190  
others help us to sort of complete the

1267  
00:55:12,268 --> 00:55:16,339  
fences

1268  
00:55:13,190 --> 00:55:20,179  
of exoplanet systems in our nearby Milky

1269  
00:55:16,340 --> 00:55:21,620  
Way galaxy so one of the really neat

1270  
00:55:20,179 --> 00:55:24,829  
ways that's going to do this is by

1271  
00:55:21,619 --> 00:55:27,079  
technique called micro lensing so this

1272  
00:55:24,829 --> 00:55:29,329  
goes back to the same physics principles

1273  
00:55:27,079 --> 00:55:32,059  
as gravitational lensing is when you

1274  
00:55:29,329 --> 00:55:34,730  
have one object that passes in front of

1275  
00:55:32,059 --> 00:55:37,219  
another and in this particular case you

1276  
00:55:34,730 --> 00:55:39,710  
have a star and a planet that's gonna

1277  
00:55:37,219 --> 00:55:42,709  
pass in front of a background source and

1278  
00:55:39,710 --> 00:55:45,530  
what happens when you have this

1279  
00:55:42,710 --> 00:55:48,530  
particular arrangement is that we get a

1280  
00:55:45,530 --> 00:55:49,730  
very unique spectral signature that we

1281  
00:55:48,530 --> 00:55:53,060  
can easily detect

1282  
00:55:49,730 --> 00:55:55,820  
and that tells us that we have a planet

1283

00:55:53,059 --> 00:55:58,219  
now where's a good place to look for

1284  
00:55:55,820 --> 00:56:00,559  
this in the disk of the Milky Way if we

1285  
00:55:58,219 --> 00:56:03,199  
look right down the throat of the Milky

1286  
00:56:00,559 --> 00:56:05,509  
Way galaxy where stars are packed in

1287  
00:56:03,199 --> 00:56:07,189  
then you're very likely to have this

1288  
00:56:05,510 --> 00:56:10,010  
occurrence happening happening pretty

1289  
00:56:07,190 --> 00:56:12,679  
often and so what we expect with the

1290  
00:56:10,010 --> 00:56:15,130  
dhobi first micro lensing survey is to

1291  
00:56:12,679 --> 00:56:17,899  
see this micro lensing effect these

1292  
00:56:15,130 --> 00:56:20,570  
planets and stars passing in front of

1293  
00:56:17,900 --> 00:56:23,539  
background stars happen very often and

1294  
00:56:20,570 --> 00:56:25,910  
so this is a plot that shows down here

1295  
00:56:23,539 --> 00:56:28,130  
on the x-axis this is distance of the

1296  
00:56:25,909 --> 00:56:31,009  
planet from the star they use

1297  
00:56:28,130 --> 00:56:33,500

astronomical units one is the Earth's

1298

00:56:31,010 --> 00:56:35,810  
distance from the Sun and here's the

1299

00:56:33,500 --> 00:56:37,000  
planet's mass so the earth right there

1300

00:56:35,809 --> 00:56:40,340  
one and one

1301

00:56:37,000 --> 00:56:43,190  
so with Kepler is found again has been

1302

00:56:40,340 --> 00:56:45,890  
mostly sort of smallish planets really

1303

00:56:43,190 --> 00:56:48,320  
close to their stars what W first is

1304

00:56:45,889 --> 00:56:50,389  
gonna do is push out to find planets

1305

00:56:48,320 --> 00:56:54,110  
that are more like our gas giants that

1306

00:56:50,389 --> 00:56:59,509  
are orbiting stars close to our close in

1307

00:56:54,110 --> 00:57:03,039  
to to our solar system is so W first has

1308

00:56:59,510 --> 00:57:06,140  
all of these really sort of grand goals

1309

00:57:03,039 --> 00:57:08,809  
it's really being built to answer some

1310

00:57:06,139 --> 00:57:10,730  
of the most fundamental puzzling

1311

00:57:08,809 --> 00:57:14,900  
questions that we have in astrophysics

1312  
00:57:10,730 --> 00:57:19,639  
today so how in the world are we gonna

1313  
00:57:14,900 --> 00:57:23,809  
do this the key thing about w first is

1314  
00:57:19,639 --> 00:57:26,379  
the enormous size of the camera and of

1315  
00:57:23,809 --> 00:57:29,650  
the pictures that it will take

1316  
00:57:26,380 --> 00:57:32,440  
so that little square here it's the size

1317  
00:57:29,650 --> 00:57:33,070  
of the Hubble's camera so one pointing

1318  
00:57:32,440 --> 00:57:35,289  
with Hubble

1319  
00:57:33,070 --> 00:57:39,030  
so that Hubble ultra-deep field I showed

1320  
00:57:35,289 --> 00:57:43,239  
you all the images of the planets of the

1321  
00:57:39,030 --> 00:57:46,620  
the nebulae so W first will have an area

1322  
00:57:43,239 --> 00:57:50,649  
that's a hundred times the area of

1323  
00:57:46,619 --> 00:57:53,679  
Hubble and this is critical also with

1324  
00:57:50,650 --> 00:57:56,139  
the same depth and clarity that Hubble

1325  
00:57:53,679 --> 00:57:57,849  
has now we have telescopes on the ground

1326  
00:57:56,139 --> 00:58:01,869  
that are able to take these big wide

1327  
00:57:57,849 --> 00:58:05,079  
images but they are very shallow they're

1328  
00:58:01,869 --> 00:58:07,210  
very low resolution okay and so what you

1329  
00:58:05,079 --> 00:58:09,549  
really get with W first is sort of the

1330  
00:58:07,210 --> 00:58:12,220  
best of both worlds you get the depth

1331  
00:58:09,550 --> 00:58:15,880  
and the clarity and the precision of

1332  
00:58:12,219 --> 00:58:19,209  
Hubble with this gigantic field of view

1333  
00:58:15,880 --> 00:58:21,390  
this giant area and so this is basically

1334  
00:58:19,210 --> 00:58:24,519  
going to be Hubble times 100

1335  
00:58:21,389 --> 00:58:26,710  
so with this telescope again we hope to

1336  
00:58:24,519 --> 00:58:29,349  
sort of start to unlock some of these

1337  
00:58:26,710 --> 00:58:31,059  
mysteries of dark energy we hope to

1338  
00:58:29,349 --> 00:58:34,360  
learn more about some of the nearest

1339  
00:58:31,059 --> 00:58:36,400  
exoplanets in our own Milky Way but this

1340

00:58:34,360 --> 00:58:39,340  
telescope is also going to be an

1341  
00:58:36,400 --> 00:58:42,309  
incredible tool just for general

1342  
00:58:39,340 --> 00:58:44,980  
astrophysics so all of these surveys

1343  
00:58:42,309 --> 00:58:47,320  
that W first will take that will help us

1344  
00:58:44,980 --> 00:58:51,190  
learn about dark energy help us learn

1345  
00:58:47,320 --> 00:58:54,130  
about exoplanets will be available to

1346  
00:58:51,190 --> 00:58:55,780  
astronomers and to the public to do what

1347  
00:58:54,130 --> 00:58:58,000  
I think will be really incredible

1348  
00:58:55,780 --> 00:59:00,910  
general astrophysics so just to give you

1349  
00:58:58,000 --> 00:59:03,309  
a couple of examples of that as I

1350  
00:59:00,909 --> 00:59:04,719  
mentioned to find exoplanets the best

1351  
00:59:03,309 --> 00:59:08,469  
way to do this is to look down the

1352  
00:59:04,719 --> 00:59:10,899  
throat of our own Milky Way galaxy so

1353  
00:59:08,469 --> 00:59:13,779  
again here we have the Hubble field of

1354  
00:59:10,900 --> 00:59:16,000

view JT wristy it's very similar to

1355

00:59:13,780 --> 00:59:19,600

Hubble and then it sees a little tiny

1356

00:59:16,000 --> 00:59:22,659

picture on the sky but again dolby first

1357

00:59:19,599 --> 00:59:25,239

we get a hundred times the area and so

1358

00:59:22,659 --> 00:59:28,569

when we survey the center of the Milky

1359

00:59:25,239 --> 00:59:30,779

Way galaxy with W first in as few is

1360

00:59:28,570 --> 00:59:31,960

just you know a few less than ten

1361

00:59:30,780 --> 00:59:34,720

pointings

1362

00:59:31,960 --> 00:59:37,929

of w first you basically survey the

1363

00:59:34,719 --> 00:59:39,268

entire central center part of the Milky

1364

00:59:37,929 --> 00:59:40,918

Way galaxy

1365

00:59:39,268 --> 00:59:43,558

and you're able to learn so much more

1366

00:59:40,918 --> 00:59:45,989

about all of these different ranges of

1367

00:59:43,559 --> 00:59:47,849

astrophysics so what's going on with the

1368

00:59:45,989 --> 00:59:49,679

black the super giant black hole at the



1369  
00:59:47,849 --> 00:59:52,649  
center of our galaxy what's going on

1370  
00:59:49,679 --> 00:59:56,338  
with how young star clusters form so a

1371  
00:59:52,648 --> 00:59:58,768  
huge range of astrophysics that we'll be

1372  
00:59:56,338 --> 00:59:59,818  
able to do with these surveys and then I

1373  
00:59:58,768 --> 01:00:01,468  
mentioned that the Hubble Ultra Deep

1374  
00:59:59,818 --> 01:00:02,489  
Field was my personal favorite because

1375  
01:00:01,469 --> 01:00:05,068  
that's why I did a lot of my

1376  
01:00:02,489 --> 01:00:07,168  
dissertation research on so with the

1377  
01:00:05,068 --> 01:00:10,588  
whole Ultra Deep Field that one little

1378  
01:00:07,168 --> 01:00:14,998  
tiny piece of sky revealed ten thousand

1379  
01:00:10,588 --> 01:00:17,369  
galaxies but one pointing with w first

1380  
01:00:14,998 --> 01:00:19,379  
at a hundred of times the field of view

1381  
01:00:17,369 --> 01:00:23,309  
that's easy math right we're gonna see a

1382  
01:00:19,380 --> 01:00:26,608  
million galaxies in just one image with

1383  
01:00:23,309 --> 01:00:28,469  
W first again with the same depth and

1384  
01:00:26,608 --> 01:00:31,828  
clarity that we've been able to achieve

1385  
01:00:28,469 --> 01:00:34,048  
with Hubble and so I really believe me

1386  
01:00:31,829 --> 01:00:35,818  
being an extra galactic astrophysicist

1387  
01:00:34,048 --> 01:00:38,818  
that this telescope is gonna

1388  
01:00:35,818 --> 01:00:42,509  
revolutionize the way that we understand

1389  
01:00:38,818 --> 01:00:44,449  
how the universe works over the course

1390  
01:00:42,509 --> 01:00:46,769  
of cosmic history it'll change the way

1391  
01:00:44,449 --> 01:00:51,659  
that we understand the evolution of

1392  
01:00:46,768 --> 01:00:53,129  
galaxies over time so all of these

1393  
01:00:51,659 --> 01:00:54,989  
different things that we have planned

1394  
01:00:53,130 --> 01:00:56,909  
for the telescope again these specific

1395  
01:00:54,989 --> 01:00:59,818  
surveys to figure out how dark energy

1396  
01:00:56,909 --> 01:01:03,599  
works how exoplanet works exoplanets

1397

01:00:59,818 --> 01:01:04,949  
work I think for me one of the things

1398  
01:01:03,599 --> 01:01:06,239  
we're having we're having a science

1399  
01:01:04,949 --> 01:01:09,269  
conference right now here at the

1400  
01:01:06,239 --> 01:01:10,949  
Institute on W first science so a bunch

1401  
01:01:09,268 --> 01:01:13,288  
of astronomers are here from all over

1402  
01:01:10,949 --> 01:01:15,329  
the country all over the world to think

1403  
01:01:13,289 --> 01:01:17,639  
about what this awesome Observatory is

1404  
01:01:15,329 --> 01:01:19,409  
going to do and one of the comments I

1405  
01:01:17,639 --> 01:01:21,149  
heard yesterday I think is is probably

1406  
01:01:19,409 --> 01:01:23,608  
the most significant thing I've heard

1407  
01:01:21,148 --> 01:01:25,679  
and it was in reference to the Hubble

1408  
01:01:23,608 --> 01:01:28,108  
Space Telescope and the continent was

1409  
01:01:25,679 --> 01:01:30,298  
basically that you know Hubble was built

1410  
01:01:28,108 --> 01:01:33,808  
to answer a few key science questions of

1411  
01:01:30,298 --> 01:01:37,278

its day but if you build a telescope if

1412

01:01:33,809 --> 01:01:40,798

you build a really extraordinary machine

1413

01:01:37,278 --> 01:01:44,579

then the community is going to find new

1414

01:01:40,798 --> 01:01:46,829

and novel ways to use that machine to

1415

01:01:44,579 --> 01:01:49,559

find things about the universe that we

1416

01:01:46,829 --> 01:01:51,509

never dreamed of and to me as a

1417

01:01:49,559 --> 01:01:52,500

scientist that's the most exciting thing

1418

01:01:51,509 --> 01:01:55,559

about being a sign

1419

01:01:52,500 --> 01:01:57,719

is we build these missions with these

1420

01:01:55,559 --> 01:02:00,150

very specific questions in mind these

1421

01:01:57,719 --> 01:02:02,969

these these specific things that we want

1422

01:02:00,150 --> 01:02:06,329

to answer but the fact is is when we

1423

01:02:02,969 --> 01:02:08,549

build these telescopes we find answers

1424

01:02:06,329 --> 01:02:11,009

to questions that we didn't even think

1425

01:02:08,550 --> 01:02:14,099

to ask when we were building them and

1426  
01:02:11,010 --> 01:02:15,599  
that overall is I believe the promise of

1427  
01:02:14,099 --> 01:02:19,550  
the universe and why we build these

1428  
01:02:15,599 --> 01:02:39,289  
missions thanks so much

1429  
01:02:19,550 --> 01:02:39,289  
[Applause]

1430  
01:03:03,329 --> 01:03:06,489  
[Music]

1431  
01:03:07,309 --> 01:03:19,410  
so they were meant to seeing wide fields

1432  
01:03:14,789 --> 01:03:21,569  
for anyway the DoD gave of these years

1433  
01:03:19,409 --> 01:03:24,028  
right so we're not going down well

1434  
01:03:21,568 --> 01:03:25,380  
enough of these years I'm launching

1435  
01:03:24,028 --> 01:03:29,728  
we're planning to launch the

1436  
01:03:25,380 --> 01:03:35,009  
mid-twenties oh yeah right

1437  
01:03:29,728 --> 01:03:38,278  
we're building so the James Webb Space

1438  
01:03:35,009 --> 01:03:42,389  
Telescope gonna be launched next year

1439  
01:03:38,278 --> 01:03:44,369  
and the Webb telescope is denying answer

1440  
01:03:42,389 --> 01:03:46,978  
different questions the Webb telescope

1441  
01:03:44,369 --> 01:03:48,439  
in many ways is really the scientific

1442  
01:03:46,978 --> 01:03:52,169  
successor to Hubble

1443  
01:03:48,438 --> 01:03:54,178  
so when is going to be further into the

1444  
01:03:52,170 --> 01:03:57,809  
infrared so it sees a different part of

1445  
01:03:54,179 --> 01:03:59,818  
the spectrum so AWS is also an infrared

1446  
01:03:57,809 --> 01:04:01,679  
telescope but it only sees a little bit

1447  
01:03:59,818 --> 01:04:05,130  
of a threat and again the key thing

1448  
01:04:01,679 --> 01:04:07,858  
about 30 verses is why huge trifle of

1449  
01:04:05,130 --> 01:04:10,528  
you so we're gonna be super Hubble and

1450  
01:04:07,858 --> 01:04:13,288  
then it sees a little part of this guy

1451  
01:04:10,528 --> 01:04:15,958  
but when we're going to see much winter

1452  
01:04:13,289 --> 01:04:18,299  
pearl so what was the deeper than

1453  
01:04:15,958 --> 01:04:20,969  
problem and what will see deeper and

1454

01:04:18,298 --> 01:04:24,509  
don't we first will be more resolution

1455  
01:04:20,969 --> 01:04:26,849  
that with the web that's right yes but

1456  
01:04:24,509 --> 01:04:28,309  
we're resolution but also because he's

1457  
01:04:26,849 --> 01:04:30,500  
further

1458  
01:04:28,309 --> 01:04:35,150  
the spectrum is able to see different

1459  
01:04:30,500 --> 01:04:37,010  
things so for example I showed the sort

1460  
01:04:35,150 --> 01:04:39,980  
of flying through the holiday seal and

1461  
01:04:37,010 --> 01:04:41,960  
so in the D field we come to an edge and

1462  
01:04:39,980 --> 01:04:43,940  
what we can see with Hubble and that's

1463  
01:04:41,960 --> 01:04:47,240  
really the kind of couple cuts off at

1464  
01:04:43,940 --> 01:04:49,190  
the near-infrared wavelengths so to see

1465  
01:04:47,239 --> 01:04:51,649  
the most distant galaxies to see for

1466  
01:04:49,190 --> 01:04:53,929  
example the first segment of galaxies

1467  
01:04:51,650 --> 01:04:56,000  
that were born in the Big Bang we need

1468  
01:04:53,929 --> 01:04:58,099

to see further into the infrared part of

1469

01:04:56,000 --> 01:05:00,670

the spectrum and that's exactly what web

1470

01:04:58,099 --> 01:05:03,619

is designed to do when it will also have

1471

01:05:00,670 --> 01:05:06,680

instruments on born that are designed to

1472

01:05:03,619 --> 01:05:10,549

do transit spectroscopy so web is a

1473

01:05:06,679 --> 01:05:13,940

really really incredible high resolution

1474

01:05:10,550 --> 01:05:15,590

spectrograph that W first inhabited OB

1475

01:05:13,940 --> 01:05:17,840

first has low resolution spectrograph

1476

01:05:15,590 --> 01:05:20,960

it'll allow us to do a different set of

1477

01:05:17,840 --> 01:05:23,990

science so web and dummy first are

1478

01:05:20,960 --> 01:05:31,550

different but they're complementary and

1479

01:05:23,989 --> 01:05:33,019

so look like stronger stream is one cool

1480

01:05:31,550 --> 01:05:34,970

thing that nobody first will be able to

1481

01:05:33,019 --> 01:05:37,239

do with this huge Bible of you

1482

01:05:34,969 --> 01:05:40,519

it's mines are the most rare objects



1483  
01:05:37,239 --> 01:05:43,969  
okay so you can imagine like the the

1484  
01:05:40,519 --> 01:05:46,159  
biggest hugest discount distant galaxies

1485  
01:05:43,969 --> 01:05:48,289  
so now these are very distant but for

1486  
01:05:46,159 --> 01:05:50,149  
whatever reason have to be huge but so

1487  
01:05:48,289 --> 01:05:52,309  
they're probably really really rare

1488  
01:05:50,150 --> 01:05:55,130  
you called it my heads of other things

1489  
01:05:52,309 --> 01:05:57,199  
like this that were very rare and so you

1490  
01:05:55,130 --> 01:05:59,930  
know why will you see these rare things

1491  
01:05:57,199 --> 01:06:05,750  
and so what would be able to find these

1492  
01:05:59,929 --> 01:06:07,699  
rare things be my nursery but we might

1493  
01:06:05,750 --> 01:06:11,570  
want to go back to take detailed spectra

1494  
01:06:07,699 --> 01:06:13,759  
of them and so our hope is definitely

1495  
01:06:11,570 --> 01:06:19,390  
that double universe will launch in the

1496  
01:06:13,760 --> 01:06:22,390  
mid 2020s so we'll have morality

1497  
01:06:19,389 --> 01:06:22,389  
in-house

1498  
01:06:23,780 --> 01:06:30,360  
although Hubble doing really great way

1499  
01:06:26,789 --> 01:06:44,159  
to help Wow to have all three at one

1500  
01:06:30,360 --> 01:06:48,329  
time first of all is just the detector

1501  
01:06:44,159 --> 01:06:51,239  
detector technology so so you know Hall

1502  
01:06:48,329 --> 01:06:53,369  
has a sort of limited amount of space in

1503  
01:06:51,239 --> 01:06:55,619  
places where you can actually place the

1504  
01:06:53,369 --> 01:06:58,019  
detectors and of course you know we've

1505  
01:06:55,619 --> 01:07:02,099  
been doubling down on for the last time

1506  
01:06:58,019 --> 01:07:04,469  
so we've done our last upgrade but for

1507  
01:07:02,099 --> 01:07:07,650  
dummy versus specifically focusing on

1508  
01:07:04,469 --> 01:07:10,589  
these detector arrays that are just huge

1509  
01:07:07,650 --> 01:07:12,990  
they're massive so it's really just

1510  
01:07:10,590 --> 01:07:14,789  
hacking those detectors those advanced

1511

01:07:12,989 --> 01:07:17,729  
detectors and also detectives that are

1512  
01:07:14,789 --> 01:07:19,739  
it's just a big focal plane and then

1513  
01:07:17,730 --> 01:07:22,800  
also having just the configuration in

1514  
01:07:19,739 --> 01:07:24,359  
the telescope itself makes it such that

1515  
01:07:22,800 --> 01:07:26,730  
sort of the focal length of the

1516  
01:07:24,360 --> 01:07:29,849  
telescope allow them to housewife with

1517  
01:07:26,730 --> 01:07:31,710  
you so if you've done home housing the

1518  
01:07:29,849 --> 01:07:33,989  
size compare that oh that's a good

1519  
01:07:31,710 --> 01:07:35,940  
question and we'll get back to that so

1520  
01:07:33,989 --> 01:07:38,039  
uh so really just you know the

1521  
01:07:35,940 --> 01:07:40,440  
configuration of a telescope that focal

1522  
01:07:38,039 --> 01:07:42,900  
length and all of that gives it sort of

1523  
01:07:40,440 --> 01:07:45,570  
its parameters of how we can see the

1524  
01:07:42,900 --> 01:07:47,700  
universe so Hubble is sort of this sort

1525  
01:07:45,570 --> 01:07:51,660

of long tube but what you think of The

1526

01:07:47,699 --> 01:07:53,819

Bachelor telesco dummy versus people

1527

01:07:51,659 --> 01:07:56,129

sort of affectionately call it a stub

1528

01:07:53,820 --> 01:07:58,920

helpful so it's the same year science

1529

01:07:56,130 --> 01:08:00,420

Hubble but it's sort of sure so it's got

1530

01:07:58,920 --> 01:08:01,860

a different focal length and so it just

1531

01:08:00,420 --> 01:08:03,720

allows the CD universe in a different

1532

01:08:01,860 --> 01:08:05,519

way so just so we're going to build

1533

01:08:03,719 --> 01:08:07,980

differently and then it kind of this

1534

01:08:05,519 --> 01:08:09,780

different detector right combination

1535

01:08:07,980 --> 01:08:12,980

they make sure the be measured in the

1536

01:08:09,780 --> 01:08:15,920

wavelength coverage because

1537

01:08:12,980 --> 01:08:18,229

just read the important first kana me

1538

01:08:15,920 --> 01:08:26,420

you cannot do all about astronomy from

1539

01:08:18,229 --> 01:08:28,278

the ground is really critical here so as

1540  
01:08:26,420 --> 01:08:30,588  
astronomers we want to see the universe

1541  
01:08:28,279 --> 01:08:31,969  
in as many ways as we can so why do we

1542  
01:08:30,588 --> 01:08:35,088  
put all these different telescopes to

1543  
01:08:31,969 --> 01:08:37,630  
see University and your instead Hubble's

1544  
01:08:35,088 --> 01:08:41,509  
but only the only telescope we have

1545  
01:08:37,630 --> 01:08:44,180  
right now they can see the ultimate

1546  
01:08:41,509 --> 01:08:46,310  
universe and galaxies the only house so

1547  
01:08:44,180 --> 01:08:48,020  
he has to set a little bit but whether

1548  
01:08:46,310 --> 01:08:50,989  
you've ability right now Hubble is the

1549  
01:08:48,020 --> 01:08:53,239  
prime telescope for ultraviolet visible

1550  
01:08:50,988 --> 01:08:55,968  
and then all things get a little bit as

1551  
01:08:53,238 --> 01:08:58,459  
we near infrared so dummy first is

1552  
01:08:55,969 --> 01:09:01,399  
planned to see in the infrared and then

1553  
01:08:58,460 --> 01:09:03,230  
when will be infrared plus out to the

1554  
01:09:01,399 --> 01:09:06,019  
mid infrared so it's just sort of about

1555  
01:09:03,229 --> 01:09:07,548  
covering the whole spectrum and then I'm

1556  
01:09:06,020 --> 01:09:10,700  
sawing about here but to answer your

1557  
01:09:07,548 --> 01:09:13,850  
question about size so Hubble it on the

1558  
01:09:10,699 --> 01:09:17,389  
sides was a school bus roughly it's

1559  
01:09:13,850 --> 01:09:20,960  
neater it's Mears 2.4 meters that's the

1560  
01:09:17,390 --> 01:09:25,190  
same size of the W first mirror when is

1561  
01:09:20,960 --> 01:09:28,310  
its primary mirror is six and a half

1562  
01:09:25,189 --> 01:09:31,519  
meters so about 22 feet across so what

1563  
01:09:28,310 --> 01:09:35,900  
is huge to go back to this other picture

1564  
01:09:31,520 --> 01:09:37,790  
computer when is by are the biggest

1565  
01:09:35,899 --> 01:09:44,329  
telescope that we've ever sent to space

1566  
01:09:37,789 --> 01:09:46,009  
can you back to in there we go so top to

1567  
01:09:44,329 --> 01:09:49,390  
bottom this is six and half meters not

1568

01:09:46,009 --> 01:09:52,479  
21 feet what you don't see in this image

1569  
01:09:49,390 --> 01:09:52,479  
[Music]

1570  
01:09:55,569 --> 01:10:00,679  
this structure he's looking on the

1571  
01:09:57,680 --> 01:10:03,349  
bottom a tennis court to talk about

1572  
01:10:00,679 --> 01:10:05,719  
over three stories tall so it's fun for

1573  
01:10:03,349 --> 01:10:08,208  
the big telescope we are into space so

1574  
01:10:05,719 --> 01:10:10,399  
what is it definitely unique in essence

1575  
01:10:08,208 --> 01:10:23,538  
and how big it is then of course we have

1576  
01:10:10,399 --> 01:10:25,879  
to fold it up to watch it I just have a

1577  
01:10:23,538 --> 01:10:28,399  
quick question so you had an image that

1578  
01:10:25,880 --> 01:10:30,618  
showed the visible matter and the dark

1579  
01:10:28,399 --> 01:10:32,598  
energy of the dark matter but you had it

1580  
01:10:30,618 --> 01:10:34,098  
narrowed down to percent so how are you

1581  
01:10:32,599 --> 01:10:42,769  
able to figure out sixty eight and

1582  
01:10:34,099 --> 01:10:47,619

twenty seven and five constraints that

1583

01:10:42,769 --> 01:10:47,619

we measure from the very early universe

1584

01:10:48,359 --> 01:10:51,460

[Music]

1585

01:10:53,828 --> 01:11:02,149

through this imprint this image of the

1586

01:10:57,649 --> 01:11:04,339

baby universe that it's about 400,000

1587

01:11:02,149 --> 01:11:08,089

years after the Big Bang and we can

1588

01:11:04,340 --> 01:11:09,889

basically measure sort of details about

1589

01:11:08,090 --> 01:11:12,139

that image that tell us a little bit

1590

01:11:09,889 --> 01:11:13,969

about one thing evolution of the

1591

01:11:12,139 --> 01:11:16,219

universal being what the different

1592

01:11:13,969 --> 01:11:19,550

percentages will be so this is deep into

1593

01:11:16,219 --> 01:11:20,689

the theoretical cosmology so mostly what

1594

01:11:19,550 --> 01:11:23,269

I've talked about tonight is

1595

01:11:20,689 --> 01:11:25,610

observational cosmology or observational

1596

01:11:23,269 --> 01:11:27,559

astrophysics I'm a conservationist



1597  
01:11:25,609 --> 01:11:29,058  
this is families data to study the

1598  
01:11:27,559 --> 01:11:31,279  
University of courses and there's this

1599  
01:11:29,059 --> 01:11:34,159  
whole other set of astronomers that we

1600  
01:11:31,279 --> 01:11:40,090  
work really closely with that do

1601  
01:11:34,158 --> 01:11:42,408  
complete you know and then there's a

1602  
01:11:40,090 --> 01:11:44,599  
sort of one that same scale

1603  
01:11:42,408 --> 01:11:47,319  
there are astronomers that out-of-work

1604  
01:11:44,599 --> 01:11:49,819  
man was confused those that develop

1605  
01:11:47,319 --> 01:11:51,299  
computer models of how we work and so

1606  
01:11:49,819 --> 01:11:55,439  
all these sort of different

1607  
01:11:51,300 --> 01:11:58,480  
work together so the theoretical

1608  
01:11:55,439 --> 01:12:00,129  
resistance are the ones that work out

1609  
01:11:58,479 --> 01:12:01,689  
what these different percentages should

1610  
01:12:00,130 --> 01:12:03,850  
be we don't think those different

1611  
01:12:01,689 --> 01:12:07,239  
percentage those percentages have always

1612  
01:12:03,850 --> 01:12:09,670  
been that so for example the universe

1613  
01:12:07,239 --> 01:12:13,269  
and the center as we know is expanding

1614  
01:12:09,670 --> 01:12:15,130  
and so the volume of the universe is

1615  
01:12:13,270 --> 01:12:18,130  
getting bigger over time so we think

1616  
01:12:15,130 --> 01:12:23,289  
these percentages have changed over the

1617  
01:12:18,130 --> 01:12:26,140  
course of time so it's a complex fast by

1618  
01:12:23,289 --> 01:12:29,140  
nature is a complex question with a

1619  
01:12:26,140 --> 01:12:32,520  
complex answer there's lots of different

1620  
01:12:29,140 --> 01:12:35,380  
ways of observation that leads to us

1621  
01:12:32,520 --> 01:12:37,120  
kind of right at those numbers as one of

1622  
01:12:35,380 --> 01:12:42,210  
those theorists I can give you a real

1623  
01:12:37,119 --> 01:12:44,289  
destroyed answer the Spanish computer

1624  
01:12:42,210 --> 01:12:47,500  
decelerating and then takes over has

1625

01:12:44,289 --> 01:12:49,510  
accelerate the timing of that change or

1626  
01:12:47,500 --> 01:13:11,859  
when it goes from decelerating to

1627  
01:12:49,510 --> 01:13:16,350  
acceleration is thank you yes on that

1628  
01:13:11,859 --> 01:13:18,939  
same point so 27% dark matter

1629  
01:13:16,350 --> 01:13:21,100  
does that mean that the mean density of

1630  
01:13:18,939 --> 01:13:23,349  
the universe is now greater than the

1631  
01:13:21,100 --> 01:13:25,120  
critical density meaning that it's a

1632  
01:13:23,350 --> 01:13:27,550  
finite volume and closed

1633  
01:13:25,119 --> 01:13:30,909  
this is also for dr. summers to people

1634  
01:13:27,550 --> 01:13:33,430  
but but beyond that if the universe is

1635  
01:13:30,909 --> 01:13:36,010  
also expanding meaning the space fabric

1636  
01:13:33,430 --> 01:13:37,960  
itself is moving in some and though the

1637  
01:13:36,010 --> 01:13:41,880  
way how then you calculate the volume

1638  
01:13:37,960 --> 01:13:41,880  
and is there a contradiction here

1639  
01:13:47,050 --> 01:13:53,810

[Music]

1640

01:13:48,310 --> 01:13:56,180  
yes we know the universe's so it's

1641

01:13:53,810 --> 01:14:09,860  
closed and find a new buyer at this

1642

01:13:56,180 --> 01:14:12,800  
point so we're pretty sure that the

1643

01:14:09,859 --> 01:14:16,099  
geometry here versus flat we know that

1644

01:14:12,800 --> 01:14:18,739  
is expanding we have this celery

1645

01:14:16,100 --> 01:14:22,010  
we think that volume is getting bigger

1646

01:14:18,739 --> 01:14:24,649  
but again the best theories of dark

1647

01:14:22,010 --> 01:14:28,610  
energy tell us that empty space is

1648

01:14:24,649 --> 01:14:31,670  
constantly creating new spaces right and

1649

01:14:28,609 --> 01:14:34,009  
so on so even though the the volume is

1650

01:14:31,670 --> 01:14:38,720  
getting bigger that so the density

1651

01:14:34,010 --> 01:14:42,380  
overall is should be going down so in so

1652

01:14:38,720 --> 01:14:44,630  
in the past the fraction of dark matter

1653

01:14:42,380 --> 01:14:46,460  
would have for example the greater the

1654  
01:14:44,630 --> 01:14:48,739  
Russian variance would be greater so

1655  
01:14:46,460 --> 01:14:51,980  
dark meters you have less of an effect

1656  
01:14:48,739 --> 01:14:53,840  
early on in the universe okay so the

1657  
01:14:51,979 --> 01:14:57,549  
infected dark energy is getting greater

1658  
01:14:53,840 --> 01:14:57,550  
because the universe is accelerating

1659  
01:15:11,368 --> 01:15:49,779  
the universe extreme acceleration so I

1660  
01:15:47,349 --> 01:15:52,899  
question W first be able to answer

1661  
01:15:49,779 --> 01:16:24,188  
whether supernovae are composed of

1662  
01:15:52,899 --> 01:16:34,559  
single degenerate or BB heads and so we

1663  
01:16:24,189 --> 01:16:34,559  
will of course get tons of spectra also

1664  
01:16:34,679 --> 01:16:42,719  
the same thing I wanted to be there

1665  
01:16:43,810 --> 01:16:48,649  
[Music]

1666  
01:17:39,060 --> 01:17:42,149  
[Music]

1667  
01:17:43,159 --> 01:17:49,739  
pretty easy fix it something's in space

1668  
01:17:47,420 --> 01:17:52,380  
in the hole we were able to send

1669  
01:17:49,739 --> 01:17:54,210  
astronauts up to fit but not being able

1670  
01:17:52,380 --> 01:17:55,319  
to back sweat what's going to be about

1671  
01:17:54,210 --> 01:17:59,340  
million miles away

1672  
01:17:55,319 --> 01:18:06,630  
not these Inhumans to fix it so space is

1673  
01:17:59,340 --> 01:18:09,300  
hard but we do have so right now at NASA

1674  
01:18:06,630 --> 01:18:10,890  
there are studies going on these teams

1675  
01:18:09,300 --> 01:18:15,329  
of astronomers that have gotten together

1676  
01:18:10,890 --> 01:18:19,619  
and are studying specific concepts for

1677  
01:18:15,329 --> 01:18:21,630  
the next big telescope so there are four

1678  
01:18:19,619 --> 01:18:24,449  
these teams and they're each focused on

1679  
01:18:21,630 --> 01:18:28,890  
different things one is study an x-ray a

1680  
01:18:24,449 --> 01:18:31,979  
focus telescope one study giant tools go

1681  
01:18:28,890 --> 01:18:34,680  
that would focus in on exoplanets I want

1682

01:18:31,979 --> 01:18:37,619  
to study a different brownier telescope

1683  
01:18:34,680 --> 01:18:40,140  
and I wanted to study a basically a sort

1684  
01:18:37,619 --> 01:18:42,989  
of a Super Bowl that would do sort of

1685  
01:18:40,140 --> 01:18:44,490  
you need to infrared actual physics in

1686  
01:18:42,989 --> 01:18:49,819  
space that will be even bigger than wet

1687  
01:18:44,489 --> 01:18:49,819  
so we hope

1688  
01:18:53,479 --> 01:19:02,189  
[Music]

1689  
01:18:57,050 --> 01:19:04,770  
the W first launches again mid 2020s is

1690  
01:19:02,189 --> 01:19:08,819  
what we hope so this is next week

1691  
01:19:04,770 --> 01:19:11,969  
telescope will be selected in the next

1692  
01:19:08,819 --> 01:19:14,429  
seven years so these big big telescopes

1693  
01:19:11,969 --> 01:19:16,469  
like Hubble and Webb W first our

1694  
01:19:14,429 --> 01:19:19,020  
Germany's blanketed everything in here

1695  
01:19:16,469 --> 01:19:20,550  
so these are part what's called decade

1696  
01:19:19,020 --> 01:19:22,949

old survey that some of you may have

1697

01:19:20,550 --> 01:19:25,260

heard of so every 10 years astronomers

1698

01:19:22,948 --> 01:19:28,349

from around the world get together and

1699

01:19:25,260 --> 01:19:30,420

ask what are our biggest questions so

1700

01:19:28,350 --> 01:19:34,889

they cry over time to these astronomy

1701

01:19:30,420 --> 01:19:36,899

questions and then they finally agree on

1702

01:19:34,889 --> 01:19:38,310

them and he's come out these big

1703

01:19:36,899 --> 01:19:40,500

questions come out and what are called

1704

01:19:38,310 --> 01:19:43,830

decadal surveys astronomy take a survey

1705

01:19:40,500 --> 01:19:45,810

and blew those big questions come the

1706

01:19:43,829 --> 01:19:52,769

technology that we need to answer the

1707

01:19:45,810 --> 01:20:16,400

questions so in that technology when it

1708

01:19:52,770 --> 01:20:16,400

was you know

1709

01:20:33,020 --> 01:20:39,200

in space a lot of good job moving around

1710

01:20:37,250 --> 01:20:42,170

like that - you can't absorb infrared



1711  
01:20:39,199 --> 01:20:43,880  
from the ground but large parts out that

1712  
01:20:42,170 --> 01:20:46,159  
our water completely blocked or

1713  
01:20:43,880 --> 01:21:04,250  
partially block at atmosphere which

1714  
01:20:46,159 --> 01:21:06,409  
turns out for humans energy dark matter

1715  
01:21:04,250 --> 01:21:25,729  
is there any difference between those

1716  
01:21:06,409 --> 01:21:27,649  
two and nothing we know that we have all

1717  
01:21:25,729 --> 01:21:30,379  
these different lines of evidence for

1718  
01:21:27,649 --> 01:21:34,839  
both for dark energy interim higher on

1719  
01:21:30,380 --> 01:21:41,270  
the tell us that there is happy

1720  
01:21:34,840 --> 01:21:44,360  
observable effects on the universe so it

1721  
01:21:41,270 --> 01:21:47,120  
is something matter if dark matter is is

1722  
01:21:44,359 --> 01:21:50,269  
something that gravitationally interacts

1723  
01:21:47,119 --> 01:21:53,059  
with other matter and we observe that

1724  
01:21:50,270 --> 01:21:55,670  
so if dark matter is affected by gravity

1725  
01:21:53,060 --> 01:21:57,320  
in the handle we see that front of the

1726  
01:21:55,670 --> 01:21:59,270  
rotation curves of spiral galaxies we

1727  
01:21:57,319 --> 01:22:02,059  
see that from how galaxies and questions

1728  
01:21:59,270 --> 01:22:03,650  
move we see that from the lensing and

1729  
01:22:02,060 --> 01:22:05,240  
similarly with dark energy we see all

1730  
01:22:03,649 --> 01:22:08,239  
these different clues the points on

1731  
01:22:05,239 --> 01:22:11,630  
there's something out there is causing

1732  
01:22:08,239 --> 01:22:20,319  
the universe to behave so it is nothing

1733  
01:22:11,630 --> 01:22:20,319  
it's nothing

1734  
01:22:21,979 --> 01:22:25,069  
[Music]

1735  
01:22:27,229 --> 01:22:30,289  
[Music]

1736  
01:22:37,658 --> 01:22:43,119  
us that if the space is not really empty

1737  
01:22:40,448 --> 01:22:45,039  
that it's sort of always fluctuating and

1738  
01:22:43,119 --> 01:22:46,750  
always had this out of this one of the

1739

01:22:45,039 --> 01:22:48,789  
theories you know dark energy one of the

1740  
01:22:46,750 --> 01:22:51,609  
candidates that Alice's it's sort of

1741  
01:22:48,789 --> 01:22:54,310  
vacuum energy this part of the

1742  
01:22:51,609 --> 01:22:57,009  
space-time that is because of just the

1743  
01:22:54,310 --> 01:23:10,750  
way it is it has quality of having this

1744  
01:22:57,010 --> 01:23:13,420  
energy so there was one group working on

1745  
01:23:10,750 --> 01:23:17,310  
an x-ray telescope but then way or way

1746  
01:23:13,420 --> 01:23:20,380  
to beginning there was an x-ray image of

1747  
01:23:17,310 --> 01:23:22,030  
the Crab Nebula so I'm wondering how

1748  
01:23:20,380 --> 01:23:25,050  
we've got that image and then also if

1749  
01:23:22,029 --> 01:23:28,208  
there if it's possible to be a gamma ray

1750  
01:23:25,050 --> 01:23:28,208  
[Music]

1751  
01:23:38,158 --> 01:23:44,948  
Chandra and it's been up there a long

1752  
01:23:42,279 --> 01:23:47,679  
time so it's been doing very x-ray

1753  
01:23:44,948 --> 01:23:49,719

astrophysics for a very long time so

1754

01:23:47,679 --> 01:23:53,969

yeah the image of show of the galaxy

1755

01:23:49,719 --> 01:23:56,948

clusters of the sort of pink blue so the

1756

01:23:53,969 --> 01:23:59,770

signatures of the gas in those galaxy

1757

01:23:56,948 --> 01:24:02,408

clusters it's really hot hot mountains

1758

01:23:59,770 --> 01:24:03,670

with minutes and the x-rays and so we do

1759

01:24:02,408 --> 01:24:09,029

have this awesome Chandra x-ray

1760

01:24:03,670 --> 01:24:14,440

telescope which has fabulous things

1761

01:24:09,029 --> 01:24:17,469

studying for the next thing surveys and

1762

01:24:14,439 --> 01:24:20,929

in yes we also have very small scales in

1763

01:24:17,469 --> 01:24:24,230

his face the very tools

1764

01:24:20,930 --> 01:24:24,590

is it's been up now gosh almost ten

1765

01:24:24,229 --> 01:24:28,369

years

1766

01:24:24,590 --> 01:24:30,800

decade only and it is primarily focus in

1767

01:24:28,369 --> 01:24:33,500

theatres so it's actually been a lot of

1768  
01:24:30,800 --> 01:24:36,110  
cool recent study and goal enough layers

1769  
01:24:33,500 --> 01:24:38,600  
cutting the details but of the money

1770  
01:24:36,109 --> 01:24:42,819  
waste return is looking for gamma rays

1771  
01:24:38,600 --> 01:24:47,020  
from these uh basically

1772  
01:24:42,819 --> 01:24:47,019  
particle/anti-particle annihilation

1773  
01:24:49,810 --> 01:25:34,280  
interesting yes exoplanet arena come on

1774  
01:25:31,489 --> 01:25:36,889  
down arenal am Brady's I guess how you

1775  
01:25:34,279 --> 01:25:38,899  
pronounce relax close enough okay

1776  
01:25:36,890 --> 01:25:41,060  
she will take people across to the

1777  
01:25:38,899 --> 01:25:42,529  
Maryland Space Grant observatory if you

1778  
01:25:41,060 --> 01:25:45,860  
would like to look through the telescope

1779  
01:25:42,529 --> 01:25:48,109  
and see what's up there and let us one

1780  
01:25:45,859 --> 01:25:48,949  
more time give amber a warm round of

1781  
01:25:48,109 --> 01:26:08,219  
applause

1782  
01:25:48,949 --> 01:26:08,220  
[Applause]

1783  
01:26:16,429 --> 01:26:21,980  
stop mass